Reducing Climate Impacts in the Transportation Sector

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Preface and Acknowledgements

Climate change has fully entered the public consciousness. Newspapers barrage readers with stories of shrinking glaciers, disappearing species, and cataclysmic weather. A documentary on climate change wins an Oscar, a Noble Peace Prize is awarded to scientists studying climate change, and arcane scientific debates become front page news. The reality of climate change and the imperative to do something is now widely accepted. But that is where the agreement largely ends. What to do and how fast to do it remains intensely controversial.

Those questions about what to do about transportation to bring it in line with climate goals was the focus of a high level meeting in California in August 2007. Two hundred leaders and experts were assembled from the automotive and energy industries, start-up technology companies, public interest groups, academia, U.S. energy laboratories, and governments from around the world. Three broad strategies for reducing greenhouse gas emissions were investigated: reducing vehicle travel, improving vehicle efficiency, and reducing the carbon content of fuels. This book is an outgrowth of that conference.

The conference was not a one-off event. It was the latest in a series of conferences held roughly every two years on some aspect of transportation and energy policy, always at the same Asilomar Conference Center near Monterey on the California coast. The first conference in 1988 addressed alternative transportation fuels, the last two have focused on climate change. The full list appears below:

I. Alternative Transportation Fuels in the ‘90s and Beyond (July 1988)
II. Roads to Alternative Fuels (July 1990)
III. Global Climate Change (August 1991)
IV. Strategies for a Sustainable Transportation System (August 1993)
V. Is Technology Enough? Sustainable Transportation-Energy Strategies (July 1995)
VI. Policies for Fostering Sustainable Transportation Technologies (August 1997)
VII. Transportation Energy and Environmental Policies into the 21st Century (August 1999)

VIII. Managing Transitions in the Transport Sector: How Fast and How Far? (September 2001)
IX. The Hydrogen Transition (July 2003)
X. Toward a Policy Agenda for Climate Change (August 2005)
XI. Transportation and Climate Policy (August 2007)

The chapters of this book evolved from presentations and discussions at the 11th Biennial Conference on Transportation and Energy Policy.

The conference was hosted and organized by the Institute of Transportation Studies at the University of California, Davis (ITS-Davis) under the auspices of the United States (U.S.) National Research Council's Transportation Research Board—in particular, the standing committees on Energy, Alternative Fuels, and Transportation and Sustainability.

The conference would not have been possible without the generous support of the following organizations: William and Flora Hewlett Foundation, Surdna Foundation, Energy Foundation, Neil C. Otto, U.S. Department of Energy, U.S. Environmental Protection Agency Office of Transportation and Air Quality, U.S. Department of Transportation Center for Climate Change and Environmental Forecasting, Natural Resources Canada, California Department of Transportation, California Energy Commission, California Air Resources Board, and the University of California Davis Sustainable Transportation Center.

The editors also want to acknowledge the Corporate Affiliate Members of ITS-Davis that provide valuable support that allows the ITS the flexibility to initiative new activities and events such as the conference upon which this book is based. Those companies are Nissan, Toyota, Shell, ExxonMobil, Subaru, Pacific Gas & Electric, Mitsui PowerSystems, Chevron, Aramco Services Company, and Nippon Oil Corporation.

The conference program was directed by Daniel Sperling, along with David Burwell, John DeCicco, Carmen Difiglio, Robert Dixon, Duncan Eggar, Lew Fulton, John German, David Greene, Cornie Huizenga, Roland Hwang, Jack Johnston, Robert Larson, Alan Lloyd, Marianne Mintz, Peter Reilly-Roe, Jonathan Rubin, Mike Savonis, Lee Schipper, Christine Sloane, and Steve Winkelman. This committee worked closely in crafting a set of speakers and topics that was engaging and insightful.

Most of all, we want to acknowledge the many attendees of the conference listed in Appendix B. These invited leaders and experts, coming from many parts of the world and many segments of society, enriched the conference with their deep insights and rich experiences.

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Chapter 1
Climate Change and Transportation

Dan Sperling, James Cannon and Nic Lutsey

More than 200 experts and leaders from around the world gathered in August 2007 at the 11th Biennial Conference on Transportation and Energy Policy at the Asilomar conference center in Pacific Grove, California. During three days, they tackled what many agree is the greatest energy and environmental challenge the world faces: climate change. The conference came at a time when the latest report by the United Nations Intergovernmental Panel on Climate Change, the most complete and authoritative scientific assessment to date, raised the spectre of even more dramatic climate changes than had been assumed in the past (IPCC, 2007a). The IPCC, together with former Vice President Al Gore, who starred in an academy award winning documentary, *The Inconvenient Truth*, received the 2007 Nobel Prize for their efforts in highlighting the dangers and risks of climate change.

