



TRANSPORTATION RESEARCH BOARD

CONFERENCE PROCEEDINGS ON THE WEB 14

Sustainable Energy and Transportation Strategies, Research, and Data

Summary of a Conference

November 8–9, 2012
Washington, D.C.



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CONFERENCE PROCEEDINGS ON THE WEB 14

Sustainable Energy and Transportation Strategies, Research, and Data

Summary of a Conference

Katherine F. Turnbull, *Rapporteur*
Texas A&M Transportation Institute
The Texas A&M University System

November 8–9, 2012
The Keck Center of the National Academies
Washington, D.C.

Sponsored by
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Research and Innovative Technology Administration
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OF THE NATIONAL ACADEMIES

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This project was sponsored by the University Transportation Centers Program, Research and Innovative Technology Administration, U.S. Department of Transportation; and the Transportation Research Board.

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Preface

The transportation sector currently accounts for approximately two-thirds of the petroleum consumption and one-third of greenhouse gas (GHG) emissions in the United States. Reducing petroleum consumption enhances energy security and slows climate change. Adopting sustainable energy technologies, practices, and policies to reduce petroleum consumption and GHG emissions faces numerous challenges.

TRB hosted the Sustainable Energy and Transportation Strategies, Research, and Data Conference at the Keck Center of the National Academies in Washington, D.C., in November 2012. This meeting was the seventh in a series of spotlight conferences, funded by the U.S. Department of Transportation's Research and Innovative Technology Administration University Transportation Centers (UTC) Program. The UTC Program awards grants to universities across the country to advance the state of the art in transportation research, to conduct technology transfer activities, and to educate the next generation of transportation professionals.

TRB assembled a planning committee appointed by the National Research Council (NRC) to organize and develop the conference program. The planning committee was chaired by Daniel Sperling from the University of California, Davis. Committee members provided expertise in energy, alternative fuels, vehicle and fuel technologies, freight, air quality, public policy, and education and training.

The planning committee was solely responsible for organizing the conference, identifying speakers, reviewing submitted poster abstracts, and developing topics for the breakout group discussions. Katherine Turnbull, from the Texas A&M Transportation Institute, served as the conference rapporteur and prepared this document as a factual summary of what occurred at the conference. Responsibility for the published conference summary rests with the rapporteur and the institution.

The conference attracted 137 participants. Agency personnel responsible for transportation, energy, and the environment joined faculty, students, and researchers from UTCs and other universities to explore programs, technologies, policies, and research to reduce petroleum consumption and GHG emissions. The conference, which was characterized by broad and active participation and discussion, considered potential research needed to further advance the development of alternatives to petroleum-based transportation and to lower GHG emissions.

The conference began with an overview of the global perspective on the status and future of energy resources and demands and the transportation sector's use of energy. Plenary sessions highlighted the interconnection of energy use, pricing, and finance; emerging vehicle and fuel technologies; freight transportation; and approaches to reducing transportation energy consumption and GHG emissions in metropolitan areas. Conference participants also had the opportunity to interact with poster authors and to discuss issues and areas for further research in breakout groups. Speakers in the closing plenary session highlighted key observations from the conference discussions and presented perspectives from a state department of transportation and the U.S. Department of Transportation.

These proceedings consist of presentation summaries from the plenary sessions. The views expressed in this summary are those of the individual speakers and discussants, as attributed to them, and do not necessarily represent the consensus views of the conference participants, the conference planning committee members, TRB, or NRC. The conference PowerPoint presentations and the poster abstracts provided by the authors are available at <http://onlinepubs.trb.org/onlinepubs/conferences/2012/UTC2012/PresentationSummaries.pdf>.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the NRC Report Review Committee. The purposes of this independent review are to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the project charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

TRB thanks the following individuals for their review of this report: Mark S. Duvall, Electric Power Research Institute, Palo Alto, California; Anne V. Goodchild, University of Washington; Michael D. Meyer, Parsons Brinckerhoff, Atlanta, Georgia; and Martin Wachs, RAND Corporation, Santa Monica, California.

Although the reviewers listed above provided many constructive comments and suggestions, they did not see the final draft of the conference summary before its release. The review of this report was overseen by Susan Hanson, Distinguished University Professor Emerita, School of Geography, Clark University, Worcester, Massachusetts. Appointed by the NRC, she was responsible for making certain that an independent examination of this summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this proceeding rests entirely with the rapporteur and the institution. Karen S. Febey, Senior Report Review Officer, TRB, managed the report review process.

PREFACE

The conference planning committee thanks Katherine Turnbull for her work in preparing this conference summary report and extends a special thanks to the Research and Innovation Technology Administration for providing the funding support that made the conference possible.

OPENING SESSION

The Challenge of Energy Sustainability in Surface Transportation

Gregory D. Winfree, *Research and Innovative Technology Administration*

Peter D. Blair, *National Research Council*

David L. Greene, *Oak Ridge National Laboratory*

Daniel Sperling, *University of California, Davis, presiding*

This session provided an introduction to the conference. Speakers provided an overview of the conference and the context of current and future surface transportation energy challenges, including economic and environmental considerations. Key issues covered included uncertain world oil supply trends, including peaking of conventional oil; uncertain costs and environmental effects of unconventional fuels; and uncertain climate change and energy security. Speakers noted that the policy and technology options are equally complicated by a number of considerations that include pricing and financing, efficiency and greenhouse gas (GHG) standards, alternative vehicle and fuel technologies, equity of access, energy and transportation infrastructure needs, and operational enhancements.

OVERVIEW AND CONTEXT

Daniel Sperling

Daniel Sperling welcomed participants to the 7th University Transportation Center (UTC) Spotlight Conference, Sustainable Energy and Transportation: Strategies, Research and Data. He recognized the Research and Innovative Technology Administration (RITA) of the U.S. Department of Transportation (U.S. DOT) for sponsoring the conference. He recognized members of the TRB staff for their hard work in organizing the conference. He summarized the conference goals, highlighted personal examples of research and activities related to sustainable energy, and reviewed the conference program. The following topics were covered in his presentation.

- The three conference goals are (a) promote collaboration and cooperation among researchers, practitioners, and policy makers to address important issues

of sustainable energy and transportation; (b) highlight research on energy and transportation by UTCs and other groups; and (c) highlight research needs for universities, governments, and industry concerning sustainable energy as it relates to transportation. Buried in that list of goals is a related but higher-order goal. That goal is to encourage universities to be more engaged and more responsive to the energy needs of the country and the world.

- Holding the transportation seat on the California Air Resources Board (CARB) for the past 6 years provided Sperling with the opportunity to be actively involved in developing policies in the state. CARB is a semi-independent agency responsible for traditional air pollution policy and regulation. A decade ago, CARB was tasked by the California legislature and the governor to formulate and adopt climate policies for the state. Sperling noted that in recent years, CARB has adopted aggressive GHG standards for vehicles and low-carbon fuel standards (LCFS), requiring a shift to alternative fuels; a cap-and-trade program that reduces emissions from electricity and industry, including refineries; GHG targets for urban travel; and emissions reductions at seaports. He suggested that these represent the most comprehensive set of climate policies for transportation in the world. He further suggested that the California example provides inspiration for creative approaches to addressing the energy and climate research challenges facing local communities, the United States, and the world.

- According to Sperling, the expertise available at universities throughout the country is needed by agencies at all levels of government. While there are good examples of partnerships between universities and state departments of transportation and other agencies, he characterized these as a shadow of what is possible and what is desirable. A chasm exists between government and universities, which has much to do with different cultures and reward systems. There is extraordinary expertise at universities, he observed, and governments at all levels need technical assistance, increasingly so as budgets shrink and internal technical capabilities are lost through retirements.

- He provided a personal example involving the LCFS when he was asked by the governor to help lead a university team to design a low-carbon fuel policy in 2007. Having spent his entire career on alternative fuels, life-cycle analysis, and policy analysis, Sperling noted he thought he knew 90% of the issues, but found that he knew only a small percentage. Issues associated with equity across companies, industries, and population groups; environmental justice issues; the way to design simple but robust policies that are enforceable and resistant to legal challenges; soil impacts of farming and forestry, and more were all new to him. Fortunately, the University of California, Davis (UC Davis), and the University of California, Berkeley, had the needed expertise to address those concerns.

- A second example Sperling highlighted relates to GHG targets for urban travel. California approved a vague law in 2008 to reduce sprawl and GHGs from passenger travel. As Sperling became involved in translating the vague goals into real policies and rules, it became apparent to him that despite decades of research into land use and transportation relationships and models, there was not a single programmatic approach that could be used to implement an enforceable performance target for cities.

- He stated his belief that the need for good science inputs in transportation is greater now than ever. Universities have tremendous expertise, but bringing science to policy is not easy. He suggested that the functionality of passenger vehicle systems has seen little innovation in many decades. Cars are much safer and more comfortable than ever and more convenient to use in part because of global positioning navigation systems. He observed, however, that cars still operate at the same speeds, have the same carrying capacity, and rely on internal combustion engines. He remarked that buses and rail transit systems have seen even less innovation. All roads still serve all vehicles, all vehicles serve all purposes, all vehicles operate on petroleum, and pricing the use of transportation is largely an alien concept. He noted there has been more innovation on the freight side. Additional innovations are needed with freight, however, with a focus on system efficiency and the public interest.

- He observed that change and innovation is on the way—in technologies, behaviors, and institutions. Vehicles and fuels are about to be transformed. Many city centers are being revived. The information technology revolution is about to invade transportation with new types of mobility services, such as smart carpooling, demand-responsive services such as Uber, peer-to-peer car sharing, and much more. He indicated that it is not unrealistic to think that much of the passenger transportation system will be transformed in the coming decades—and possibly freight as well. As one small example, he asked participants to think about the possibilities with 3-D printing and how that could transform the delivery of goods to businesses and households.

- He noted that smart people and smart research are going to be needed. Partnerships between researchers and agencies are needed to help address climate change, energy, and GHG emissions. He suggested that researchers will need to make greater effort at collaborating with policy makers and agency personnel. The slogan of the new Policy Institute at UC Davis is “leveraging university expertise to advance policy.” The institute focuses on transportation, but also on energy, water, and agriculture.

- Sperling thanked RITA for sponsoring the conference and gave special thanks to RITA Administrator Gregory D. Winfree and to Robin Kline, Thomas G. Bolle, and Kevin Womack for their assistance with the conference. He recognized the work of the conference planning committee, as well as the efforts of TRB staff members Ann R. Purdue, Matt Miller, Thomas M. Palmerlee, and Mai Quynh Le.

WELCOME FROM THE U.S. DEPARTMENT OF TRANSPORTATION

Gregory D. Winfree

Gregory D. Winfree provided a welcome from RITA and the U.S. DOT. He thanked Daniel Sperling for chairing the conference planning committee and recognized his leadership on sustainability issues, which has helped make UC Davis one of the premier transportation research programs in the country. He expressed the gratitude of the Obama Administration and the U.S. DOT for current research efforts conducted by the UTCs and other groups on sustainable energy. He highlighted activities under way at the U.S. DOT related to energy, sustainability, and the environment. Winfree covered the following topics in his presentation.

- Climate change and other issues that affect sustainability did not get much attention during the 2012 presidential campaign. According to Winfree, the problem for America and the problem for the global community is that these issues affect the economy as well as the people. He cited Hurricane Sandy as a reminder that Mother Nature has no political constituency—nothing can make a super storm change its direction or make it vanish. Sandy devastated New York City, New Jersey, and many communities along the East Coast. While a clear link between climate change and a hurricane of that magnitude and duration has yet to be established, he noted that the Atlantic Ocean was warmer than it was supposed to be at that time of year. What is almost as terrifying as Sandy itself, he added, is the prospect of this kind of catastrophe becoming the new normal.

He quoted President Obama, who said on election night, “We want our children to live in an America that isn’t threatened by the destructive power of a warming planet.” Winfree went on to say that humankind has already set the world on a dangerous course, driven by an unquenchable thirst for fossil fuels with the resulting GHG emissions—a course forged by virtue of the growing need for energy, which is supplied largely from coal, oil, and natural gas.

- He noted that taking responsibility to prepare for the consequences of a warming planet is critical. Bold steps are needed to ensure that future generations have the opportunity to meaningfully address these challenges. The president and leaders and decision makers at all levels cannot address energy issues without considering the implications for the transportation system.

- This spotlight conference is especially prescient, he noted, and the research under way at all levels is important for the nation. According to the U.S. Environmental Protection Agency, building more fuel-efficient vehicles and investing in alternative and renewable fuels in the United States alone provide the opportunity to significantly mitigate almost a quarter of the world’s GHG emissions. He stated

that the Obama Administration and the U.S. DOT are taking a broad approach to clean energy, while focusing federal research—and federal dollars—on the most promising technologies.

- He observed that President Obama and U.S. DOT Secretary LaHood have taken action on fuel-efficiency standards and have pushed for much stronger investments in the research, development, and commercialization of electric vehicles. This strategy is already paying off. A new study by the University of Michigan found that the average fuel economy of new vehicles sold in the United States has increased by 4 mpg since October 2007. That improvement equates to one less metric ton of carbon dioxide (CO₂) per vehicle. He remarked that, while a positive step, it does not go far enough in addressing the problem. Intelligent transportation systems (ITS) have the potential to reduce the time motor vehicles spend on the road, to increase the fuel efficiency of vehicles operating on the roadway system, and to reduce the amount of fossil fuels vehicles burn in the process. The U.S. DOT ITS Joint Programs Office is currently testing 3,000 motor vehicles equipped with state-of-the-art connected vehicle technology in Ann Arbor, Michigan. The results from this demonstration have the potential to transform vehicle fleets in concert with efforts to reduce reliance on internal combustion engines. Using vehicle-to-vehicle and vehicle-to-infrastructure communications, this approach will give transportation managers the data needed to make roads and communities more efficient—and empower Americans with information to make more sustainable decisions about roadway travel.

- He stressed his belief that it is critical that the United States succeed in creating a clean energy economy and transportation system. Moving forward at a pace that reflects the magnitude of the climate and energy sustainability problems is key. He noted that for any solution to be enduring—to be truly successful—the nation will need government, industry, and the academic community working together. That is why the UTC program—and the work of all the UTCs and their partners across the country—is so vital to RITA and to the U.S. DOT. The UTCs are the innovators, with the knowledge and expertise the nation needs to move forward. Most of the research conducted by UTCs goes on behind the scenes. Investment bankers do not court UTCs. Nor are UTCs receiving pre-initial public offering stock options, at least not yet. Researchers are committed to advancing science and policy, however. Researchers understand the importance of the issues and care about making things better.

- He concluded by observing that the conference includes excellent speakers and discussion sessions on key issues. Research on the nation's energy sustainability challenges is an honorable and noble cause, even if it does not make headlines. The results of this conference will be of benefit to RITA, the U.S. DOT, the UTCs, and other groups interested in sustainable energy.

GLOBAL ENERGY SUPPLY AND DEMAND: THE WORLD TURNED UPSIDE DOWN

Peter D. Blair

Peter D. Blair, Executive Director of the Division on Engineering and Physical Sciences, National Research Council (NRC), discussed the world energy situation, including the forces shaping energy supply and use. He highlighted the changing energy structure of the U.S. economy, the historical and current energy and policy context, and implications for energy use in transportation. Blair covered the following topics in his presentation.

- There continue to be numerous reviews, assessments, studies, and reports on the global and U.S. energy situation. He noted that the recent report *America's Energy Future* by the Committee on America's Energy Future, the National Academy of Sciences, the National Academy of Engineering, and the NRC forms the basis of much of the information in this presentation. Many other studies and projections have been completed by federal agencies, national and international organizations, corporations, and scientific organizations.
- According to Blair, there are a number of key forces shaping the U.S. energy situation. Increasing world energy demand, particularly in China and other developing nations, is tightening world energy markets. New sources of unconventional gas and oil resources are fundamentally changing the U.S. supply picture, especially in electric power, and to a degree the world outlook as well. Structural change in the U.S. economy continues apace. Energy price volatility remains and continues to complicate market decisions and influences world energy markets. He suggested that continuing concerns about global change remain a significant factor in energy decisions, especially outside the United States. He noted that U.S. oil imports increased from 40% of total oil consumption in 1990 to 60% in 2005, but fell to 49% in 2010, and continue to decline. He remarked that the U.S. energy infrastructure is massive and adapts slowly to change. It is increasingly vulnerable to natural disasters and terrorism.
- In 2006 the Energy Information Administration (EIA) projected that China would pass the United States in energy use in 2027. EIA's 2009 projection revised the date to 2014. The 2010 and 2011 projections indicated that China had already surpassed the United States in energy use in 2009. While there are questions about whether or not the rapid growth in China is sustainable at those rates, it is nonetheless a remarkable dynamic affecting the world energy situation.
- Figure 1 presents world energy consumption by region. Most of the recent growth in energy consumption has been in the developing nations. EIA projects that half of the growth in world energy uses will be in China and India.