Most environmental scientists now acknowledge that climate change is a real global problem, and that transportation is a key contributor. But the world is still near the starting line in doing much about it.

The 2007 Asilomar Conference examined the role of transportation in reducing greenhouse gas (GHG) emissions. This book is based on presentations and discussions that took place there. It draws upon the knowledge and insights of the world's experts.

Transportation and Climate Change

Transportation accounts for about one-fifth of global GHG emissions causing climate change, but close to 30 percent in most industrialized countries. The United States far exceeds the rest of the rest of the world when it comes to transport-related GHG emissions. While China, India, and other countries in the developing world are rapidly motorizing, causing rapid increases in their

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Table 1.1 U.S. GHG emissions by energy sector since 1990 (Tg CO2e), (EPA, 2006)

Energy sector	1990	1995	2000	2004	2005
Tranportation	1,467.0	1,593.3	1,787.8	1,868.9	1,897.9
Industrial	1,539.8	1,595.8	1,660.1	1,615.2	1575.2
Residential	929.9	995.4	1,131.5	1,175.9	1,208.7
Comercial	759.2	810.6	969.3	999.1	1,016.8
Total U.S. Territories	28.3	35.0	36.2	54.0	52.5
Total	4,724.0	5,030.0	5,584.9	5,713.0	5,751.2
Total Electrical Generation	1,810.2	1,939.3	2,283.5	2,315.8	2,381.2

GHG emissions, their transport emissions are still a fraction of those in the U.S.

As indicated in Table 1.1, transportation activities accounted for 33 percent of GHG emissions in the United States in 2005. Virtually all of the transportation energy consumed came from petroleum products. Over 60 percent of the emissions resulted from gasoline consumption for personal vehicle use.

As shown in Fig. 1.1, U.S. GHG emissions have varied widely since 1990, but generally have increased about 1 percent per year, roughly half that increase coming from transportation (EPA, 2006).

Transport-related energy use and GHG emissions are expected to continue increasing into the foreseeable future. The U.S. government, in its “Annual Energy Outlook 2008” report, forecasts a 25 percent increase in total oil use between 2006 and 2030, from 20.7 to 24.9 million barrels per day. About 2/3 of that oil will be used for transportation (EIA, 2007).

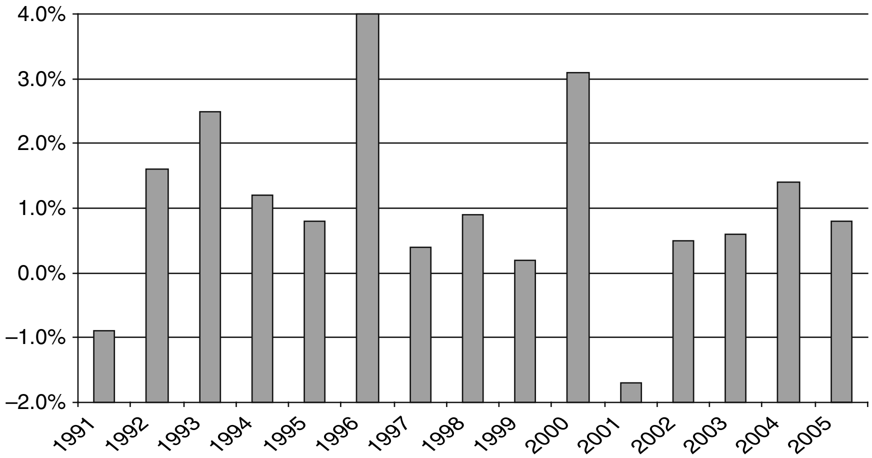

Fig. 1.1 Annual percent change in U.S. GHG emissions since 1990 (EPA, 2006)

Trends in Climate Change

The climate change debate intensified dramatically in 2007. A study by the United Nations Environment Program (UNEP, 2007), prepared by 390 experts and reviewed by more than 1,000 others, concluded that climate change is one of several pressing global problems that are putting the human race at risk. The report warned that unmitigated climate change would, in the long term, likely swamp the capacity of natural, managed and human systems to adapt.

Perhaps most instrumental was the release of the latest IPCC report (IPCC, 2007a). The most complete and authoritative scientific assessment to date, reflecting the views of thousands of climate scientists, it clearly affirmed the role of human activities, primarily fossil fuel burning, in creating climate change. It documented rising air and ocean temperatures, accelerated melting of glacial snow and ice, and slow but steady rising of ocean levels. Eleven of the last 12 years evaluated by the IPCC ranked among the warmest years since 1850.

The evidence of change is powerful and compelling. The IPCC found that average Northern Hemisphere temperatures were higher during the second half of the 20th Century than during any other 50-year period in the last 500 years and likely the highest in at least the past 1,300 years. If global temperatures increase another 1.5–2.5°C, which is likely in the 21st Century, unless GHG emissions are dramatically curtailed, as many as 20–30 percent of plant and animal species are likely to be at increased risk of extinction, according to the IPCC.

Temperature increases will not be uniform. Average temperatures in the Arctic are rising twice as rapidly as in the rest of the world. Satellite data since 1978 show that Arctic sea ice has shrunk in surface area by 2.7 percent per decade, with much greater shrinkage in summer. Equally disconcerting is the rise in sea levels. The global average sea level has risen at an average rate of 1.8 millimeters per year since 1961. Since 1993, the rise has accelerated to 3.1 millimeters per year, caused by melting glaciers, ice caps and polar ice sheets.

The Political Will to Counter Climate Change

There is now little expectation that adaptation or mitigation alone can avoid all climate change impacts. However, they can complement each other and together can significantly reduce the risks of climate change. Adaptation is necessary to address impacts resulting from warming, while early mitigation actions would avoid further locking-in carbon intensive infrastructure and would reduce climate change and associated adaptation needs.

A global attempt to develop and implement a politically viable short term mitigation strategy has been underway for several decades, but with little success. Voluntary reductions in GHG emissions were endorsed by delegates from 189 countries at an international conference held in 1992 in Rio de Janeiro, Brazil.

More serious and mandatory emission reduction targets were incorporated into the 1997 Kyoto Protocol, endorsed by delegates from more than 160 countries meeting in Japan. The protocol took effect in 2005, when countries representing the required 55 percent of global GHG emissions formally signed on.

The global response to climate change set into motion by the Kyoto Protocol has been widespread, even in the United States (Lutsey and Sperling, 2008). But opposition by the United States has continued and rapid growth in GHG emissions in developing nations, particularly in China and India, which are exempted from the protocol's GHG reduction targets, has undermined its effectiveness. By late 2007, it was apparent that the world was not only falling short of complying with the Kyoto Protocol target of a 6–8 percent reduction in GHG gases from 1990 levels, but it was, in fact, still moving in the wrong direction. Global GHG emissions had grown by 20 percent since the Kyoto Protocol's adoption a decade earlier.

Against this backdrop, delegates from 190 countries reconvened at another United Nations Climate Change Conference in Bali, Indonesia in December 2007 to develop a new roadmap. After intense debate that ran a day past the scheduled close of the conference, the group failed to reach a consensus about how best to move ahead after the provisions of the Kyoto Protocol expire in 2012. Instead, the group voted to undertake a set of negotiations aimed at crafting a new international agreement, scheduled to be drafted by 2009.

Combating Climate Changes in the Transportation Sector

GHG mitigation strategies for transportation can be grouped into three categories: vehicle efficiency, low-carbon fuels, and travel reduction. Potential GHG reductions are very large, with varying levels of cost effectiveness. Virtually all provide large co-benefits, including energy cost savings, oil security, and pollution reduction. Table 1.2 categorizes these GHG mitigation options into near and mid-term options and lists key supporting policies and practices needed for their implementation.

Vehicle Efficiency

Available and emerging vehicle efficiency improvements can be categorized into three groups: incremental vehicle technologies, advanced technologies, and on-road operational practices. Incremental improvements include more efficient combustion through such technologies as variable valve systems, gasoline direct injection, and cylinder deactivation; more efficient transmissions, including 5- and 6-speed automatic, automated manual, and continuously variable configurations; use of lightweight materials; and more aerodynamic designs. GHG

Table 1.2 Summary of transportation GHG mitigation options (Lutsey, 2008)