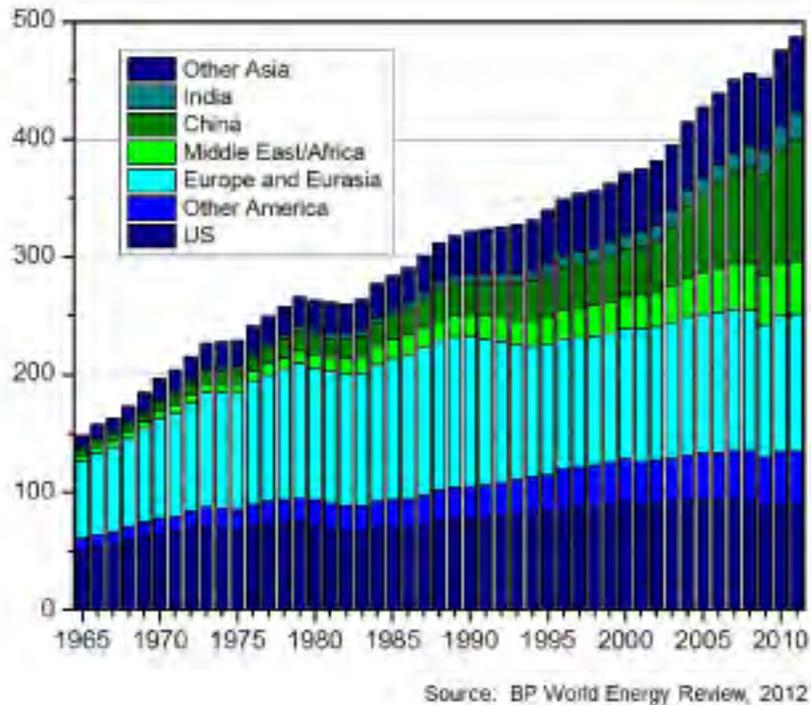


FIGURE 1 World primary energy consumption by region.

- It was noted that world energy consumption by fuel type is also changing. Although the United States is experiencing an increase in the use of natural gas, EIA projects that the share of the world's total use of natural gas will remain constant at 23% through 2035. The share of renewable energy sources, excluding biofuels, is projected to increase significantly, but from a modest base relative to fossil fuels.
- Blair indicated that the Middle East still dominates the projected growth in world natural gas supply. The unconventional gas supply picture is dominated by the shale gas resources being developed in North America. There are shale gas resources in 32 countries, however, which may result in shifts in natural gas in world markets. The United States dominates the unconventional gas resource prospects, but Canada and China also have major unconventional gas resources. The United States is also dominating the early development of shale gas resources, which has offset declines in other U.S. natural gas production sources. He noted that natural gas production and consumption in the United States at current prices have led to substantial fuel shifting in electric power generation and industry, and potentially in transportation as well. He suggested that it appears possible the United States could become a net exporter of natural gas, which would be a fundamental change in patterns of U.S. energy supply and demand and world gas markets.

- The energy intensity of the U.S. economy, as measured by energy consumed per dollar of the gross domestic product (GDP), declined from the 1970s through the 2000s with the exception of electricity. This trend is changing, and energy per capita, which is another measure of energy intensity, is not declining as quickly. According to Blair, these trends suggest that factors in addition to improved energy efficiency are influencing the decline in energy intensity, including the evolution of the U.S. economy from an energy-intensive industrial base to more of a services base; the balance of trade, especially of energy-intensive goods; and population growth.
- He suggested that several forces are influencing a change in the energy structure of the U.S. economy. Energy efficiency improvements, largely coupled with increasing price and regulation, account for about two-thirds of the decline in total energy intensity. The economic structural change, following an eroding energy-intensive U.S. industry base being replaced by a services base, accounts for approximately one-third of the decline in total energy intensity. U.S. imports of energy-intensive products are increasing; the U.S. demand for such goods induces energy-consuming and pollution-emitting production elsewhere in the world.
- It was noted that the United States continues to have the highest energy intensity per capita worldwide. There are variations in energy intensity among states in the United States, with per capita electricity consumption in California and New York leveling off, while continuing to increase for the country as a whole.
- According to Blair, energy price volatility has influenced a change in new motor vehicle sales. The increase in the price of gasoline early in this decade influenced a decline in the market share of sport utility vehicles (SUVs) relative to other types of vehicles. As the price of gasoline declined, sales of SUVs increased. He noted that it appears that at current price levels, fuel prices do influence new vehicle purchasing decisions.
- He pointed out that despite the growth in natural gas worldwide, coal is expected to continue to dominate in electric power generation. China accounts for nearly three-quarters of the expected world increase in coal-fired electric power generation through 2035. Non-Organization for Economic Co-operation and Development Asia accounts for almost 75% of the expected world increase in energy-related CO₂ emissions.
- It was noted that comparing the U.S. oil consumption projections made in 1991, 2009, and 2012 helps identify some of the changes that have occurred during the past 20 years. Alternative fuels were just beginning to be introduced in 1991, while the 2009 projections were influenced by the worldwide depression, which was an important force shaping energy supply and demand. In 2008, net imports were approximately 57% of U.S. oil consumption. EIA is now projecting a decline in net imports to 36% by 2035 as a result of the new corporate average fuel economy (CAFE) standards and enhanced domestic oil production. Natural gas liquids are projected to play a new role in domestic production as well.

- It was observed that energy policy in the United States is largely a derivative policy with its roots in economic, national security, and environmental policies, and with shifting priorities over time among those policies. He suggested that simplistically, the United States challenges focus on “coal and cars.” Shale gas production is helping address the coal situation and the implications for climate change. He further noted that technology may be able to help address key transformations relating to the efficient use of energy, the sources of energy for producing electricity that emits less CO₂, and transportation fuels that derive from alternatives to petroleum. Research and development is needed to develop solutions that have broad appeal in a complicated and complex environment.

THE CHALLENGE OF ENERGY SUSTAINABILITY IN SURFACE TRANSPORTATION

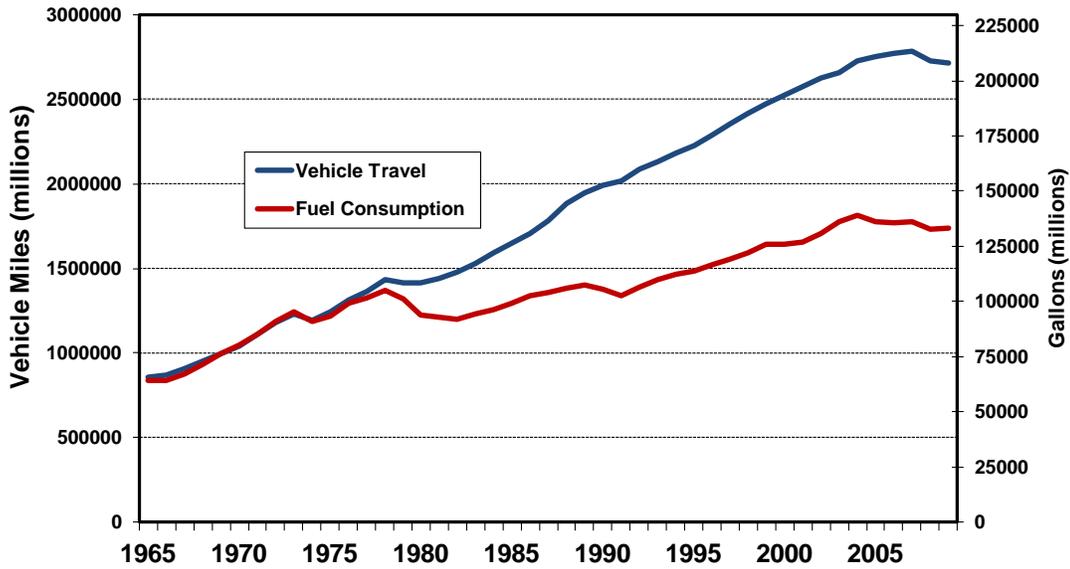
David L. Greene

David L. Greene discussed the transportation energy situation in the United States. He provided a definition of sustainable energy, described oil dependence, and presented potential future scenarios for reducing GHG emissions and the nation’s dependency on oil. Greene covered the following topics in his presentation.

- The International Institute for Applied Systems Analysis recently completed the Global Energy Assessment, a comprehensive examination of the worldwide energy situation. Greene suggested that the following two quotes from the report help set the stage for this conference. “Without question, a radical transformation of the present energy system will be required over the coming decades.” “An effective transformation requires immediate action.” Further, he noted that there continues to be uncertainty over the transportation vehicles and fuels of the future; hydrogen fuel cells, biofuels, electric battery, and other technologies are being tested and used. Discussion at this conference can help reduce this uncertainty, he added.

- Greene indicated that sustainable energy can be defined as ensuring that future generations have energy resources that enable them to achieve a level of well-being at least as good as that of the current generation. Energy is essential to transportation. Transportation is work and work requires energy. Economical energy is needed for mobility and access. Mitigating GHG emissions, addressing climate change, reducing petroleum dependence for energy security, and reducing the other environmental and public health effects of energy use are also important elements of sustainable energy.

- Figure 2 illustrates vehicle miles traveled (VMT) and fuel use by light-duty vehicles from 1965 to 2009. Until 1975, VMT and fuel use were on the same path. The first fuel economy standards were approved by Congress in 1975 in response to the oil crisis in 1973 and 1974. The standards took effect in 1978 and resulted



SOURCE: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, Table VM-1.

FIGURE 2 Miles of travel and fuel use by light-duty vehicles, 1965–2009.

in the decoupling of VMT and fuel use. Greene suggested that the figure illustrates that energy efficiency does work and is cost-effective. Approximately 70 billion gallons of fuel are saved annually. According to Greene, the public supports fuel economy standards, but they are not enough to meet the needs of reducing energy use and GHG emissions.

- It was noted that uncertainty surrounds all of the promising long-term solutions. The standard for renewable fuels has been lowered regularly. Progress is being made in biofuels, land use and VMT reduction, alternative modes, electric vehicles, and fuel cell vehicles, but he suggested that none appear to provide major solutions without policy changes or technology breakthroughs.
- Greene observed that the petroleum-fueled, internal combustion engine-powered transportation system has been locked in by a century of learning, technological evolution, and investment. Even with advances in other fuels, approximately 95% of the U.S. transportation sector depends on petroleum. He noted that it is not easy to change from this long-standing dependence on petroleum.
- According to Greene, the transportation sector is the major contributor to GHG emissions. The U.S. transportation system emits more CO₂ than any country's entire economy, except China's. Highway vehicles account for more than 80% of transportation energy use and GHG emissions. By 2025, the new fuel economy

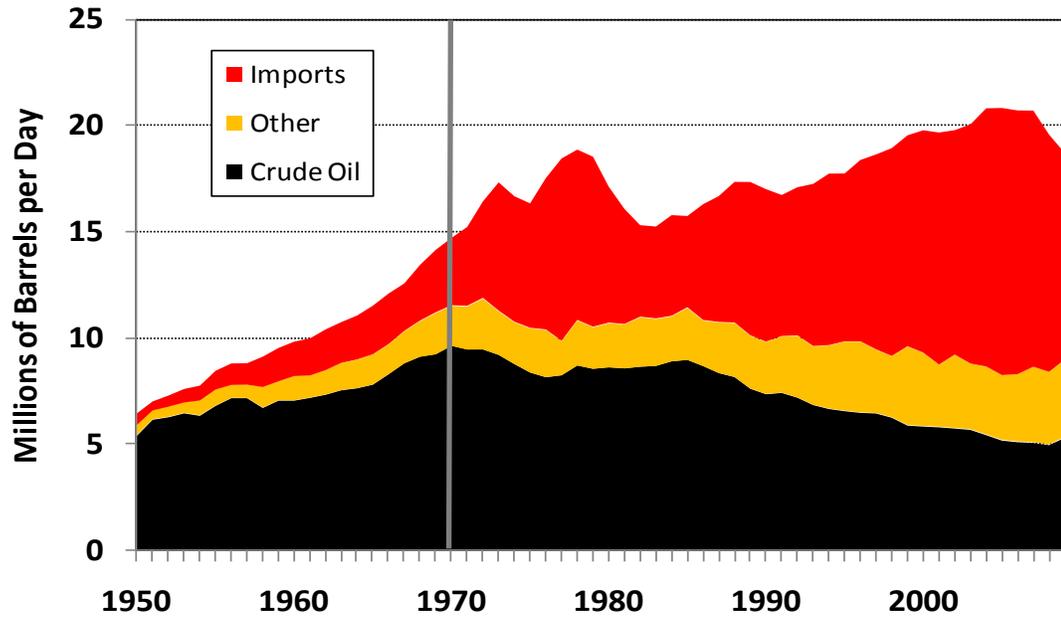
standards will save another 70 billion gallons per year. The new CAFE rule will reduce light-duty vehicle energy use and GHG emissions and produce a modest decrease in transport sector energy use. The new standard will not result in the targeted 80% reduction in petroleum use, however.

- Greene noted that oil dependence is primarily an economic problem with significant national security implications caused by the importance of oil to the economy, the lack of economical substitutes for oil, and the use of market power by oil producers. Members of the Organization of Petroleum Exporting Countries (OPEC) own 70% of the world's proven oil reserves. National oil companies own most of the remaining oil reserves. It is not a competitive market. Rather, it is a market based on nation states determining what to do with their resources and a cartel trying to obtain the highest prices. Oil dependence cost the U.S. economy approximately \$500 billion in 2008 and 2011, and \$2 trillion during the 5-year period from 2007 to 2011. According to Greene, oil dependence costs the United States in three ways—the transfer of wealth as a result of monopoly pricing, the loss of potential GDP as a result of restricting the economy's ability to produce, and price shocks that further reduce the GDP.

- Figure 3 illustrates the U.S. petroleum supply from 1950 through 2009. Greene noted that the cartel's market power was strengthened by growing world demand, its increasing market share, and the peaking of U.S. crude oil production in 1970. The International Energy Agency, as well as major oil companies, foresees a plateau in non-OPEC conventional and unconventional oil production from now to 2035. Approximately 1 trillion barrels of oil have been produced throughout history, with one-fourth produced in the past 10 to 15 years. He observed, however, that there are vast quantities of unconventional fossil resources that can be produced at competitive prices.

- As of 2004, the atmosphere contained approximately 800 gigatons of carbon (GtC). The world's natural gas and oil resources added together account for approximately 530 GtC. Greene indicated that if all of these gas and oil resources were burned, approximately half—265 GtC—would end up in the atmosphere. Thus, burning all the conventional oil and gas in the world will not double the atmospheric concentration of carbon. Burning coal and all the unconventional oil and gas resources could cause severe problems with the atmosphere concentrations, however.

- According to Greene, the proposed 2017–2025 U.S. fuel economy standards appear to put light-duty vehicles on a path toward oil independence and an 80% reduction in CO₂ emissions for the next 10 to 20 years. The U.S. 2014–2018 heavy-duty vehicle fuel economy standards require modest gains of 9% to 23% reduction in fuel consumption. NRC's study estimates that more can be done to address emissions from heavy-duty trucks.



Source: EIA, Annual Energy Review 2009, Table 5.1.

FIGURE 3 U.S. petroleum supply, 1950–2009.