Category	Today's measures (deployable 2007–2015)	Tomorrow's measures (deployable 2010–2030)	Supporting policies and practices
Vehicle efficiency	Incremental efficiency improvements in conventional gasoline automobiles and diesel trucks "On-road" improvements in maintenance practices, technology, driver education and awareness	Increased vehicle electrification (hybrid gas-electric, plug-in hybrid, battery electric) Fuel cell vehicles	Vehicle efficiency performance standards (fuel economy, CO2 emission rate) Voluntary industry commitments Vehicle purchasing incentives (rebates, feebates for low-CO2, high fuel economy) Government and company fleet efficient vehicle purchasing
Low greenhouse gas fuels	Mixing of biofuels in petroleum fuels Use of lower GHG-content fossil fuels (e.g. diesel, compressed natural gas)	Electricity (in plug-in hybrids and battery electrics) Cellulosic ethanol Hydrogen from renewable sources Mobile air-conditioning (MAC) refrigerant replacement	Biofuel blending mandates Low GHG fuel standards Carbon tax on fuels Government and company fleet incorporation of alternative fuels
Vehicle demand reduction	Intelligent transportation system (ITS) technologies to improve system efficiencies Mobility management technologies Inclusion of GHG impacts in land use and transport planning Incentives and rules to reduce vehicle use	Greenhouse gas budgets for households and localities Modal shifts (road to rail freight, public transit systems) ITS technologies to create new more –efficient transport modes	Road, parking, congestion pricing Investment in public transit Public awareness, outreach, education campaigns

emissions rates can be reduced by as much as 30 percent with these approaches. Most studies show that fuel savings more than outweigh the increased vehicle cost when considered over the life of a vehicle (using appropriate discount factors). Similar GHG reductions are possible with commercial freight trucks, also with net cost savings over the life of the vehicle.

Much greater GHG reductions are possible with electric drive propulsion technologies. These include gasoline-fueled hybrid electric vehicles, plug-in hybrids, which use both electricity stored from the grid and petroleum fuels, battery electric vehicles, and hydrogen-powered fuel cell vehicles. These technologies can double vehicle fuel efficiency. When low-carbon electricity, hydrogen and biofuels are used with these vehicles, the lifecycle GHG emissions can be reduced 80 percent or more. However, these advanced technologies involve either larger initial costs for electricity and hydrogen storage or have high development and commercial deployment costs. Because vehicle turnover is slow, it would take a long time to realize these potential reductions.

The third category, on-road efficiency improvements, involves a combination of consumer education, vehicle maintenance practices, and "off-cycle" vehicle technologies. These on-road vehicle efficiency improvements can reduce GHG emissions by up to 20 percent. Improved vehicle maintenance practices for tires, wheels, oil, and air filters can improve vehicle operating efficiencies. Inexpensive new technologies can be added to vehicles to raise driver awareness of fuel use. These include dashboard instruments that display instantaneous fuel consumption, efficient engine operating ranges, shift indicator lights, and tire inflation pressure. Other changes include replacing the conventional air conditioning refrigerant, hydrofluorocarbon HFC-134a, with gases that pose less of a threat to the climate.

A variety of policies aimed at vehicle makers and policies could accelerate these efficiency improvements. These include requirements for more efficient vehicles aimed at automakers and incentives targeted at manufacturers to sell those more efficient vehicles and to consumers to purchase them. If these vehicle policies are linked with actions that increase the supply of low-carbon alternative fuels, as discussed below, the GHG and oil benefits would be still greater.

Low-Carbon Fuels

Increased use of fuels with lower lifecycle GHGs emissions can greatly reduce overall transportation GHG emissions. Most low-carbon transportation fuels face a combination of infrastructural and economic barriers. There are three sets of transportation fuels that have the potential to replace large amounts of petroleum and eliminate large quantities of GHGs. They are biofuels, electricity, and hydrogen.

Biofuels are the easiest since fuels made from food products have been well known for millennia and small amounts can be readily blended into gasoline and diesel fuel. Indeed the United States and many other countries have been doing so for many years, mostly with ethanol made from corn and sugar, but also biodiesel oils extracted from plants and animal fats. Brazil has gone furthest, first using ethanol made from sugar cane in dedicated vehicles in the 1980s and more recently in fuel-flexible vehicles. In Europe, Brazil, and the

United States, biodiesel is used in limited amounts in diesel cars, buses, and trucks. Biodiesel and ethanol, as currently produced, are expensive and divert farmland to energy use, pushing up food prices.

The GHG benefits of ethanol made from sugar cane are substantial, compared to gasoline, but that is not true for ethanol made from corn. In the case of corn, GHGs are reduced only about 10–20 percent, and perhaps not at all if new scientific findings about GHG releases from soils prove correct (Searchinger et al., 2008). Future biofuels, made from cellulosic materials such as grasses and trees, would have much higher lifecycle GHG benefits, especially those made from crop residues and other waste materials. For both GHG and food production reasons, it is entirely possible that the biofuels industry of the future will be based almost solely on waste materials, limiting the scale of potential biofuels production.

Large GHG benefits are possible from hydrogen fuel cells and battery electricity vehicles, including plug-in hybrid electric vehicles that use both gasoline and electricity. If the fuels are obtained from low-carbon feedstocks, such as biomass, wind, or nuclear, or from fossil energy coupled with carbon capture and storage, the result could be tremendous GHG reductions. Both electricity and hydrogen face many barriers, though. All electric vehicle technologies must overcome the high cost and low energy density of batteries, and hydrogen fuel cells must overcome the challenge of jointly deploying an entirely new propulsion technology and fuel.

Alternative fuels have been subsidized and mandated by various governments at various times. A biofuel mandate exists in Europe and ethanol subsidies and mandates have been in place in the United States and Brazil for decades. In December 2007, the United States passed a law requiring 36 billion gallons of biofuels by 2022, including 21 billion gallons of advanced biofuels, expected to be mostly made from cellulosic materials.

A new policy instrument gaining much attention worldwide is the low carbon fuel standard (Farrell and Sperling, 2007). In this case, the government sets a GHG intensity target, for example 10 percent reduction by 2020, and allows companies to meet the requirement however best suits them. Companies are allowed to buy credits when they fall short of the targets and to sell them when they exceed the targets. This innovative approach provides a durable policy framework that can be tightened over time, and avoids the pitfalls of governments picking winners or losers. California adopted this rule in 2007, and many others, including the European Union, are in the process of adopting it as this book goes to press.

The transition to low-carbon alternatives will not be straightforward or unchallenged. Already, the oil industry is investing many tens of billions of dollars in high-carbon unconventional fossil alternatives. These alternatives include tar sands in Canada, very heavy oil in Venezuela, U.S. oil shale, and coal in a variety of countries, especially China, South Africa, and the United States. Fuels made from these sources require much more energy for extraction and processing and therefore have considerably higher GHG emissions than gasoline and diesel fuel made from conventional oil. Only if the carbon is captured at the site and sequestered underground could GHG emissions from these sources be reduced relative to conventional gasoline and diesel fuels.

Travel Reduction

The same technologies and practices implemented by local governments to manage vehicle travel and traffic congestion can also be used to reduce GHG emissions. Strategies to reduce vehicle travel can be sorted into three broad groups: information and communication technologies to provide new and more efficient mobility services; incentives and pricing schemes to encourage less-GHG-intense travel; and denser land use that more efficiently organizes businesses, residences, and services so as to reduce vehicle travel.

Information and communication technologies can be used to simultaneously improve mobility and reduce transport GHG emissions. Incremental enhancements include automating urban traffic signals to streamline traffic and reduce stop-and-go conditions; implementing integrated "smart cards" to facilitate multi-modal travel and increase transit use; and providing real-time traffic data to traffic managers and vehicle users to improve efficiency. More transformational changes are possible that could result in far greater reductions in vehicle travel. These include creating entirely new modes of travel, such as carsharing, paratransit that provides door-to-door service without advanced reservations, and organized ridesharing.

Various incentive and pricing schemes can be designed to reduce GHG-intense travel. Road pricing to reduce congestion in city centers and on clogged highways can smooth flows, encourage transit modes, and reduce vehicle travel. Parking policies that encourage higher occupancy travel modes and internalize the full cost of parking can be highly effective at reducing use of single-occupant vehicles. Workplace incentives to promote telecommuting and carpooling can also help mitigate peak-time congestion travel.

The real key to reduced vehicle travel is creating more choice for travellers, beyond the dominant single-occupant vehicle, and to pursue multiple strategies, especially increased densification of land use. Research shows that residents in more densely populated areas and in areas with better mixes of land uses tend to emit far less GHG emissions from their travel (Boarnet and Crane, 2001; Handy et al., 2007). They tend to walk more, use more public transportation, and drive less. Policies aimed at increasing density and influencing local governments to make land use development and zoning decisions based on likely impact on GHG emissions could be highly effective at reducing emissions. Combined with targeted vehicle and road pricing initiatives, more high quality travel choices, and improved conventional transit services, the result could be a substantial reduction in vehicle travel. At the Asilomar Conference, John Horsely, head of the conservative American Association of Safety and Highway

Officials, announced that his organization now advocates cutting in half the projected increases in vehicle travel. Many believe much larger reductions are possible and desirable (Reid Ewing et al., 2007).