- Greene noted that reducing global transportation energy intensity by 50% or more could hold energy use at today’s level in 2050. A 50% reduction in some combination of the carbon intensity of fuel and the amount of transportation activity is needed, however. Without energy efficiency improvements, other initiatives will be needed to reduce emissions. Thus, energy efficiency improvements are very important, but are not enough.
- Greene suggested that the great energy transformations of the past were driven primarily by technological change and market forces, not by public policy. Creating a transition for the public good presents a new challenge. Changes in technology take time. As a result, sustainable energy for transportation poses a new, heroic challenge for public policy. According to Greene, urgent action is required. The benefits probably outweigh costs by an order of magnitude. There is deep uncertainty about the paths to take and the outcomes, however. He underscored the need for researchers to help define a new paradigm for public policy and to reduce the uncertainties associated with technology and policy changes, noting that the need for research and information is enormous in addressing the challenges.

PLENARY SESSION 1

Interconnection of Energy Use, Pricing, and Finance

Martin Wachs, *RAND Corporation and University of California, Los Angeles*

B. Starr McMullen, *Oregon State University*

Arlee Reno, *Cambridge Systematics, Inc.*

Paula J. C. Hammond, *Washington State Department of Transportation, presiding*

Speakers in this session examined the relationship of current finance and pricing policies with efforts to reduce energy use and greenhouse gas (GHG) emissions. Speakers addressed questions related to the way current and proposed energy policies will affect the sustainability of transportation finance that is based on the gasoline tax and to what research is needed to help identify new options in which transportation finance, pricing, energy, and GHG policies are compatible and sustainable.

INTERCONNECTING TRANSPORTATION FINANCE, PRICING, AND ENERGY USE IN WASHINGTON STATE

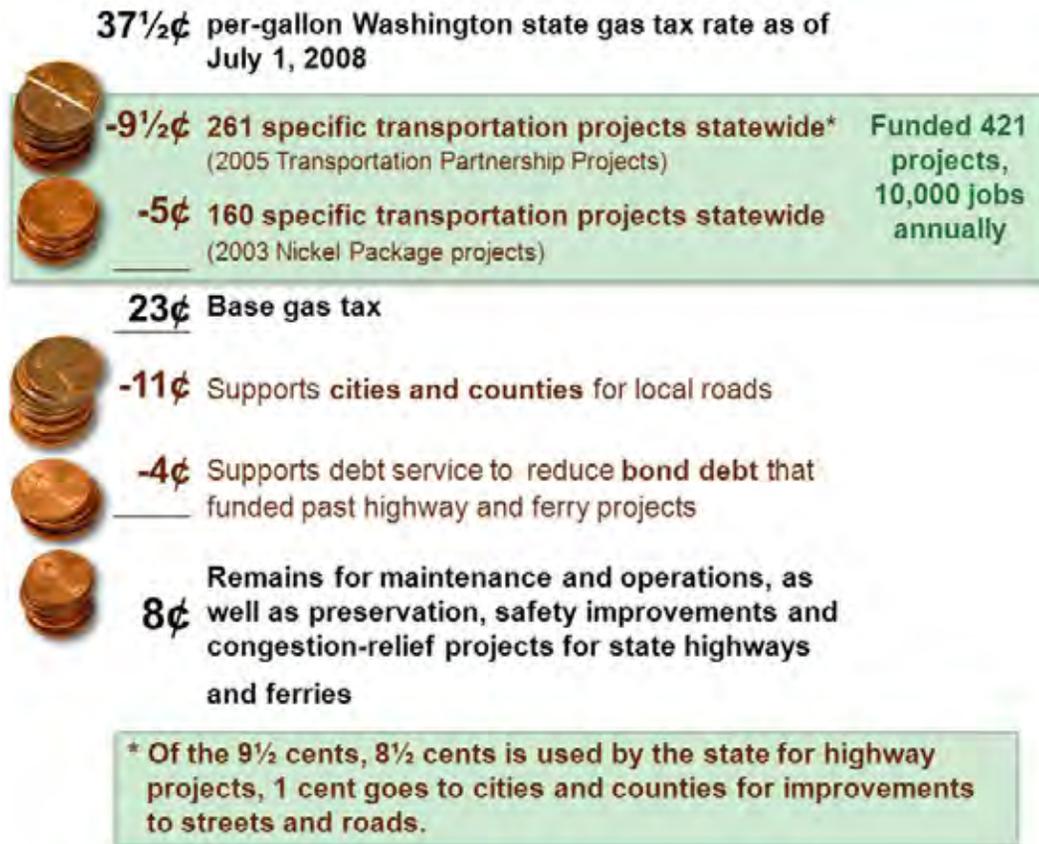
Paula J. C. Hammond

Paula J. C. Hammond introduced the plenary session by providing examples from Washington State related to the interconnection of transportation finance, pricing, and energy use. She noted that the Washington State Department of Transportation (DOT) and other state transportation agencies throughout the country focus on delivering transportation services on a daily basis. Working with universities and other groups to consider policies to address current and future funding needs, as well as sustainable energy, is essential to ensure the ongoing viability of the transportation system. Hammond covered the following topics in her presentation.

- Voters in Washington State approved increases in the state gasoline tax in 2003 and 2005. Combined, these two increases resulted in 421 projects representing a \$16.3 billion investment to help improve the transportation system to meet the growing needs and demands of travelers and commerce. Washington State DOT is currently at the peak of delivering these projects. The gas tax increases were fully bonded, meaning that Washington State DOT will be collecting a gasoline tax of 14½

cents per gallon for the next 25 to 30 years to pay for the projects being used today. The benefits from these projects are being realized today, but current funding is not adequate to meet basic maintenance and operation needs. As illustrated in Figure 4, the current gasoline tax is 37½ cents. Only 23 cents is left, however, after taking off the 14½ cents that is bonded for the next 25 to 30 years. The 23-cent base gasoline tax has been in place in the state since 1991. A total of 11 cents of the tax is dedicated to cities and counties for local roads, and 4 cents supports debt service to pay off bonds from past highway and ferry projects. Only 8 cents per gallon remains available from the 37½ cents per gallon gasoline tax for maintenance, operations, preservation, safety, and congestion relief for state highways and ferries.

- Hammond estimated that in Washington State, the state gas tax funds approximately 76% of all transportation investments. The combination of fuel-efficient vehicles and a weak economy affects fuel sales. Fewer gallons of gasoline sold equals reduced gas tax revenue projections. Since March 2007, projected fuel tax revenues have been revised downward by \$3.6 billion during the 13-year period from 2007 to 2020.



SOURCE: Washington State DOT.

FIGURE 4 Gasoline tax in Washington State.

- Hammond concluded her remarks by noting that Washington State is examining options, including treating the transportation system as the utility it is. The mileage-based user fee concept is being considered as one option. Issues associated with equity, freight movement, and other concerns are being examined. A road usage charge assessment study is being conducted in collaboration with the Washington State Transportation Commission. The study is examining administrative and operational questions related to how a road user system could be applied in the state. Washington State DOT is also collaborating with Oregon, Nevada, Colorado, and other western states on possible pilot tests of mileage-based user fee collection systems. Discussions with policy makers and the public are key parts of these efforts. Pricing to obtain desired emissions reductions are being considered. Many other states are also considering mileage-based user fees or other approaches, including possible pilot programs.

INTERCONNECTION OF ENERGY USE, PRICING, AND FINANCE

Martin Wachs

Martin Wachs discussed the interconnection of transportation energy use, pricing, and finance. He described the current funding crisis in transportation, emerging financing options, urban form and energy efficiency, and research challenges. He noted that the methods used to finance the transportation system and collect revenue, directly affect energy use and GHG emissions and that public policy currently focuses on the use of general revenues and not pricing on the basis of travel or the computation of energy. Wachs covered the following topics in his presentation.

- Transportation is facing a funding crisis. Many state DOTs are unable to fund standard maintenance, much less system expansion or environmental improvements. Currently, less than half of state transportation expenditures come from user fees. Increasingly, states are borrowing to pay for maintenance and operations. The Federal Highway Trust Fund and many state transportation funds are in deficit, while most legislators oppose any increase in user fees.
- New directions are emerging in transportation finance. Wachs suggested that it is imperative to find new sources of revenue for transportation infrastructure and operation. He noted that the manner in which revenue is collected does affect energy consumption. There is a need to link revenue strategies to energy efficiency. Numerous opportunities exist for research in that area.

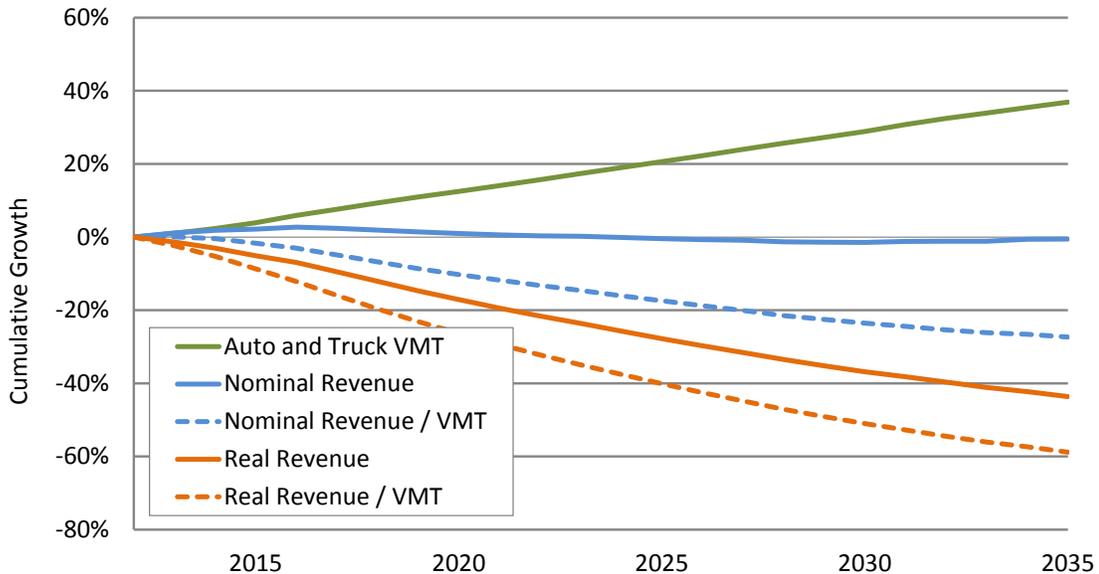
- Wachs cited three policy concerns associated with the current situation. The first policy concern is the decline of user fees as the basis of revenue for transportation and the growth of non-user-based finance. The second is the possibility of a new generation of user fees based on vehicle miles traveled. The third focuses on urban form and smart growth. Research opportunities exist with all of these policy concerns.

- Oregon was the first state to adopt a motor fuel tax in 1918. Motor fuel taxes were popular in the early years, with support from automobile manufacturers and users, automobile clubs, and bicycle groups. At the time, the need for roadway improvements was widespread and the logic of charging users was convincing. The federal motor fuel tax was implemented in the 1930s and was the fundamental mechanism used to finance the Interstate system, which was initiated in the 1950s. By 1940 all states had adopted some form of user fees, including gasoline taxes, and vehicle licensing and registration fees. Motor fuel taxes have worked well for a century. The collection costs associated with motor fuel taxes are very low; they are collected at the wholesale point and passed on to consumers.

- Numerous issues are associated with motor fuel taxes, according to Wachs. With increasing vehicle fuel efficiency, motor fuel taxes produce less revenue, even as driving increases. He suggested that high fuel prices discourage state legislatures and Congress from considering tax increases. Indexing motor fuel taxes has been adopted in some states. It appears to be a short-term fix, however, as at least seven states have discontinued indexing in response to higher gasoline prices. Corporate average fuel economy (CAFE) standards are increasingly demanding, resulting in declining revenues in relation to travel. The introduction of alternative fuels and the purchase of electric or other alternatively fueled vehicles further reduce the revenues generated from the gasoline tax. He noted that legislators often want to encourage alternative fuels by keeping taxes on them low, while not raising taxes or fees on travel or petroleum.

- Wachs observed that while the higher CAFE standards have numerous energy and environmental benefits, they do not benefit user fee revenues. By 2025 the fleetwide average will be 54.5 mpg. Consumers will have saved \$1.7 trillion at the fuel pump over the life of the program. A family that purchases a new vehicle in 2025 will save \$8,200 in fuel costs when compared with a similar vehicle purchased in 2010. During the life of the program, the standards will save 12 billion barrels of oil and eliminate 6 billion metric tons of carbon dioxide pollution.

- Wachs referred to Figure 5, which illustrates that the real fuel tax revenue per mile of travel could decline significantly, even with an increase in VMT. Although VMT has remained flat recently, growth in VMT can be expected as the country emerges from the recession. He suggested that revenues needed to maintain the system will not be available to meet that growth.



SOURCE: Calculations by author based on U.S. Energy Information Administration's Annual Energy Outlook projections for 2012 and current federal fuel tax rates.

FIGURE 5 Projected real fuel tax revenue per VMT.

- Wachs noted that numerous options are being used to address this situation, and others are being considered. First, general funding financing is increasing in many states. Voters in many states have approved bond measures and sales tax increases, in some cases multiple times. He suggested that this approach generally does not contribute to energy efficiency and may not be sustainable in the long term. New forms of user fees are possible and could advance energy efficiency. Examples of new approaches include mileage-based user fees and more toll roads, including the use of open road tolling.

- The trend of using ballot measures to fund transportation improvements began in California in the 1980s but has spread throughout the country. Most of these measures focus on general revenue rather than on user fees. Further, many are at the county level, although some are at the regional or state level. It has taken two or more attempts to win voter approval in some areas, while voters in other areas have approved multiple measures over the years. The percentage of transit ballot measures approved by voters ranged from 46% to 83% annually between 2000 and 2009, with approximately 70% passing.

- In 2011, 33 of 39 ballot measures in nine states were passed. In 2012, there were 18 ballot measures in 12 states. Of these, eight involved sales taxes, four involved regional transportation authority participation, two were advisory, and one involved property taxes. There was also one anti-transit measure, one bond measure,

and one gas tax measure. Wachs suggested that these types of measures do little to promote energy efficiency.

- User fees are also under consideration in some areas. He noted there is less public support or enthusiasm for these approaches, which include mileage-based user fees, open road tolling, and tolling allowed on Interstates. These approaches can contribute to energy efficiency and sustainability.

- Wachs observed that mileage-based user fees appear to be a promising approach, as revenues continue to be produced even when vehicles are no longer powered by petroleum fuels. This approach comes close to meeting the goals for road user fees that existed in the 1920s and is more direct than fuel taxes. Technology for use in mileage-based user fees and tolling is advancing rapidly and is in use in several countries in Europe. Tests have been conducted in the United States, including “pay at pump” demonstrations in Oregon. Mileage-based user fees provide policy flexibility as the fees can vary by type of vehicle, type of roads, hour of day, or other factors. Mileage-based user fees can be structured to promote energy efficiency.

- Forecasts suggest that VMT growth will continue to outpace fuel consumption in the coming decades. Wachs observed that a revenue-neutral switch to VMT fees in 2015 should produce much higher revenue by 2030 compared with continuing the motor fuel tax. Mileage-based fees will be more challenging to implement than fuel taxes, however. A major change is in the point of collection. Rather than a few hundred collection stations used under the gasoline tax, millions of drivers would be charged. He noted that technical complexity includes choices for metering mileage by location, collecting fees, preventing fraud or evasion, and protecting privacy.

- Wachs indicated that the way a transition would be made from the current fuel tax to a mileage-based tax is a critical question. The ability for direct charging may need to be phased into new vehicles over time. One approach that has been suggested is to begin with electric vehicles, which do not currently pay any user fee or gasoline tax. He noted that at least a decade will probably be needed for political and public acceptance to grow. Privacy concerns will need to be addressed. A strong case for trials can be made, but the Moving Ahead for Progress in the 21st Century Act did not provide funding for demonstrations or tests. Many research needs are associated with the transition to mileage-based user fees.

- Wachs underscored that there is a growing policy consensus on the role of urban form in promoting energy-efficient cities. Smart growth concepts are being adopted and implemented in many areas. For example, in California, Assembly Bill 375 requires metropolitan areas to have plans that concentrate development around public transit stations and to achieve reductions of VMT through the transformation of urban form. Metropolitan areas are developing and adopting these plans. This consensus is occurring at the same time that household structure, demographics, and market preferences are changing radically. These changes include the aging of the baby boom generation and smaller households. It is difficult to separate the influence of public policies and consumer preferences on these changes.

- Wachs noted that there are still many debates and conflicting conclusions about the potential effect of urban form on energy efficiency. For example, conclusions about the effect of urban form vary with data and the scale of analysis. Some have suggested that as vehicle fuel efficiency improves over time, urban form may not matter as much. More research is needed to better understand the causal connections between energy price, travel costs, and urban form. Even the direction of causality is unclear.

- He noted that the transition away from motor fuel taxes could take different paths or different forms. Even if motor fuel taxes continue for the short term, they are not a viable long-term solution. General revenue support, which has devolved to states and local governments, seems viable in the short term but has limits. He further noted that while new forms of user fees are attractive to researchers and technology groups, they appear to be falling flat with the public. What this situation means for the future of transportation funding and energy efficiency can be debated.

- According to Wachs, research is needed to help advance the discussion and the implementation of future financing options. A first research challenge is examining the revenue streams created by different approaches. An examination of which forms of charging produce the most robust revenue streams, are most effective in creating energy-efficiency transitions, and are most politically feasible would be beneficial. Privacy issues, the costs of implementation, and equity implications need to be considered in this analysis. Exploring which forms of charging achieve the best balance among the competing criteria of cost, efficiency, and equity is also needed.

- A second research challenge suggested by Wachs focuses on collection technology development, integration, and interoperability, including hardware and software. The institutional arrangements for monitoring, collecting, and distributing revenues need to be considered. Integrating the transportation system with telecommunications systems and networks also needs to be examined. Consortiums of hardware and software companies, financial institutions, and other groups are likely to be needed.

- A third research challenge Wachs posed focuses on assessing the effects and implications of different user fees. Examining how different methods for pricing travel affect urban form and how urban form affects travel and therefore the revenue stream would be beneficial. He suggested that assessing how pilot programs have performed and developing case study research are crucial to additional progress. Public opinion research may be as important in the early stages as behavioral research and modeling. For example, there is a need to better understand why the public prefers general revenue finance although energy efficiency is better served by user fees.

- Finally, a fourth research challenge Wachs noted is examining the interaction between technology-based solutions, pricing, and urban form. This relationship is dynamic and critically important and researchable through modeling and scenario-based analysis. There is also uncertainty concerning the role telecommunications technology will play in replacing travel.

REDUCING ENERGY USE AND DEPENDENCE ON FOSSIL FUELS: INTERCONNECTIONS WITH PRICING AND FINANCE

B. Starr McMullen

B. Starr McMullen discussed the interconnection of reducing energy use and dependence on fossil fuels, pricing, and finance. She discussed research challenges associated with considering the effects of different pricing policies to create incentives to reduce energy use. McMullen covered the following topics in her presentation.

- Reducing GHG and fossil fuel energy consumption has been illustrated as the four-legged stool. The four legs focus on using more fuel-efficient vehicles, using alternative fuels, reducing VMT, and improving vehicle and system operations. Policies related to these elements may have conflicting results. More fuel-efficient vehicles and alternative fuels reduce the per-mile cost of driving and reduce revenue to the highway fund, but increase VMT and damage to the roadway system. Some policies may result in unintended consequences.

- Jan Tinbergen, the first recipient of the Nobel Prize for Economics, emphasized that achieving the desired values of multiple policy goals requires multiple tools or instruments. He also emphasized that care should be taken to avoid unintended consequences with these policies. McMullen suggested that multiple transportation policies are needed to address energy, GHG emissions, and finance issues. Designing policies that build on each other to support multiple goals represents a viable approach.

- McMullen noted that a VMT-based fee system could help stem revenue loss from increased fuel efficiency and the use of alternative fuels. If properly set according to optimal pricing principles, the system could significantly reduce damage to the highway system, meaning that less funding would be needed for ongoing maintenance. It could also be supplemented to help promote other goals such as a reduction in fuel consumption, congestion, and other externalities. One flat VMT pricing strategy cannot achieve multiple goals, however.

- According to McMullen, one research challenge is assessing the effect of alternative fee designs. Possible approaches include flat fees, additional fees to deal

with other externalities, differential additional fees, and rebates or redistribution of fees to deal with potential equity concerns. She suggested that examining the effects of these different approaches on revenues, VMT, GHG emissions, public acceptance, and other factors would be beneficial.

- She noted that it is important to consider freight in the assessment of different VMT pricing strategies. Freight represents a key part of the U.S. economy, and trucks are a major component of the freight transportation system. Freight trucks are responsible for almost 20% of all transportation-related fuel consumption and GHG emissions in the United States. Freight highway VMT is growing faster than overall VMT. She indicated that trucks do more damage to the roadways than personal vehicles. A number of factors contribute to this increase in freight VMT. According to a 1997 study, considering the current fuel tax structure, large trucks on average pay about half of their share of the cost of maintaining the road system.

- Oregon is one of four states that currently have a weight-mile tax (WMT) for heavy vehicles. Oregon has had a WMT since 1948. The current tax structure charges higher rates per mile for vehicle configurations that impose greater damage to the roadways. At one time, 11 other states had a WMT, but only three other states—New Mexico, Kentucky, and New York—have continued this approach.

- McMullen stated that of the four states Oregon has the most sophisticated WMT system. In Oregon, the mills per mile are lower for a given truck weight using more axles because less damage is done to the roadways. She noted that from an economic standpoint, heavy trucks in Oregon do pay their cost responsibility. Thus, a WMT can both increase revenues and reduce damage to the roadways. A 1989 study suggests that WMT can be optimally designed to reduce damage to roads and to increase revenues, resulting in net improvements in highway finance.

- McMullen suggested that a second research challenge is assessing the effects of a national WMT for heavy vehicles. This study could examine the effects a national WMT, such as the Oregon system, would have on highway finance, highway damage, and highway revenues. It could also explore possible effects on overall economic activity, consumer costs, and international competitiveness. Exploring operational issues related to truck size and weight limits, which are not usually considered in energy discussions, would also be beneficial. For example, allowing triple trailers and other large commercial vehicles may reduce the number of trucks on the road, reduce fuel consumption, and lower overall transport costs.

- A third research challenge presented by McMullen was examining the effect of national harmonization of truck size and weight limits. It would be beneficial to assess how energy use would be affected by harmonizing intrastate size and weight limits and by allowing larger commercial vehicles. The research could also explore other implications of such a policy on overall transport costs.

- The final research challenge identified by McMullen was examining the optimal share of highway costs that users and nonusers of the system should pay.

Nonuser funding sources are increasingly being applied in many areas, as mentioned by Martin Wachs. McMullen noted that this trend may distort pricing and incentives, but nonusers of the system do benefit from freight use of the system.

U.S. AND INTERNATIONAL DATA ON ECONOMICS, ENERGY, AND TRANSPORTATION

Arlee Reno

Arlee Reno discussed trends in U.S. travel, the economy, and energy. He provided a comparison with European trends related to those factors. Reno covered the following topics in his presentation.

- The AASHTO Bottom Line report estimated how much additional revenue was desirable to invest in highways and public transportation. The need for higher annual levels of capital investment in the range of \$60 billion to \$100 billion was identified. This level of funding can be satisfied with a fuel tax increase of 35 to 60 cents. Reno noted that this level of tax increase, which is smaller than recent fuel price changes, would have small effects on total travel costs, and thus, small effects on energy usage and sustainability. He suggested that although it is desirable to consider revenues and sustainability together, solving the revenue issue does not necessarily solve the sustainability and energy issues.

- Martin Wachs noted in his presentation that public support for transportation ballot measures and fuel tax increases appears to depend on how the revenues will be used, more than on the source of the revenues. This response reinforces the need to focus on the benefits of investments using new or enhanced revenues. Reno indicated that future revenue is likely to be higher from fixed VMT fees than from fixed fuel taxes, even if VMT growth remains modest. As a result, he noted, some forms of pricing may produce additional benefits. A recent study conducted by the Puget Sound Regional Council (PSRC) examined the benefits to different user groups from spending less time in traffic versus the cost of tolls for using the system. PSRC estimated benefits from pricing itself rather than from the use of revenues, and those benefits to user groups from pricing alone were less than the fees paid, as would be expected before considering only the effects of generating revenues rather than considering the benefits of investments. Reno's analysis added in the average benefits per investment in highways as estimated in the latest AASHTO Bottom Line analysis; these benefits were about \$2 for each \$1 of revenue generated for highways. Results indicate that although all user groups would benefit when the effects of making investments with revenues are included in addition to the effects of pricing itself, commercial operators would gain the most from pricing combined with investments, and that higher-income personal-vehicle users will gain more than lower-income

personal-vehicle users. A study by the Massachusetts Institute of Technology (MIT) has also examined the effect of a carbon tax and a lump sum rebate by household. The MIT study results indicated that it is possible to address equity concerns about the effects on low-income households by using rebates as the remedial equity action.

- Some basic facts related to travel and the economy in the United States show that highway use of motor fuel in 2010 accounted for 168 billion gallons, annual VMT has been approximately 3.0 trillion for each of the past 8 years, and operating plus travel time cost per mile for highway travel is slightly more than \$1 per mile for individual vehicles. The 2 cents per mile collected in federal plus state motor fuel taxes for personal vehicles represents a small percentage of this cost, and travel demand changes will not be great if costs change by a small amount.

- Although VMT has grown in the past, there has been no growth in VMT during the past 8 years. In addition to higher gasoline prices, households below the very top income levels have experienced losses of real income since 2000. Further, incomes below the top were also stagnant from 1980 to 1992. All income groups experienced gains from 1992 to 2000, with higher-income groups realizing the largest gains.

- According to Reno, overall, the United States has been improving consistently in regard to lowering energy and GHG emissions per unit of real dollar gross domestic product. This improvement has been driven by major efficiency gains in the non-transportation industries, however. Transportation energy use improvements in the United States were affected by the conversion of substantial technical advances after 1982 into higher horsepower rather than into higher average miles per gallon. This will change with the new fuel economy standards.

- Automobiles and light trucks are the predominant mode for passenger travel in all western nations. The United States has higher miles of travel per capita and higher transportation GHG emissions per capita than all nations except Luxembourg, which sells inexpensive fuel to users in neighboring countries. The United States has lower percentages of travel by bus, urban rail, and passenger rail than the other western nations.

- European highway fees per capita are higher than those in the United States. The European Union (EU) Road Federation estimates 381 billion euros of total fuel and vehicle fees in 2006 for the EU-15 countries, accounting for a population of 380 million. These figures are equal to \$1,400 per person in U.S. currency (at one euro equal to \$1.40). Highway Statistics 2007 identified \$120 billion in total U.S. federal and state highway user fees, which is equal to approximately \$400 per person. Adding \$1,000 per person for the United States to have fees comparable with the EU fees would generate approximately \$315 billion in revenue per year, which would represent a very significant increase in net federal tax revenues in the United States. Reno said further that measures such as investment in public transportation and more compact development can slow VMT growth without negative effects on mobility or on personal income. These approaches have only modest effects, however. Public

transportation now accounts for only 1% of total personal travel in the United States and doubling it to 2% would affect only about 1 year's worth of VMT growth. Land use changes may have slightly greater effects, but would occur during a very long time period.

- Reno noted that a number of different groups have provided forecasts of average annual growth in VMT that can be used to estimate the potential effects of pricing levels needed to reduce VMT. The AASHTO Bottom Line report 2008 base case and the U.S. Department of Energy Alternative Energy Outlook 2009 base case both used a 1.4% average annual growth in VMT. This figure results in an increase of 32% in VMT over 2010 levels by 2030 and 74% increase by 2050. The 2008 AASHTO Sustainability Goal uses a 1% average annual growth in VMT, resulting in an increase of 22% over 2010 levels by 2030 and 49% increase by 2050. The National Surface Transportation Policy and Revenue Study Commission 2007 base case used a 1.8% average annual growth in VMT, resulting in a 43% increase over 2010 levels by 2030 and a 104% increase by 2050. Substantial pricing for travel would be needed to reduce VMT in the face of that growth. The relationship of pricing to VMT and fuel growth is important and needs to be examined in more detail.

- In summary, Reno said that current economic factors are now leading to major income losses for the great majority of Americans. Economic growth, equity, and environmental quality are desired policy outcomes. Greater fuel efficiency and some travel activity strategies achieve very positive policy results, such as reducing oil dependence, GHG emissions, and costs, without negatively affecting mobility. These strategies reduce revenues from current or proposed user fees, however. Higher investment in transportation is needed, but any pricing actions will also need to be accompanied by effective actions to address potential equity concerns.

PLENARY SESSION 2

Emerging Vehicle and Fuel Technologies

Challenges and Opportunities

David Sandalow, *U.S. Department of Energy*

Thomas Bradley, *Colorado State University*

Thomas Turrentine, *Institute for Transportation Studies, University of California, Davis*

Mark S. Duvall, *Electric Power Research Institute, presiding*

Speakers in this session examined the role fuels and propulsion technologies may play in reducing petroleum use and greenhouse gas (GHG) emissions. The effect of public policies, such as fuel economy and GHG standards, zero-emissions vehicle (ZEV) mandates, and renewable low-carbon fuel standards, were explored, as well as the analyses and data needed by government and industry in crafting effective policies and investment strategies.

EMERGING VEHICLE AND FUEL TECHNOLOGIES

David Sandalow

David Sandalow discussed research and development activities under way at the U.S. Department of Energy (DOE) related to emerging vehicle and fuel technologies. He described projects and programs associated with electric vehicles (EVs), advanced biofuels, advanced internal combustion engines (ICEs), natural gas, and hydrogen fuel cells. Sandalow covered the following topics in his presentation.

- He noted that President Obama focused on clean energy and alternative fuels during his re-election campaign when he said that “We should be using that money to double down on investments in clean energy technologies that have never been more promising. Investments in wind power, in solar power and biofuels. Investments in fuel-efficient cars and trucks and energy efficient homes and buildings. That’s the future.”

- Sandalow further noted that U.S. DOE Secretary Chu is also a strong supporter of advanced vehicles, as evidenced when he said that “DOE is working to promote alternatives such as biofuels and EVs. We have the innovation, skills, and abilities to really be the major player in this field.” The secretary is focusing on accelerating the rate of energy innovation in the United States to reduce the dependence on oil.

- Sandalow noted that one question Secretary Chu likes to ask is, what does a Boeing 777 have in common with a bar-tailed godwit bird? The answer is that both can fly 6,800 mi nonstop. The bar-tailed godwit flies nonstop from Alaska to New Zealand in one migration cycle. A second part of the answer is that at takeoff, the fuel accounts for approximately 50% of their total weight. DOE is examining numerous areas, approaches, and tools to promote energy innovation, including bio-mimicking. High-performance computing has also been used recently to optimize the location and power generation from large wind turbine farms and to reduce aerodynamic drag and improve the energy efficiency of large trucks.

- Petroleum accounts for approximately 94% of the energy used to power automobiles and trucks in the United States and in the world. This dependence on petroleum has environmental, geopolitical, and economic implications. According to Sandalow, diversifying the reliance of the transportation sector away from petroleum is an important objective. DOE is investing in five technologies—EVs, advanced biofuels, advanced ICEs, natural gas, and hydrogen fuel cells.

- President Obama announced the EV Everywhere Grand Challenge in North Carolina in March 2012. Secretary Chu participated in the first of five EV Everywhere Framing Workshops in June 2012. The objective of this effort was to create EVs for the American public that are as convenient and affordable as any ICE vehicle. A number of topics are being addressed, including battery research, deployment issues related to charging locations and signing, and techniques to promote EVs. The cost of plug-in hybrid batteries are being reduced, and it appears that the goal of \$300 per kilowatt hour by 2014 will be met.

- Many models of EVs are available today, and more will be introduced during the next 12 months. EVs accounted for approximately 12% of all vehicles sold last month. The American Reinvestment and Recovery Act of 2009 (Recovery Act) includes the world’s largest documented electric-drive vehicle demonstration. Data from this demonstration are still being analyzed.

- Sandalow noted that there will be numerous activities under way focusing on next-generation biofuels. The Recovery Act included more than \$600 million in matching funds for pilot projects, demonstrations, and commercial-scale biorefineries. The first commercial-scale biorefineries are coming online in Florida and Iowa. He suggested that gasification and thermochemical offer other promising routes to advanced biofuels. Cellulosic ethanol is beginning to come to market. Transforming technologies for drop-in fuels that do not require infrastructure modifications are also being developed.