Greenhouse Gas Mitigation Supply Curves

Studies of cost effectiveness generally find transportation GHG reductions more expensive than reductions in most other sectors (IPCC, 2007b; McKinsey, 2007). The high estimated cost is due to low fuel price elasticity by owners of passenger cars and light trucks; strong demand for personal travel; the difficulty of introducing new low-carbon fuels and new fuel-efficient propulsion technologies; deteriorating quality of public transport; and the increasing share of goods carried by truck. In addition, petroleum fuel use is becoming more carbon intense, as easily accessed and high quality reserves are depleted, and as remote sources of unconventional fossil energy are tapped and as additional refining is required to upgrade fuel quality.

On the other hand, many transportation strategies to reduce GHG emissions are highly cost effective. Many generate cost savings over the life of an investment, when future energy savings are calculated using normal discount factors. When other co-benefits are included, such as improved energy security and traffic congestion, many transport GHG mitigation options become attractive. These findings are counter to the conventional thinking that often ignores co-benefits and emphasizes near-term resistance to expanded technology and behavioral options.

GHG mitigation strategies can be ranked using a supply curve framework. They are ranked according to their GHG reduction cost effectiveness, or cost-per-tonne CO_2 equivalent emission reduction. Both the initial costs of the GHG technologies and the lifetime energy savings are included in the cost-per-tonne metric. Co-benefits are usually ignored, but could be added.

Figure 1.2 shows a supply curve of GHG mitigation actions for all sectors of the U.S. economy, with transportation-specific measures highlighted (Lutsey, 2008). The non-transportation actions include electric power sector actions, such as greater use of natural gas, nuclear, and renewable energy, and constructing and retrofitting buildings to be more energy efficient. Other analyses, for instance by McKinsey & Co (2007), find similar relationships.

Whether GHG mitigation is easier or harder in transport than other sectors is an important debate that will continue into the future. What is certain, though, is that many attractive strategies and actions are available. The question is how aggressively the GHG reductions will be pursued by government, industry, and consumers. The existence of large co-benefits, including energy security and oil import reductions, will undoubtedly be influential. There will be many other forces at work, however. Consumers are already altering their behavior to be more environmentally conscious, for instance buying

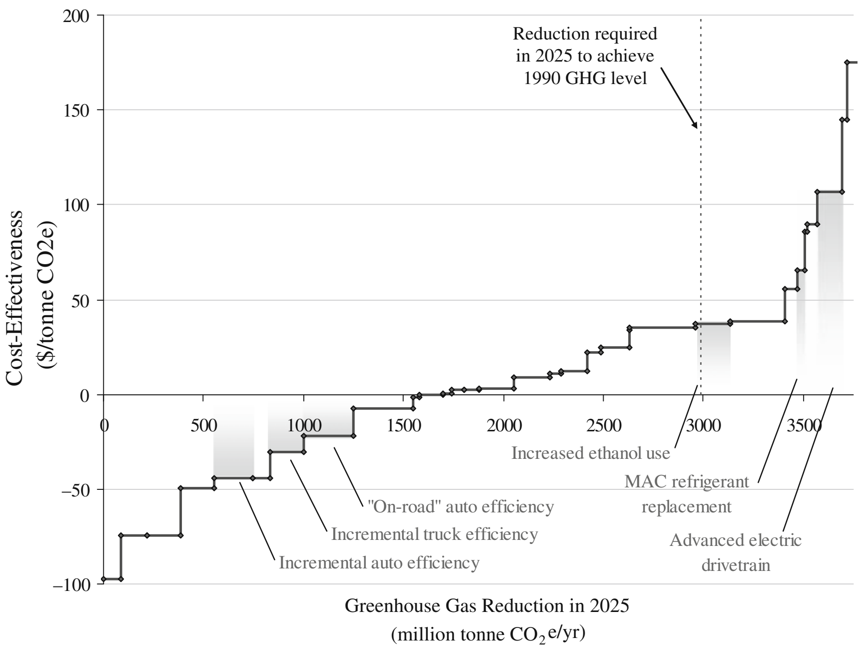

Fig. 1.2 Cost-effectiveness supply curve of available GHG mitigation technologies (Lutsey, 2008)

high-priced hybrid electric vehicles. Moreover, innovations with vehicles, fuels, and new mobility services will undoubtedly lead to new investments in low-GHG options. Competitive forces are at work. Toyota's experience with the Prius hybrid electric car vividly demonstrates the "halo" benefits of being a leader in environmental action. The "halo" created by the successful Prius has increased the attractiveness of Toyota's other vehicles. Companies are increasing their investment in a wide variety of new low-carbon fuels and efficient advanced propulsion technologies to achieve the same halo benefits.