- Improving the efficiency of ICEs has also been a priority of the Obama Administration. The new combined fuel efficiency standards are 35.5 mpg by 2016 and 54.4 mpg by 2025. These standards are projected to reduce oil consumption by about 1.8 billion barrels over the lifetime of vehicles sold in the next 5 years. DOE is supporting research on ICEs, including loans to Ford Motor Company to raise the fuel economy of 2 million new vehicles a year by 20% through the use of direct injection, smart turbocharging EcoBoost engines, and other technologies. Research and development activities are also under way to raise the fuel economy of trucks by 50% and light-duty engines by 25% to 40% through a variety of technology pathways.

- Sandalow noted that the recent increase in natural gas production from shale in the United States has created opportunities in the transportation sector. Investments in natural gas-based heavy-duty vehicle fleets are being made. Transformational approaches for fueling tanks and for home-refueling of personal vehicles are also being examined. The Advanced Research Projects Agency–Energy MOVE program (for Methane Opportunities for Vehicular Energy) is funding 13 new cutting-edge research projects focusing on new ways of harnessing America’s abundant natural gas supplies.

- Sandalow reported that DOE has funded numerous research and development projects related to hydrogen and fuel cell technologies, which have led to 363 patents, and 35 commercial and 65 emerging technologies. It has also enabled an 80% cost reduction in polymer electrolyte membrane fuel cells since 2002 and a doubling of durability since 2006.

- According to Sandalow, on a worldwide perspective, the growth in the vehicle fleet in China has been dramatic. The rapid growth in motor vehicle fleets is projected to continue. The United States has ongoing diplomatic interaction with China, encompassing both cooperation and competition. These efforts focus on addressing concerns over trade disputes and finding ways to promote common interests. The United States and China are the two largest oil consumers and oil importers, resulting in a common interest to diversify petroleum-based vehicle fleets.

IDENTIFYING RESEARCH NEEDS FOR EMERGING TECHNOLOGIES

Thomas Bradley

Thomas Bradley discussed research needs associated with plug-in EVs (PEVs) and other emerging technologies. He described the total cost of ownership (TCO) model, consumer acceptability research, and policies to drive incentives for new technologies. Bradley covered the following topics in his presentation.

- He suggested that PEVs are an acknowledged means to achieve sustainability, economic, and policy goals. PEVs reduce petroleum consumption and reduce carbon dioxide (CO₂) emissions and criteria pollutants, relative to conventional vehicles. He noted that these benefits come at an incremental up-front cost to the consumer, which reduces consumer acceptability of PEVs. Research topics focus on the role of total ownership cost in mitigating these up-front costs and whether the plug-in hybrid EV (PHEV) incremental cost to the consumer will be equal to its incremental cost to manufacture.

- A number of studies have examined PHEV TCO modeling and analysis. These studies reach similar conclusions, that there are two methods to improve PHEV market acceptability. The first is dramatic technology improvements related to battery cost to lower the incremental costs of PHEVs. The second is policy or macroeconomic forces that result in gasoline prices in the range of \$5 per gallon.

- Bradley noted that current TCO models are not harmonized in their methods or inputs. Differences exist in vehicle usage assumptions related to annual vehicle distance traveled, vehicle life, utility factor type, fuel economy method, and use of the U.S. Environmental Protection Agency adjustment of fuel economy. Differences also exist in the consumer preference model used.

- Bradley discussed a research project examining harmonized and comprehensive TCO modeling. A number of research tasks were carried out. A review of harmonized TCO modeling performed to date was completed, including examining vehicle component cost models and developed and updated Electric Power Research Institute vehicle-component cost models. Researchers also reviewed and developed maintenance cost models, loan models, and salvage value models. A more comprehensive TCO model for PHEVs was constructed. Sensitivity analyses were performed, which demonstrated the utility of TCO in understanding consumers' surveyed understanding of TCO versus upfront cost trade-offs.

- According to Bradley, a comparison of TCO literature without harmonization illustrates the differences in input variables and results. A comparison of TCO literature with harmonization also illustrates many differences, suggesting that structural harmonization is needed.

- The sensitivity of the payback period to TCO input parameters was examined for a midsize car class and large SUV class. Some variables were sensitive while others were not. The sensitivity of payback period to TCO contributing analyses indicated that the payback period varies by vehicle and that consideration of EV supply equipment is more important than the battery lasting the lifetime of the car.

- Bradley noted that research on unifying TCO with consumer acceptability was also assessed. In the available literature on vehicle TCO, there is a philosophical interest in the metric of vehicle payback period, informed by the assumption that

rational PHEV consumers will insist on recouping their investment in the costs of PHEV components with equivalent or greater benefits. Although these studies report TCO, payback period, and net benefits, consumers do not report performing TCO calculations to inform their vehicle-type decision making. It appears the payback period is a sensitive metric of TCO and consumer acceptability.

- Consumer acceptability integrated with TCO modeling indicated that consumer preference is roughly aligned with economic rationality. Bradley noted that it also indicated that purchase price sensitivity and undervaluation of TCO benefits is present and that PHEVs are accessible to economically rational consumers. Battery cost modeling illustrates that battery pack costs in production quantities are going down.

- Bradley suggested that bottom-up TCO models do not represent the complicated reality. These TCO models assume that all vehicles have the same profit margins and strategic values. In reality, automakers allocate production costs and profit margin across car lines to maximize profitability, meet sales dependent regulatory requirements, build market share, and compete with other automakers. The value of PHEVs in relation to corporate average fuel economy (CAFE) cost of compliance was also examined.

- Bradley noted that policy can drive incentives for new technologies. There are incentives for PHEVs that are implicit in present regulations. For example, the CAFE costs of compliance benefits are robust across automakers. Automakers and policy makers set the conditions under which a technology will or will not succeed.

- In summary, Bradley said that economics are not a rational disincentive for PHEV purchases as the TCO is beneficial for an economic life of approximately 5 years. Consumer preference surveys show that some consumers are willing to purchase PHEVs with longer payback periods. The payback period is a sensitive metric of comparison between technologies. Cost reductions will incrementally improve the consumer acceptability of PHEVs. Vehicle supply and vehicle demand must be considered to predict market penetration.

OPPORTUNITIES AND CHALLENGES FOR THE PLUG-IN VEHICLE MARKET: DEVELOPING THE PLUG-IN ELECTRIC VEHICLE ECOSYSTEM

Thomas Turrentine

Thomas Turrentine discussed opportunities and challenges associated with the PEV market, including developing the PEV ecosystem. He described the results of numerous household surveys and data collection activities conducted by the University of California, Davis (UC Davis) on different types of alternative-fueled vehicles. Turrentine covered the following topics in his presentation.

- UC Davis has conducted numerous household surveys and other data collection efforts since the 1990s. Activities in the 1990s focused on compressed natural gas and methanol vehicles, and early EV drivers. For instance, household interviews and statewide surveys were completed and a small demonstration of EVs was conducted in Davis. Studies on the station cars focused on the Nissan Hypermini, hybrid EVs (HEVs), PHEV conversions in 80 households, fuel cell vehicle demonstrations, and the BMW MINI E. Since 2010 statewide surveys of all PEV owners have been conducted along with studies associated with the Nissan Leaf infrastructure use, world EV cities, and energy interface.

- Turrentine described how the PEV goals and rate of change in the market are influenced by the sales targets set by vehicle manufacturers and by public policy. Original equipment manufacturers' stated PEV annual sales goals, which focus on volume to reduce costs, are 45,000 for the Volt and 20,000 for the Leaf. He noted that political and social goals driving the introduction of PEVs include climate change and energy independence. Further, California has a target of ZEVs accounting for 5% of the fleet, which equates to approximately 1.5 million vehicles, by 2015. The Obama Administration has identified a target of 1 million PEVs in the United States by 2015, which would be 0.3% of the vehicle fleet. Germany and France have targeted 1 million to 2 million EVs by 2020.

- Researchers at UC Davis identified a range of values for growth of the PEV market in California, using the ZEV program as a floor. The total annual sales of light-duty vehicles in California are 1.2 million to 1.5 million vehicles, and the fleet is approximately 26 million. This analysis follows the sequence of market launch, market growth, and market takeoff. Turrentine suggested that the first generation of U.S. PEV sales indicated that PHEVs are coming on strong. California represents approximately 55% of Year 1 sales and 33% of Year 2 sales. After the early market, which focused on early innovative buyers, there was concern about the "Valley of Death," before the market takes off when more economic-minded consumers drive sales up. He noted that the sale of HEVs did not fall into the chasm, but purchases were dominated by Prius. Annual sales of the Volt and PEVs were ahead of the Prius and HEV sales during the first 2 years of the rollout in the United States. He suggested that the response to the second-generation PEVs will be important.

- Turrentine cited a survey conducted involving 2,526 PEV owners in California; the survey had a total of 1,419 PEV owners responding for a response rate of 56%. Approximately 96% of the survey respondents own their own homes, and 91% live in single-family detached homes. Approximately 71% of the respondents were male, 91% reported using their PEVs for daily driving, and 96% owned a Leaf. The survey results further indicate that Leaf owners in California have several other automobiles available for use, with only 5% reporting a Leaf as their only vehicle. There also appears to be strong neighborhood effects on the market. For example, there are neighborhoods with PEVs every few blocks.

- Turrentine indicated that a number of opportunities and challenges can be identified related to developing an EV ecosystem and consumer value. Challenges include the slow turnover in the automobile market, high purchase prices, and consumer unfamiliarity with technology or electricity as a fuel. Opportunities include lower vehicle operating cost, owners' positive reactions, and numerous designs to meet customer needs. He suggested that PEVs meet many daily and local driving needs, but it may be difficult to meet infrequent or imagined driving needs and wants. Private infrastructure can meet most daily needs, but the concerns of buyers are often about trips to less frequent and more distant locations. He noted that while there is no social momentum in the market yet, it appears social networks and neighborhoods do spread the technology. There is potential in the future for clean transport and even more renewable fuels, but today electricity varies in CO₂ by regions and PEV interaction with the grid is not optimized.

- According to Turrentine, survey and study results indicated that drivers like the feel of EVs, including the smooth acceleration, good launch, and regenerative braking. Further, owners report that PEVs are simple to drive. Studies also indicated that the most limiting factor in market growth will be the consumer experience with PEVs. Most of the drivers and households interviewed in the various studies were satisfied with PEVs. The interviews of 102 drivers in the BMW MINI E study found that 71% were more likely to consider purchasing an EV now than they were a year ago.

- Study results also showed a wide distribution in the daily driving patterns among PEV owners, with 89% responding that the PEV is their primary car. For example, daily miles of Leaf owners was 30 mi, compared with 39 mi for Volt owners. Slightly over half of the Leaf owners reported they have not driven beyond the range of a home charge. It also appears that PEV owners drive their PEVs a little less than other new automobiles are driven.

- A study of Leaf drivers in San Diego, California, examined infrastructure needs and preferences. In the study, Leaf drivers were able to select up to five charging destinations and Level 2, or DC fast, charging. The first choice tended to be at home, while Choices 2 through 5 expanded the territory. A simulation was conducted to examine the potential increase in electric vehicle miles traveled (eVMT) for different infrastructure investments. An optional network of chargers in southern California was developed. A DC fast network simulation for 80-mi battery EVs (BEVs) suggested that eVMT could be increased 10% to 15%. The workplace represents a strategic place for chargers for PHEVs, and a strategic place to introduce other drivers to and educate them about PEVs.

- Turrentine suggested that more BEV and PHEV designs will be needed to expand the market, including crossover vehicles and pickup trucks. There is also a need to coordinate incentives with second- and third-generation rollouts. Approaches to help expand the market include mobilizing the first-generation buyer community

to explain the benefits of PEVs to potential owners and organizing workplaces, schools, and Internet communities as support institutions. He noted that managing the transition with periodic survey data and optimizing the charger network with better travel data would also be beneficial.

- Finally, Turrentine underscored that a variety of data needs can also be identified to help expand the EV market. Monitoring attitudes, experience, and market segment development as part of an annual research process is needed. Monitoring households with PEVs on vehicle use and other characteristics would also be beneficial. Information on the types of vehicles, use patterns, eVMT, and potential of households who invest in PEVs to migrate to an e-mobility ecosystem would be of benefit.

PLENARY SESSION 3

Freight Transportation

Challenges and Opportunities

Paul Bingham, *CDM Smith*

Lance R. Grenzeback, *Cambridge Systematics, Inc.*

Laetitia Dablanc, *French Institute of Science and Technology for Transport, Development, and Networks, University of Paris–East*

Genevieve Giuliano, *University of Southern California, presiding*

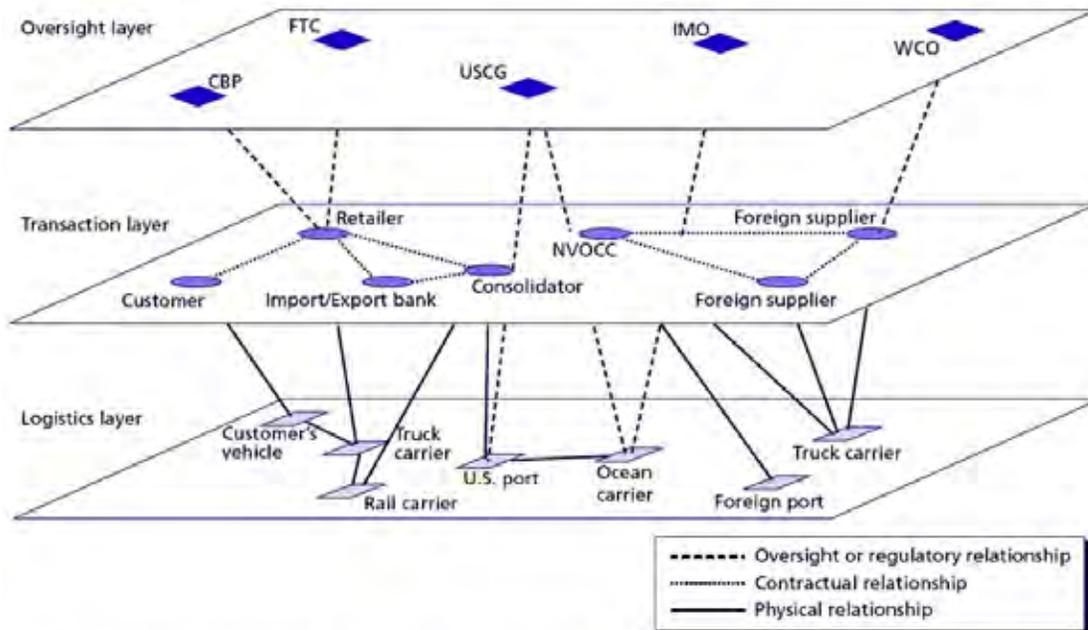
Speakers in this session explored the complexities of the freight transportation industry, including factors affecting freight transportation operations, supply and demand, and opportunities to provide freight service more efficiently. Attention was given to long-haul transportation and intermodal choices—especially truck and rail—and metropolitan freight transportation, including the last mile for local deliveries. Emerging fuel and vehicle technologies were also discussed.

FREIGHT TRANSPORTATION SYSTEMS OVERVIEW

Paul Bingham

Paul Bingham provided an overview of the freight transportation system. He described the complexity of the freight business, energy use by the freight sector, and opportunities to reduce freight transportation energy use and emissions. Bingham covered the following topics in his presentation.

- Freight is a for-profit, private-sector service business. Freight transportation systems coexist with the public transportation sector and passenger elements of the transport system. Bingham noted that in freight transportation, every activity must ultimately contribute to the bottom line. Distance, weight, and volume all have costs, as does unreliability. He indicated that the freight industry has realized significant increases in productivity through economic deregulation, containerization, growth of intermodal rail service, and the application of information technology. These gains have largely been passed on to freight industry customers in a competitive market, enabling innovation in logistics and distribution. He noted that freight systems today are highly complex, cost competitive, and with the exception of the slow-changing U.S. public infrastructure, subject to rapid change.



FTC = Federal Trade Commission; CBP = U.S. Customs and Border Protection; USCG = U.S. Coast Guard; IMO = International Maritime Organization; WCO = World Customs Organization; NVOCC = Non-vessel Operating Common Carrier

SOURCE: Page Siplon, Georgia Center of Innovation for Logistics.

FIGURE 6 Freight transportation complexity: additional dimensions beyond space and time.

- Bingham pointed to Figure 6, which illustrates the complexity of the freight transportation system. The logistics layer includes ports, trucks, railroads, ocean carriers, and other modes. The transaction layer includes customers, retailers, consolidators, suppliers, and other groups. The oversight layer includes the various regulatory agencies.
- Freight transportation demand grows as a result of increases in population (consumption), economic activity (production), trade (exchange), business practices (logistics), and technology. The additional 100 million people forecast to be living in the United States by 2050 adds substantial freight demand, even without any increase in consumption patterns. Trade growth, especially exports, further adds to freight demand. Bingham noted that freight flow patterns will evolve with the potential for continuing urbanization, trade, and changes in sourcing and manufacturing.
- He pointed out that trucks are currently the dominant mode for freight movement. Trucks are projected to continue to be the dominant mode in 2017 through 2023. Rail intermodal freight grows the fastest long term, but from a base of 1.3% of the total.
- According to Bingham, the total productivity of the freight transportation system is projected to increase as the result of a combination of factors. Multifactor, multiphase freight productivity gains will be achieved from incremental improvements throughout the transportation system.

- He explained that freight transportation is a heavy industry operating under the laws of physics in the work required for the physical movement of mass through space and time. Efficient freight energy use is critical to maintaining productivity and profitability, and for minimizing emissions. Petroleum fuels are the dominant energy form used to power freight transportation modes.

- Bingham noted that examining carbon dioxide (CO₂) emissions by mode and 20-ft equivalent unit per kilometer indicates that maritime transport has the lowest energy use and the lowest environmental impact for long-distance freight shipments. Air has the highest energy use. He noted that the freight share of U.S. CO₂ emissions is projected to increase as a result of the growth in freight activity, despite efficiency gains in the freight transportation system. Freight truck CO₂ emissions are forecast to increase by 70% by 2050, with emissions from freight rail increasing by 39%.

- Bingham indicated that opportunities exist for the U.S. freight transportation system to reduce energy use and emissions. These opportunities include improved fuels, such as low-sulfur and higher-grade fuel oil, and alternative power, such as biofuels, compressed natural gas (CNG), liquid natural gas, and electricity. Opportunities related to equipment include improved aerodynamics, larger size vehicles, lighter materials, and engine enhancements. Improved operations focus on speed, idling, routing, and maintenance. Improved network capacity utilization and safety enhancements represent still other opportunities. Future opportunities may also exist for substitution of lower-emissions modal options. Packaging efficiencies may be realized related to volume, weight, and materials. Finally, Bingham said that supply chain integration may help minimize freight activity.

LONG-HAUL FREIGHT TRANSPORTATION SYSTEMS: INTERMODAL CHOICES

Lance R. Grenzeback

Lance R. Grenzeback described the characteristics and use of long-haul freight transportation modes in the United States, including truck and rail. He discussed the importance of shipment, travel time, reliability, and cost. He also highlighted future scenarios based on population and economic growth and the potential to shift freight from truck to rail. Grenzeback covered the following topics in his presentation.

- He noted that freight travels long distances. The United States imports consumer goods from China, fruit from South Africa, luxury automobiles from Europe, and oil from the Middle East. These goods and domestically produced food, fuels, manufactured products, building materials, and other commodities are routinely transported throughout the country on a daily basis.

- Grenzeback indicated that the vast majority of these goods are moved by trucks. He noted that as the country produces higher-value goods, more freight is transported by truck and air than by rail and water. Trucks are less energy efficient than rail and water for long-haul movements. The potential to shift goods from truck to rail or water to realize energy savings has been examined in different settings. He further noted that while there has been some shift from truck to rail, as characterized by modern intermodal rail, additional major changes are more difficult. Potential energy benefits from these shifts may be less than some groups suggest. There is a need for more and better data to analyze possible alternatives and effects.

- According to Grenzeback, long-haul freight can be defined in a number of different ways. Long-haul freight can include international shipments and transcontinental shipments. In general, truck freight shipments of more than 300 to 500 mi may be candidates to move to intermodal rail.

- Grenzeback noted that examining ton-miles by distance indicates that the majority of tonnage is accumulated at distances under 150 mi. These figures do not capture goods movements at the metropolitan scale, however. Most of the short-haul freight movements are at the local level. Trucks dominate freight shipments under 750 mi.

- Approximately 30% to 40% of the tonnage is in the 750- to 2,000-mi range. Grenzeback suggested that there may be the potential to shift 10% to 15% of this tonnage from truck to rail with the positive convergence of demand, cost, technology, policy, and regulatory factors. He noted that it may take several decades for this shift to occur, however, as large capital investments are needed.

- Grenzeback outlined four major reasons why this shift may not occur soon. These reasons focus on commodity volumes, rail capacity, cost, and shipper logistics. (a) The commodity volume in specific rail lines may not be large enough to warrant rail shipments. Rail shipments require much larger volumes, carried over long distances, to be cost competitive. (b) There is also not a lot of unused capacity in the domestic rail system. Adding capacity requires significant capital investments. (c) Cost is also a factor. Shipping by truck is relatively easy and low cost. A shipment is loaded at the shippers dock, driven to the destination, and unloaded. Intermodal rail shipments are more complex, travel times are longer, trip-time reliability may be slightly lower if there are multiple connections and railroads involved, and costs and labor needs are higher. Economies of scale must be realized over longer distances to be competitive with trucks. (d) Shipper logistics consider the overall performance of a supply chain; very tight delivery windows to avoid stock-outs at stores and production stoppages, security requirements, and other factors are included. He suggested that shifting freight from truck to rail may save energy and reduce greenhouse gas (GHG) emissions on one leg of an intermodal trip, but increase costs, energy consumption, and GHG emissions elsewhere along the shipper's supply chain.

- Grenzeback described a study being conducted modifying the freight analysis framework to analyze energy use and GHG emissions under different scenarios. He noted that it is a descriptive model and that no economic behavior or elasticities are included. A number of different scenarios are being examined. One scenario focused on extrapolating current population and economic growth trends to 2050, which resulted in an increase in ton-miles of approximately 75% and an increase in CO₂ emissions of approximately 70%. Shifting 10% of freight shipments over 500 mi from truck to rail and rerunning the model resulted in an increase in ton-miles to approximately 80% and an increase in cycle CO₂ emissions of approximately 60%. A scenario involving larger and denser cities and megaregions; more imports at East and Gulf Coast ports; more agriculture, natural resource, and manufacturing exports; and the shifting of 10% of freight shipments over 500 mi from truck to intermodal rail service was also modeled. Under this scenario ton-miles increased by approximately 90% and CO₂ emissions increased by approximately 70%. A final scenario examined a 25% to 50% improvement in the energy efficiency of heavy-duty truck engines. This scenario resulted in a 75% increase in ton-miles, which is the same as the first scenario, but with only a 5% to 25% increase in CO₂ emissions.

METROPOLITAN FREIGHT TRANSPORTATION

Laetitia Dablanç

Laetitia Dablanç discussed freight transportation in metropolitan areas. She described metropolitan freight issues in Europe and the United States and highlighted information from research projects in Paris; Los Angeles, California; and Atlanta, Georgia. Dablanç covered the following topics in her presentation.

- She noted that the freight system has evolved over time to meet the needs of metropolitan and urban areas. Recent trends in metropolitan economies and freight include less inventory held by businesses, more customized products, and more frequent deliveries. She observed that the service economy requires more express deliveries and that there has also been major growth in e-commerce and home deliveries. There are approximately 1 million freight deliveries and pickups in the Paris metropolitan area daily. There are as many urban logistics chains as there are different economic sectors, with diverse vehicles, delivery times, and organizations. This diversity makes data collection difficult. Major metropolitan areas throughout the world also serve as trade nodes and logistic hubs, accommodating imports and exports. This role generates additional freight movements within metropolitan areas.
- Dablanç pointed out that vans and trucks remain a major source of CO₂ emissions and poor air quality in metropolitan areas. Most freight vehicles operate on diesel fuel. In many countries, trucks often end their life cycle in local and regional operations. Truck operations include constant acceleration and deceleration for

delivery stops, traffic lights, and congestion. Many areas are experiencing increased truck miles for final deliveries. She reported that in large European cities, freight is responsible for a quarter of transport-related CO₂, a third of transport-related oxides of nitrogen, and half of transport-related particulate matter.

- A 2005 study commissioned by the city of Paris examined the carbon footprint for the city, which totaled 6.55 million tons equivalent CO₂ in total on a yearly basis. Buildings, passenger transportation, and freight transportation accounted for 1.75 million tons equivalent each.

- According to Dablanc, the urban trucking market is flexible and competitive. In Paris, it is an easy job market to enter, but the working conditions can be difficult and salaries are low compared with long-distance trucking. Many local carriers are self-employed, often acting as subcontractors to large freight companies. She noted that there are approximately 12,000 small freight transport companies in the Paris metropolitan area, with half estimated to not be legally registered. She suggested that this situation can result in inefficient operations and the use of older vehicles.

- She discussed the dramatic growth in warehouses and mega distribution centers around metropolitan areas in both Europe and the United States. Between 1998 and 2009 freight facilities and warehouses in Atlanta and Los Angeles grew by more than 200%. These facilities serve an import-based economy and global supply chains. She noted that there has been a spatial deconcentration of these facilities. Differences in land prices, the need for modern facilities and large parcels, the availability of road infrastructure, and the need for connectivity with other major consumer markets have all driven this deconcentration of freight facilities.

- She noted that the location of freight and logistics facilities became more dispersed during the past 10 years. The average distance of terminals to their barycenter, or center of gravity, has increased from 17 to 20 mi (or by 3 mi) in Atlanta and from 26 to 32 mi (or by 6 mi) in Los Angeles. The same sprawl indicator for all business establishments, representing economic activities in general, has increased at a lower rate during the same time period—by 1.3 mi in Atlanta and 0.1 mi in Los Angeles. She suggested that these results indicate that logistics activities have decentralized more than economic activities in general, which means more truck miles to connect urban destinations to and from freight terminals. These trends mean more energy use and more CO₂ emissions. A Paris case study examining actual truck traffic data for the parcel and express transport industry estimated a net effect of 16,000 tons of CO₂ a year as a result of the sprawl of warehousing and distribution facilities.

- Dablanc said further that a number of experiments are under way in Europe focusing on last-mile deliveries and smart city logistics. These experiments are receiving a lot of media attention and interest from local governments, including financial support. These experiments typically address only a small portion of the total metropolitan freight movement, however. Examples of techniques being tested include cross-docking terminals in urban centers and urban consolidation centers, electric delivery vehicles, off-hour deliveries, and low-emissions zones.

- Dablanc observed that two major retailers in Paris have been using trains and barges for urban deliveries but have taken different approaches. The 90 Monoprix stores have been supplied by rail since 2007. Trains arrive at a renovated freight terminal close to the center of Paris and CNG trucks are used for the final distribution to stores. The 80 Franprix stores have been supplied by barge since 2012. This supply chain includes 2 mi by truck from the distribution center to the suburban port of Bonneuil and 13 mi by barge to the Paris port de la Bourdonnais. The final delivery is made by truck to the stores. The rail scheme generates a saving of approximately 410 tons of CO₂ per year, but also increases transportation costs by 26%. The barge scheme is expected to save 240 tons of CO₂ per year.
- Dablanc noted that electric deliveries using a variety of electric vehicles are becoming more common in European cities. Many initiatives for clean deliveries in business districts and other locations use small hybrid electric trucks and vans. For example, Sephora, in France, is supplied entirely by electric trucks. Cargocycles are in use by the start-up company La Petite Reine in Paris, reducing CO₂ emissions by 203 tons. Chronopost in Paris uses 12 electric delivery vehicles and an urban cross-docking terminal under the Place de la Concorde in a municipal car park, saving 33 tons of CO₂ per year.

In conclusion, Dablanc said that the metropolitan freight system is highly flexible and meets the needs of shippers. It supports changing consumer and business demands, as well as the trade node function of large cities. Energy consumption and emissions remain major issues despite recent private and public-private initiatives. While contributing to some reduction in CO₂ emissions by supporting last mile delivery initiatives, cities often ignore freight and logistics global economic drivers and rapidly changing land uses.

PLENARY SESSION 4

What Can Metropolitan Areas Do to Reduce Transportation Energy Consumption and Greenhouse Gas Emissions?

Michael D. Meyer, *Parsons Brinckerhoff*

Matthew Barth, *University of California, Riverside*

Mike McKeever, *Sacramento Area Council of Governments*

Robert B. Noland, *Rutgers, State University of New Jersey, presiding*

Speakers in this session discussed potential strategies that could be used by metropolitan planning organizations (MPOs) and local governments to reduce vehicle travel and promote the use of more energy-efficient transportation practices. Examples of strategies highlighted by speakers included transit-oriented development (TOD), ride sharing, telecommuting, eco-driving, traffic smoothing, and other operational improvements to the transportation network that reduce greenhouse gas (GHG) emissions at a relatively low cost in the near term. Attention was also given to the effect of consumer demand and demographic trends and increased energy efficiency on the viability of those strategies.

WHAT CAN METROPOLITAN AREAS DO TO REDUCE TRANSPORTATION ENERGY CONSUMPTION AND GHG EMISSIONS THROUGH LAND USE STRATEGIES?

Michael D. Meyer

Michael D. Meyer discussed land use strategies in the context of energy, sustainability, and GHG emissions. He reviewed recent research projects, highlighted findings from different studies, and identified possible research topics. Meyer covered the following topics in his presentation.

- NCHRP Project 08-36 (Task 107): Synthesis of State Departments of Transportation and MPO Strategies to Reduce Greenhouse Gas Emissions included a survey of state departments of transportation and MPOs. Of the 30 MPOs responding

that they have or will be considering GHG emissions in the planning process, 18 indicated that land use codes, regulations, and policies were being included in the plans. These results indicate that land use strategies are being considered by many MPOs and local governments to help address energy and GHG emissions.

- Meyer discussed how the focus of most recent studies on land use strategies has been on four areas: urban form and spatial distribution of activities and how they relate to energy consumption; density and compact urban form and the relationship to travel patterns; urban design; and connectivity strategies and corresponding policies such as parking that can encourage or discourage more efficient travel options at particular locations.

- Meyer noted that sustainable building energy footprints have been receiving a lot of professional attention in recent years. The “whole-building” site selection evaluation process currently considers transportation-related energy effects in relatively simplistic ways. He indicated that a recent Ph.D. dissertation at the Georgia Institute of Technology examined elements of the whole-building site selection process from a transportation, energy consumption, and GHG emissions perspective. The analysis found that approximately 84% to 87% of the total energy consumption of a building comes from transportation, depending on the location and building design components. The analysis further noted that as building energy efficiency continues to improve, the transportation-related energy effects associated with specific buildings could become even more important from a relative perspective.

- A number of recent studies—including the *Moving Cooler* and *Growing Cooler* reports, as well as *TRB Special Report 298: Driving and the Built Environment*—have developed a range of vehicle miles traveled (VMT) and GHG emissions reduction estimates assuming compact development patterns. Meyer suggested that these estimates, which some have described as “heroic,” are based on assumptions that large segments of future housing developments will be much more compact, which may not be realistic considering local land use policies and preferences.

- For example, Meyer cited *TRB Special Report 298: Driving and the Built Environment*, which examined the effects of compact development on travel, energy use, and carbon dioxide (CO₂) emissions. One of the general findings was that more compact development, with higher residential and employment densities, is likely to reduce VMT. More compact, mixed-use development can produce reductions in energy consumption and CO₂ emissions, both directly and indirectly. The study also found that the literature generally suggests that doubling residential density across a metropolitan area might lower household VMT by 5% to 12%. If coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures, household VMT might be reduced by as much as 25%. Illustrative scenarios suggested that significant increases in more compact, mixed-use development would result in modest short-term reductions in energy consumption and CO₂ emissions, but that these reductions would grow over time. Further, the report suggested that promoting more compact,

mixed-use development on a large scale would require overcoming numerous obstacles, including the traditional reluctance of many local governments to zone for such development and the lack of either regional governments with effective powers to regulate land use in most metropolitan areas or a strong state role in land use planning. Changes in development patterns significant enough to substantially alter travel behavior and residential building efficiency entail other benefits and costs that were not quantified in the study.