Overview of the Remaining Chapters

Discussions at Asilomar largely followed the topics addressed above, with debates centering on the attractiveness of different policy instruments and differences across the United States., Europe, and the rest of the world. The 10 chapters that follow offer in-depth analyses of many of the most salient issues discussed at Asilomar and increasingly in global public debates. They are authored by presenters or participants at the Asilomar conference, in some cases assisted by colleagues.

The next two chapters set the stage for the discussion of strategies to reduce global climate change from the transportation sector. Amy Myers Jaffe, Associate Director of the Baker Institute at Rice University, examines in her chapter the major supply risks that face international oil markets and considers the carbon emission implications of the kinds of energy supplies that the United States may turn to in an effort to diversify away from rising dependence on Middle East oil. Most of the "easy" oil has already been found, she says, and new supplies are likely to be more difficult to extract technically, be found in more politically problematic countries, and produce more, not less, GHG emissions when processed and burned. Her calculations suggest U.S. energy independence is impossible given the projected growth in domestic oil demand. Therefore, a more ambitious national strategy is needed to address reductions in GHG emissions from transportation. This strategy should address the key international geopolitical issues that undermine energy security as well as climate change.

Jack Short, Secretary General of the International Transport Forum in Paris, France, and his colleagues Kurt Van Dender and Philippe Crist note that actions to combat climate change are now at unprecedented levels. Even so, the growth in GHG emissions from the transportation sector is quickly getting worse. The transportation sector is different in nature and degree from other energy sectors, and it presents unique challenges to policy developers. Their chapter examines present policy measures to reduce CO_2 emissions from private cars in Europe and discusses the implications of tough CO_2 targets for transport policy and for the structure of the transport sector.

The next group of three chapters examine the policies and technologies that are now commercially available or near to commercial viability and that could reduce GHG emissions from motor vehicles. John Heywood at the MIT Laboratory for Energy and Environment and his collaborators, Lynette Cheah, Christopher Evans, and Anup Bandivadekar, examine the vehicle design and sales mix changes necessary to double the average fuel economy or halve the fuel consumption of new light duty vehicles by model year 2035. The analysis concludes that available automotive technologies can do the job, although significant changes in vehicle design are required. There are trade-offs between the performance, cost, and fuel consumption reduction benefits. For example, the extra cost of the 2035 model year vehicles is estimated to be between $54 and $63 billion, or about 20 percent more than the baseline cost. This corresponds to a cost of $65 to $76 per ton of equivalent CO_2 emissions. Heywood et al. warn that the changes required to meet this goal run counter to the trend towards larger, heavier, more powerful vehicles over the last 25 years. Instead, their scenarios depict a transportation future where automakers face higher costs to produce smaller vehicles with performance similar to today's.

John German, Manager of Environmental and Energy Analysis at American Honda Motor Company, discusses technology development for cars and light trucks that meet the needs of customers and the global need to address climate change. He believes that the automotive industry is in a period of unprecedented technology development that will move a long way towards sustainable mobility. Gasoline engine technology is maturing rapidly and manufacturers are working hard on diesel engines suitable for use in light duty vehicles. Automakers are rapidly commercializing a variety of hybrid electric vehicles, dedicated compressed natural gas vehicles, and flexible-fuel vehicles that run on mixtures containing up to 85 percent ethanol. Fuel cells are being heavily researched and developed. All of these vehicles achieve CO_2 reductions compared to conventional gasoline vehicles. Demand for transportation energy is so immense that no single technology can possibly be the single solution, however.

Anthony Greszler, Vice President of Advanced Engineering at Volvo Powertrain North America, turns to the heavy duty sector. His chapter notes that trucks consume over 20 percent of fuel transportation burned in the United States and that this sector is growing rapidly. He argues that control of CO_2 emissions from heavy duty trucks requires unique metrics, technologies, and public policies. His analysis concludes that it should be possible to achieve 20–30 percent efficiency improvement from proven technologies, but the only realistic way to obtain significant GHG reductions in the face of a growing reliance on heavy duty trucks is to deploy low-carbon alternative fuels. Alternative fuel technologies exist, he adds, but need further development and their cost must be reduced.

Another set of three chapters focus on strategies to tackle transportation GHG emissions not by reducing vehicle emissions, but rather by reducing reliance on automobiles themselves. David Burwell, a Partner in the BBG Group, addresses the question whether or not reducing vehicle miles travelled (VMT) is a sensible strategy for reducing both traffic congestion and transportation-related emissions of CO_2. He finds the answer to be yes, and discusses the leadership of state government agencies in reducing VMT within their jurisdictions.