- Meyer noted that a report from the Urban Land Institute defines successful compact development as a land use settlement pattern that features concentrations of population or employment or both, medium to high densities appropriate to the context, and a mix of uses. The report also indicates that such strategies are supported with other design actions that supplement the “compact” nature of the development, such as interconnected streets, innovative and flexible approaches to parking, access and proximity to transit, and pedestrian-, bicycle-, and transit-friendly design.

- In addition, Meyer discussed a recent SHRP 2 project that examined state and local government strategies that could influence transportation-related GHG emissions and energy use. Land use codes, regulations, and other policies were included in the study. Approaches considered as part of the portfolio of such strategies included integrating regional transportation and land use planning and visioning, and infrastructure investments to support in-fill and TOD. Funding incentives and technical assistance for local policies for compact development, walkable communities, mixed-use development, and reduced parking requirements were also examined. In addition, state or local tax policies that discourage low-density development were included under a taxation and pricing strategy.

- Meyer said that the California Sustainable Communities and Climate Protection Act of 2008 (SB 375) resulted in numerous planning activities by MPOs, regions, and local government. He suggested that one of the best examples of a metropolitan area response, the Sacramento Blueprint Growth Strategy, includes a number of land use strategies, including offering housing choices and opportunities, taking advantage of compact development, encouraging mixed land uses, and encouraging distinctive, attractive communities with quality design.

- Meyer suggested that the California Air Resources Board (CARB) is one of the leading agencies in the country in examining a broad range of strategies for addressing GHG emissions and energy. A recent CARB study indicates that GHG reductions from increasing residential density will be modest in the near term, but can accumulate over time, especially if multiple policies are implemented. He noted that examples of CARB land use strategies include increasing residential density, providing transit access, promoting land use mixes, providing network connectivity and regional accessibility, and increasing jobs–housing balance. CARB also identified potential reductions in VMT for different types of strategies on the basis of studies documented in the available literature. In particular, strategies focusing on reducing the distance to transit services and encouraging land use mix were examined.

- Meyer indicated that the Los Angeles sustainable corridors program provides a local-level example of land use and transportation strategies. The Orange Line Bus Rapid Transit Sustainable Corridor Implementation Plan developed through this program contains a number of land use and development strategies. Examples included in the plan are targeting funding to stations with the greatest capacity to influence adjacent land use patterns, creating programs and activities to enhance the identity of the Orange Line, and enhancing destinations along the corridor. Other strategies focused on creating TOD guidelines, creating TOD-supportive development incentives, implementing existing land use plans, and creating new plans or updated community plans. Revisiting industrial land policies, pursuing joint development at Orange Line stations, pursuing workforce and affordable housing, and creating modified parking requirement districts are some additional strategies.
- Meyer noted that several MPOs have developed their own approach or method for analyzing the effect of urban design strategies. In Portland, the GreenSTEP Scenario Analysis tool has been developed to estimate the effects of different urban design strategies. The Denver Council of Government Scenario analysis approach includes a number of land use strategies focusing on more development around transit, more development downtown, more development in urban centers, and less land consumption.
- Meyer said that with respect to research needs, Special Report 298 identified several potential topics that focus on changing housing and travel preferences. Examining the housing preferences and travel patterns of an aging population, new immigrant groups, and young adults was noted as a need to help determine whether future trends will differ from those of the past. Another research need was conducting longitudinal studies based on panel data. These studies would allow better control for socioeconomic characteristics and self-selection, thus helping to isolate the effects of different types of development patterns on travel behavior.
- Examining studies of spatial trends within metropolitan areas was another research area in Special Report 298. Research studies that track changes in metropolitan areas at finer levels of spatial detail over time could help determine the needs and opportunities for policy intervention. These studies could examine the evolution of employment subcenters and changing patterns of freight distribution, as well as other spatial trends in metropolitan areas.
- Meyer stated his opinion that conducting before-and-after studies of policy interventions to promote more compact, mixed-use development is a particularly important research need. Evaluating pioneering efforts to promote more compact, mixed-use development would help determine the effects of different strategies. The results of these studies would be of benefit to other areas interested in pursuing similar strategies. He suggested that a related research topic is examining threshold population and employment densities to support alternatives to automobile travel. Studies of the threshold densities required to support rail and bus transit would help

guide infrastructure investments as well as zoning and land use plans around stations. Similar threshold information to determine desired development densities and land use patterns to support walking and bicycling would also be beneficial.

- Meyer suggested that examining the evolving relationship between energy cost, travel behavior, urban form, and technology substitutes is one of the most important research topics. Examining different applications of land use scenario analyses in determining resulting energy consumption would be beneficial. Assessing whether current land use models, which allocate activities on the basis of travel costs as well as other factors, are robust enough to reflect the changing energy and technology context would also be beneficial. Approaches to modify models to address any limitations could be identified. The perspective of local officials is also important to determine how seriously land use policies will be considered. Examining the effects of changing demographics and land use scenario planning in energy analyses is another research need.

TRAFFIC OPERATIONS AND ECO-DRIVING

Matthew Barth

Matthew Barth discussed the use of traffic operations and eco-driving to reduce transportation energy consumption and GHG emissions. He described the different categories of eco-driving and research projects under way at the University of California, Riverside (UC Riverside). Barth covered the following topics in his presentation.

- He noted that a number of approaches can be used to minimize the energy and emissions effects of transportation, including the four-legged stool noted by other speakers. The four legs focus on building cleaner and more efficient vehicles, developing and using alternative fuels, decreasing the total amount of driving, and improving transportation system efficiency. He noted that traffic operations, eco-driving, and intelligent transportation systems (ITS) are all part of improving transportation system efficiencies.

- Barth said that a number of operational strategies can be used to reduce on-road emissions. Congestion mitigation strategies, speed management techniques, and traffic flow smoothing techniques can all be used. The effects of different strategies can be examined at a high level by using emissions-versus-speed curve. Many of the traffic flow smoothing techniques provide reductions in on-road emissions in the 5% to 15% range.

- Barth said that eco-driving consists of changing driving behavior to maximize the fuel economy of existing cars, while minimizing carbon emissions. It is a modified way of driving that is best suited for modern engine technology, taking into

account various driving conditions. Eco-driving research and programs can range from providing advice on anticipating changes in traffic, smoother acceleration and braking, and proper vehicle maintenance, all the way to receiving real-time information on how to drive in current traffic conditions or what route to take. Eco-driving offers numerous benefits, including reductions in GHG emissions, fuel cost savings, improved safety, and greater comfort.

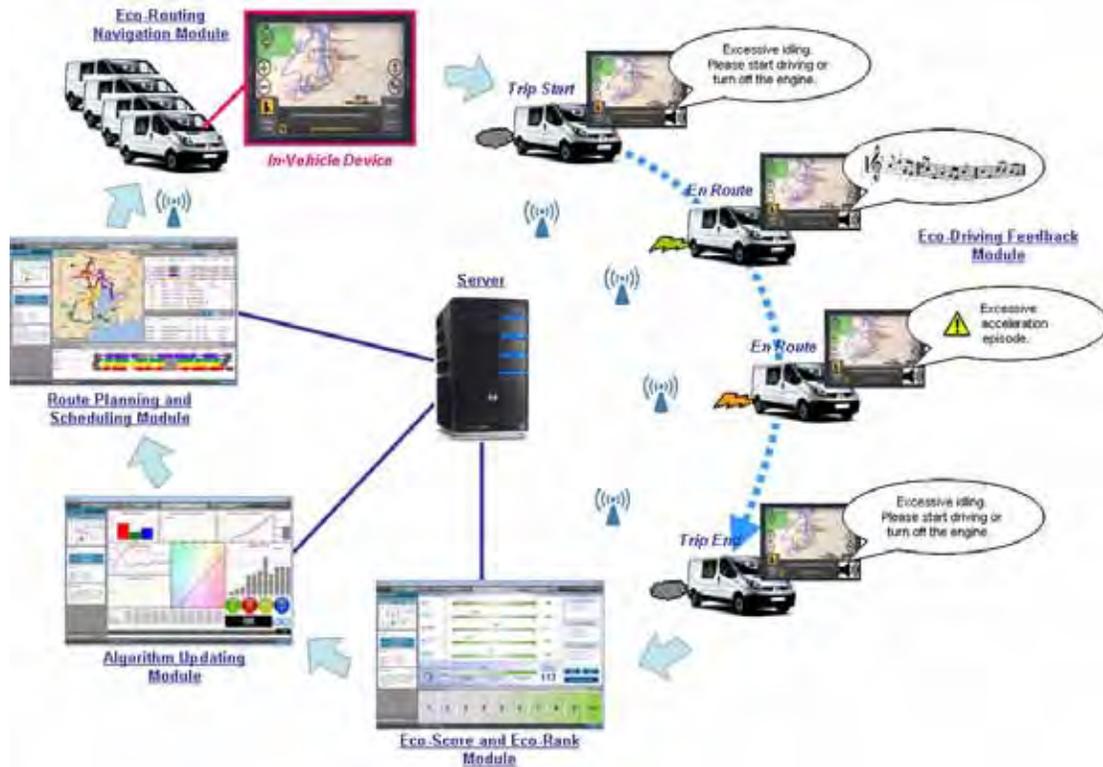
- According to Barth, eco-driving can be classified into categories according to the level of feedback provided to drivers on their driving behavior. Static eco-driving is the most common approach, providing one-time training and advice to drivers on methods to save fuel. Before-and-after studies indicate that this approach is effective, but wears off over time because there is no feedback on actual driving behavior. Eco-driving with limited feedback involves the use of web-based tools to record and monitor driving performance. Eco-driving based on instantaneous vehicle performance uses onboard devices to provide feedback on driver behavior. Elements of this approach include instantaneous fuel economy readings and cumulative real-time travel cost displays. Dynamic eco-driving provides real-time advice and feedback. Intelligent speed adaptation, speed management, and variable speed limits are examples of techniques in that category.

- A University of California Multi-Campus Research Program on Eco-Driving is being conducted as part of the 5-year research initiative on sustainable transportation. The eco-driving research thrust involves four universities—UC Berkeley, UC Davis, UC Irvine, and UC Riverside. Topic areas in the research program include operational strategies, behavioral modeling, and policy issues and obstacles.

- The next-generation environmentally friendly driving feedback systems research and development project at UC Riverside is supported by the U.S. Department of Energy's Vehicle Technology Program. The project includes 2 years for research and development and 1 year for testing and evaluation. The goals are to develop systems that are deployable across existing vehicle fleets and to improve fleet average fuel efficiency by at least 2%. The eight project partners include public agencies, private-sector technology companies, and universities.

- Barth discussed the system components of the project as illustrated in Figure 7. The system includes an eco-driving module, an eco-score and eco-rank module, and an algorithm updating module. A feedback loop is provided to link the updated information into the route planning and schedule module and the eco-routing navigation module. He noted that the eco-driving feedback module will include simple and intuitive user interfaces. It will supplement visual feedback with auditory feedback to reduce distracted driving and improve effectiveness. The individual modules and the integrated system will be tested in a demonstration vehicle before the full-field operational test in a paratransit bus and light-duty vehicle fleets.

- Barth said that there are a number of issues and challenges associated with eco-driving. Only small-scale studies and tests have been conducted to date in the United States. He suggested that there is a need to quantify the benefits of eco-driving



SOURCE: University of California, Riverside.

FIGURE 7 System components.

on a larger scale. There are questions related to how long changes in behavior last. Advanced eco-driving requires dynamic traffic information, which is not available in all areas. There are also issues related to technology versus behavior and convincing drivers to follow advice, as well as the potential for driver distraction. He noted that the role of government, automakers, and researchers in promoting and sustaining eco-driving is yet to be determined. Establishing corporate average fuel economy credits to automobile manufacturers for installing eco-friendly technology may be a potential strategy.

- The U.S. Department of Transportation Applications for the Environment: Real-Time Information Synthesis (AERIS) Program focuses on the environmental aspects of ITS. The objectives of the program include generating and acquiring environmentally relevant, real-time transportation data and using these data to create actionable information that support and facilitate “green” transportation choices by transportation system users and operators. The AERIS Program focuses on a multimodal approach in partnership with wireless communications research to better define how connected vehicle data and applications might contribute to mitigating some of the negative environmental effects of surface transportation.

- Barth cited examples of AERIS transformative concepts including low-emissions zones, eco-signal operations, eco-lanes, and eco-integrated corridor management. UC Riverside has been conducting research and a field study on the eco-signal operations transformative concept. The study focuses on timing traffic signal controls to obtain better vehicle throughput and reduce CO₂ emissions. With connected vehicles, a traffic signal controller can also communicate with vehicles, allowing vehicles to progress through the intersection more smoothly. With signal phase and timing (SPaT), data are broadcast from the traffic signal controller (infrastructure) to vehicles. SPaT information consists of intersection map, phase and timing, and localized Global Positioning System corrections. Simulation modeling and field studies have been conducted on these applications.
- Barth described an eco-approach scenario diagram developed for the test bed signalized intersection. A number of eco-approach driving scenarios were examined in the simulation. In the first scenario, the vehicle is able to pass through the intersection on the green phase without slowing down or speeding up. This scenario is the best for fuel economy. In the second scenario, the vehicle needs to speed up safely to pass through the intersection on the green phase. Energy savings are realized with this scenario from the vehicle not having to stop and idle. In the third scenario, the vehicle needs to slow down to stop at the intersection. Energy savings can be realized with this scenario if the vehicle slows down sooner. In the fourth scenario, the vehicle needs to slow down to pass through the intersection on the green phase. Energy savings are realized because the vehicle does not have to stop and idle.
- Barth noted that as part of the project, a test vehicle was instrumented with an onboard dedicated short-range communications transceiver and an onboard computer. A pseudodashboard was installed to provide the driver interface. A test intersection was used at the Turner–Fairbanks Highway Research Center (TFHRC). The signal was set up for fixed-time phasing with 26 s for green, 4 s for yellow, and 30 s for red. A SPaT message was sent from the intersection controller at 10 Hz. The driver was given prompts from the dashboard to speed up or slow down as he or she approached the intersection. A number of test runs were conducted at different speeds and at different phases in the signal cycle. The fuel savings realized depended on the speed of the vehicle and signal cycle phase when the vehicle was approaching the intersection. Tests were also conducted at UC Riverside using a Nissan Altima. These tests realized approximately 20% fuel savings. The test at TFHRC using a Jeep Grand Cherokee realized approximately 11% fuel savings.
- In summary, Barth said that dedicated ITS strategies and systems can be designed to explicitly reduce energy consumption and CO₂ emissions. ITS goals and strategies of improving safety and improving mobility often reduce energy consumption and CO₂ emissions as a side benefit. Eco-driving can potentially reduce CO₂ emissions by 5% to 15%. Eco-signals can potentially reduce single vehicle CO₂ emissions by 5% to 20%. The effectiveness of the strategies in traffic will be reduced, but a small penetration rate of technology can have a larger traffic effect.

- Barth suggested that additional research is needed to assess whether multiple strategies are additive, resulting in greater savings. There are also challenges with advancing eco-driving and other related applications. First, better quantification tools and data are needed to fully assess the environmental effects. Second, in addition to technology research, behavioral research is also needed in developing and testing environmental ITS applications. Third, rather than making speed recommendations through displays, applying semi-automation similar to adaptive cruise control might be an option. Finally, assessing whether these traffic smoothing applications induce demand remains a key question.

THE SACRAMENTO AREA COUNCIL OF GOVERNMENTS AND CALIFORNIA'S IMPLEMENTATION OF SENATE BILL 375

Mike McKeever

Mike McKeever described the recent planning initiatives at the Sacramento Area Council of Governments (SACOG), including those related to implementing SB 375. He described the Blueprint Growth Strategy and the Metropolitan Transportation Plan–Sustainable Community Strategy (MTP-SCS). McKeever covered the following topics in his presentation.