Rex Burkholder and Eliot Rose from the Portland Metro Council examine the land use and transportation policies that have been successful so far in reducing GHG emissions in metropolitan Portland, Oregon. The Portland metro region has reduced CO_2 emissions, while becoming more liveable and reducing living costs for its residents. The region has implemented a strong land-use planning program that promotes development within an urban growth boundary. This has created a more compact, efficient city that is easier to serve with non-automobile transportation modes. Reliable bus service, streetcar and light rail lines, combined with attention to bicycle and pedestrian planning, ensure that residents who choose not to drive can take advantage of a variety of other travel options.

Gustavo Collantes and Kelly Sims Gallagher from Harvard Kennedy School's Belfer Center for Science and International Affairs modelled individual GHG reduction policies and found that no single policy is likely to achieve meaningful reductions in carbon emissions. One key message is that a policy package—as opposed to an individual policy tool—is necessary to significantly reduce carbon emissions from transportation. They conclude in their chapter that relative stabilization of GHG emissions is likely to be achieved only with a more aggressive taxing scheme. This could induce a meaningful slowdown in VMT increases over time, as well as a stronger adoption of flexible fuel vehicles. As a consequence, they believe oil imports can also be stabilized.

The final two chapters examine the role of consumers in implementing climate change strategies in the transportation sector. Carolyn Fischer, Senior Fellow at Resources for the Future, explores public apprehension over global climate change and its reflection on U.S. fuel economy policy. She argues that the success of the current approach of regulating fuel economy in new vehicles, and hence GHG emissions, depends on whether or not consumers make economically efficient choices. Other approaches, such as a carbon tax on fuel, tolls on roadways, and per-mile charges for driving, may also be needed, she says.

David Greene from the Oak Ridge National Laboratory and his colleagues John German from Honda and Mark A. Delucchi at the Institute for Transportation Studies at the University of California, Davis, explain how markets determine the energy efficiency of durable goods like automobiles. Understanding this is critical to formulating effective policies for mitigating GHG emissions and reducing oil dependence. Their chapter focuses on the consumer trade-off between purchase price and future energy savings of vehicles. The consumer's concern is the net value, the difference between the two. They conclude that this is a risky proposition involving uncertain initial costs and more uncertain future savings. Uncertainties increase the likelihood that loss-averse consumers would decline to bet on new energy efficient equipment even when the expected net present value is positive. They show that typically loss-averse consumers would reject a bet on a fuel economy increase from 28 to 35 miles per gallon, despite an expected present value of about $400 per vehicle.

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Chapter 2
Energy Security, Climate and Your Car: US Energy Policy and Beyond

Amy Myers Jaffe

The United States (U.S.) is facing daunting energy challenges. Demand for oil has been rising steadily, but growth in supplies has not kept pace. The United States is the third largest oil producer in the world, but its production has been declining since 1970 as older fields have become depleted. It is now more dependent on foreign oil than ever before, importing 12.3 million barrels per day (bpd) in 2006 or about 60 percent of its total consumption of roughly 20.7 million bpd. That is up from 35 percent in 1973. The share of imported oil is projected to rise to close to 70 percent by 2020, with the United States becoming increasingly dependent on Persian Gulf supply. U.S. oil imports from the Persian Gulf are expected to rise from 2.5 million bpd, about 22 percent of its total oil imports, in 2003 to 4.2 million bpd by 2020, at which time the Persian Gulf will supply 30 percent of total U.S. oil imports, according to forecasts by the U.S. Department of Energy's (DOE's) Energy Information Administration (EIA, 2006).

More than three decades after the 1973 oil crisis, U.S. supply of oil is no more secure today than it was thirty years ago. Moreover, its dependence on oil for mobility has never been stronger. All told, there are over 242 million road vehicles in the United States, or one vehicle for every person. Each vehicle is driven over 12,000 miles annually, and virtually all vehicles are powered by petroleum-based fuels, either gasoline or diesel. As a result, despite the fact that the United States accounts for only 5 percent of the world's population, it consumes over 33 percent of all the oil used for road transportation in the world. Future U.S. oil consumption is centered squarely in the transportation sector, which represents more than two thirds of total petroleum use and will constitute over 70 percent of the increase in demand.

As oil demand and dependence on the Middle East rises, the United States has yet to forge a thoughtful response to climate change. In 2005, it emitted a total of 712 million metric tons of carbon, 412 million metric tons of which came from road petroleum use. The country emits more energy related carbon

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