- The SACOG region covers six counties and includes 22 cities. The 2010 population of the region was approximately 2.4 million. Development patterns are similar to other areas in the country, with suburban sprawl occurring in many parts of the region. Much of the region is still rural, however, encompassing key agricultural areas of the state.
- McKeever noted that SACOG has undertaken a number of major planning initiatives during the past 10 years. Work on the Blueprint Growth Strategy was initiated in 2003, and the strategy was adopted in 2008. In 2008 SACOG adopted an updated MTP based on the blueprint and initiated the development of the Rural Urban Connections Strategy. A new state comprehensive regional planning law linking GHG emissions, transportation, land use, and housing planning (SB 375) was approved in 2008. It required CARB to set GHG targets for regions by 2010. In 2012 SACOG adopted the MTP-SCS, meeting requirements of SB 375.
- The Blueprint Growth Strategy represented information-based planning at the regional, jurisdictional, and neighborhood levels. As part of the blueprint, SACOG invested heavily in science, including current data and state-of-the-art modeling. SACOG also invested heavily in citizen democracy. McKeever noted that approximately 8,000 people participated in the blueprint planning process, with broad representation across the region and diverse interest groups. Neighborhood, county, and regional workshops were held as part of the blueprint planning process.

- McKeever said that accurate and up-to-date demographic data were a key element of the planning process. The population of the region is aging. Approximately 67% of the households in 2050 are forecast to include individuals over 55 years of age, while only 21% of households will include children. The results of a housing preferences survey indicated that approximately two-thirds of the households with members 55 years old or older who said they would move in 1 to 5 or more years wanted a housing product that was difficult to find—an attached or detached unit to own or rent with a small yard.

- Housing is the major land use in most communities, with employment using less land. McKeever suggested that a more compact growth form is needed to address the housing situation. The urban footprint adopted by the SACOG Board consumes 300 less square miles of land than the base-case footprint.

- McKeever noted that SB 375 was driven by the adoption of Assembly Bill 32 (AB 32), which required a reduction in emissions by 2020. Then-governor Schwarzenegger issued an executive order requiring reductions by 2015. The transportation sector in California accounts for approximately 37% of total GHG emissions. The growth in VMT means that just regulations requiring cleaner fuels and more efficient engines will not be sufficient to meet the requirements of AB 32. SB 375 seeks synergistic benefits from integrated housing, land use, transportation, and climate change planning. It requires CARB to set targets for each of the 18 MPOs in the state for the reduction of per capita GHG emissions from passenger vehicles for 2020 and 2035. There are also planning requirements for the MPOs. The bill does include the California Environmental Quality Act (CEQA) streamlining benefits for residential and mixed-use developments and extra CEQA benefits for transit priority projects.

- The CARB per capita GHG reduction targets for the four largest MPOs in the state are Los Angeles, 8% by 2020 and 18% by 2035; San Diego, 7% by 2020 and 13% by 2035; the San Francisco Bay Area, 7% by 2020 and 15% by 2035; and Sacramento, 7% by 2020 and 16% by 2035. The MPOs in Los Angeles, San Diego, and Sacramento have exceeded these targets in their adopted plans. The Bay Area plan, which should be adopted soon, also exceeds the targets.

- McKeever noted that a number of other benefits are also realized from the plans. Examples of these benefits include \$15 billion in reduced infrastructure costs, 33% reduction in urban water demand, and large reductions in farmland and natural resource land conversion to urban uses. Other benefits include reductions in total transportation costs and increased fare box recovery rates for transit systems.

- McKeever also said that SB 375 is driving an evolution of regional planning in California. The four largest regions are working together, learning from each other, and challenging each other. Initial resistance has been transformed to a race to the top. Technical assistance and advocacy have been especially important in the three areas of data, models, and analytics; planning practices; and citizen engagement.

- McKeever described a research study assessing the cumulative effects to 2050 between the business-as-usual scenarios and the smart-growth scenarios. The savings in automobile fuel consumed are equivalent to more than 2 years of oil imports to the United States. Approximately \$3,100 in annual automobile fuel savings per household would be realized. Savings in building energy would power all homes in California for 8 years. Water savings could fill the Hetch Hetchy Reservoir 50 times. Savings in residential water use would be equivalent to 650 showers per year for each household. Annual household costs savings of \$7,300 would be realized per household.

- The SACOG MTP-SCS reduces passenger vehicle GHG emissions to meet SB 375 targets. The most recent MTP is organized around a community typology. Each community type is based on local planning areas and the prevailing character. The community types include centers and corridors, established communities, developing communities, and rural residential communities. The VMT per capita and the share of trips by transit, bicycle, or walking varies by community type for the different scenarios. More growth in the centers and corridors and the established communities results in lower VMT and lower GHG emissions.

- McKeever discussed the housing product mix changes from the 2008 existing condition to the MTP-SCS 2035. The percentage of single-family small-lot and attached homes increases. This growth reflects market demand, which is also occurring in other metropolitan areas in the state. The share of new homes and jobs near high-frequency transit also increases through the addition of new homes in areas already served by transit.

- The MTP-SCS preferred scenario also reduces effects on farmland in the region, which is some of the richest in the state. The MTP-SCS transportation investment priority focuses on operations and connectivity. Road capital projects focus on cost-effective operational improvements, the fixing of critical bottlenecks, and support of goods movement. There is also a bicycle and pedestrian focus on urban complete streets, rural complete corridors, and regional trail connections.

- The MTP-SCS preferred scenario increases productivity to fund more transit options. There is a focus on higher-frequency service for land use supportive transit corridors. There are also new transit options to attract new transit choice riders. Technology is also being used to give transit an advantage. A 42% increase in transit service hours per capita is projected. Approximately 272,000 additional homes will be within walking distance of good transit service, including 90% of the total of all new homes constructed. A projected 380,000 additional jobs will also be within walking distance of good transit service. The improvements are projected to realize a 255% increase in total transit ridership and a 395% increase in transit commute trips. The fare box recovery rate is projected to increase from 24% to 38%. Even small increases in transit use help reduce congestion. For example, each 1% increase in commute transit mode share results in a 5% decrease in congested miles driven in the region. Typical residents will experience an absolute reduction in the amount of heavy congestion in their daily lives.

- Finally, McKeever concluded that the rural–urban connections strategy to enhancing rural economic viability and environmental sustainability represents an important element of the plan. Parcel-specific data, including a regional crop inventory, were developed for the 65% of the region that is rural. The agricultural and natural resources areas are grouped into logical categories. Examples of these categories include commodity agriculture, open space and recreation, large lot residential with agriculture, and small scale and local market agriculture. A substantial effort is being focused on innovations at the urban edge and beyond to support agricultural viability and sustainability. Examining all the infrastructure needs to support the agricultural economy is part of this process. Some of the agricultural processing facilities are economically at risk right now, which means the agricultural land use pattern is at risk.

CLOSING SESSION

Research and Data Priorities

Moving Forward to Support Sustainable Energy Transportation Systems

Michael D. Meyer, *Parsons Brinckerhoff*

Paula J. C. Hammond, *Washington State Department of Transportation*

Kevin Womack, *Research and Innovative Technology Administration*

Daniel Sperling, *University of California, Davis, presiding*

Speakers in this session provided closing comments to the conference. Speakers framed research and data needs for developing sustainable energy transportation systems in the years ahead. Key observations and issues identified in the conference plenary and breakout sessions were summarized. Speakers also provided a perspective from a state department of transportation (DOT) and from the U.S. DOT.

CONCLUDING OBSERVATIONS

Michael D. Meyer

The conference summary, provided by Michael D. Meyer, focused on four themes: the evolving context for transportation and energy, the key themes raised by the conference presenters, opportunities and challenges for the profession, and research needs. Research was further considered as a focus on basic understandings of the underlying phenomena; creation of new technology, methods, and tools; and development of effective implementation strategies. Meyer covered the following topics in his presentation.

Context

- A number of speakers addressed the context and the key forces shaping the U.S. energy situation. During the long run, perhaps most important according to Meyer, these market forces include increasing world energy demand, particularly in China and other developing nations, and increasingly tight world energy markets. New sources of unconventional gas and oil resources are fundamentally changing

the U.S. supply picture and to a degree the world outlook as well. Speakers noted that energy price volatility remains and continues to complicate market decisions and affect world energy markets. Continuing concerns about global climate change remain a significant factor in national energy decisions, especially outside the United States.

- Meyer noted that speakers discussed recent trends in oil imports, which increased from 40% in 1990 to 60% in 2005, fell to 49% in 2010, and continue to fall slowly. They noted that the U.S. energy infrastructure is massive, adapts to change slowly, and is increasingly vulnerable to natural disasters and terrorism.

- Meyer said that a number of speakers made the point that strategies to increase transportation energy efficiency through, for example, improved vehicle mileage rates have been shown to be effective and that they are, in fact, cost-effective. However, as David L. Greene pointed out in his presentation, although such strategies are essential, they are not enough. It was also noted that all promising long-run solutions, including biofuels, land use and vehicle miles traveled (VMT) reduction, alternative modes, electric vehicles (EVs), and fuel cell vehicles, have uncertainties attached to them. A sustainable energy policy for transportation poses a new and heroic challenge for public policy. Greene suggested that urgent action is required and that the benefits probably outweigh costs by a 1 to 2 order of magnitude. Uncertainty about paths and outcomes is pervasive. Public policy must follow a new paradigm and must be adaptable, which leads to the need for research and information.

- One key concern to transportation officials is the relationship between energy policies, greenhouse gas (GHG) emissions, and transportation revenues. Martin Wachs examined these relationships in his presentation. He described the current crisis facing many transportation agencies of being unable to fund standard maintenance, much less system expansion or environmental improvements. Increasingly, states are borrowing to pay for maintenance and operations. The Federal Highway Trust Fund and many state transportation funds are in deficit while legislators oppose any increase in user fees.

- Wachs further suggested that relying on the motor fuel tax is not sustainable in the long term. With increasing fuel efficiency, fuel taxes produce less revenue, even as driving increases. High fuel prices discourage elected officials from adding tax increases, and gas tax indexing is a short-term fix. The corporate average fuel economy (CAFE) standards are increasingly demanding, resulting in lower gas tax revenues per mile traveled. Alternative fuels have added to this trend and will likely exacerbate it in the future. Legislators want to encourage alternative fuels by keeping taxes on them low, while not raising taxes or fees on travel or petroleum.

- According to Wachs, less than half of state transportation expenditures currently come from user fees, with many metropolitan areas and some states relying on the use of general taxation to fund transportation projects. In 2011, 33 of 39 transportation funding ballot measures were approved by voters in nine states, an 85%

approval rate. Wachs noted that these measures very likely do not result in projects that promote energy efficiency.

- Several speakers noted that increasing user fees are also under consideration in some states, but that there is less public support for these types of measures. Examples of user fees include mileage-based user fees, open road tolling, and allowing tolling on Interstate highways. These strategies, more so than those often found on funding ballots, make a greater contribution to energy efficiency and sustainability because of their direct influence on travel behavior through pricing.

- Meyer cited the transition from the current system of transportation finance to a user fee-based system as a critical policy question. It was suggested that a phased-in process may be needed for political and public acceptance to grow. Privacy concerns will need to be addressed. A strong case can be made for field tests and trials, but the Moving Ahead for Progress in the 21st Century Act (MAP-21) does not contain any provisions or funding for these activities. Numerous research opportunities exist in that topic area.

Opportunities and Challenges

- Meyer noted that in the breakout sessions speakers and participants identified key opportunities and challenges to developing an EV ecosystem and market. Challenges include the slow turnover in the automobile market, high purchase prices, and consumer unfamiliarity with electric vehicles. Opportunities include the numerous EV designs being introduced to meet customer needs and the positive response from many drivers. The “clean vehicle” market is slowly evolving to be more appealing to consumers, and the potential for further advances in renewable energy sources for transportations is great.

- Speakers discussed approaches to expand the market for EVs. The need for numerous vehicle designs was noted, along with mobilizing the first generation of EV owners to promote the benefits to other potential buyers. Organizing workplaces, schools, and other locations to support the infrastructure was also discussed.

- The use of intelligent transportation systems (ITS) strategies and systems to reduce energy consumption and carbon dioxide emissions is a strategy that many transportation agencies can feel comfortable with. Research has been conducted on eco-driving and eco-signals and the potential benefits from those approaches. One key question raised in the discussion was how to view the energy savings benefits of multiple strategies. Are they additive and if so how does one remove the potential double counting of benefits?

- Meyer noted that there is a growing realization that freight is an important part of the transportation system and that addressing freight transportation needs in the context of energy consumption has major public policy implications. Speakers noted that freight demand can be expected to grow in future years as a result of population

increases, economic activity, trade, urbanization, and other factors. They also pointed out that freight efficiency is critical to maintaining the productivity and profitability of businesses. Approximately half of freight movement occurs in “short-distance” ranges within metropolitan areas.

- It was noted that truck movements will continue to dominate freight transportation. There is currently little unused capacity in the U.S. rail system, a circumstance that will create challenges when one considers that rail ton-miles are projected to increase by 75% by 2050 and that emissions will increase by 70%, assuming that current trends in population and growth continue.
- Speakers also discussed the broad range of opportunities to reduce freight transportation energy consumption and emissions, including the use of improved fuels and alternative fuels, improved equipment, and improved operations. Other opportunities focus on improved network operations, substitution for lower-emissions modal options, packaging efficiencies, and supply chain integration.
- Meyer suggested that goods movement in metropolitan areas creates special challenges for energy efficiency and emissions. The spatial organization of metropolitan logistics systems has sprawled much more than other economic activities. This decentralization is a critical element of the emissions and energy effects of urban goods movement. Examples of strategies being considered include smart city logistics, including cross-docking terminals, electric deliveries, off-hour deliveries, and low-emissions zones. Speakers noted that the short-haul freight category, which has been the focus of recent NCHRP research, may have the greatest potential for technology gains.

Research on Basic Understanding

- Participants in the breakout groups noted the need for a better understanding of the basic elements of urban form and the factors that influence urban factors. Studies of the housing preferences and travel patterns of an aging population, new immigrant groups, and young adults are needed to help determine whether future trends will differ from those of the past. The difference in travel patterns based on life cycle was also discussed in the breakout groups as a topic for further research.
- Participants identified a need for longitudinal studies, including examination of spatial trends within metropolitan areas, before-and-after studies, and assessment of threshold population and employment densities to support alternatives to automobile travel. Examining current and future determinants of VMT, cost signals, and elasticities represents another research opportunity identified in the breakout groups.
- Participants noted that a better understanding is needed of cost sensitivities in the freight industry, in both the short run and the long run. Participants in the breakout groups suggested learning from the experience of other sectors on consumer response to pricing, including utilities, insurance companies, and automobile rental agencies.

- Research on how to communicate value and price signals to users of the system as well as to society at large was identified as a need. It was suggested that public opinion research may be as important as behavioral research and modeling. Research on the relative values of price as compared with environmental and societal values is included. Participants in the breakout group discussed the trade-offs between costs versus willingness to pay.

- Research to identify the forms of charging for access to the transportation system that produce more robust revenue streams and that are effective in creating energy efficiency transitions was identified as a need. Examining which forms of pricing achieve the best balance among the competing criteria of cost, efficiency, and equity was also suggested. This examination could include research exploring how different pricing methods affect urban form and how urban form affects travel, and therefore the revenue stream. Another potential research topic is examining why the public prefers general revenue financing, while energy efficiency is better served by user fees.

- A number of freight-related research needs were discussed in the breakout groups. Examples of this research include examining how structural changes in the supply chain and the distribution network affect freight flows in metropolitan areas, exploring the behavioral aspects of the freight industry, and assessing the role of local public policies on land use planning and other factors in influencing freight distribution. Other potential research topics include urban area truck travel patterns, new technologies for urban transport, and engine and emissions characteristics.

Research on Technology, Methods, and Tools

- Many participants cited a need for research on how to move to a different transportation system technology that has a different energy profile, such as EV charging, which is dependent on the electric grid. The role vehicles can play as backup power generators, the costs associated with providing the needed infrastructure, and funding sources for developing and maintaining infrastructure represent important research topics.

- Meyer suggested that part of this evolution is the need to monitor technology development, integration, and in particular hardware and software interoperability. It was suggested that research on these topics would be beneficial, along with examining the integration of the transportation system with telecommunications systems and networks. Participants discussed consumer choice and consumer adoption models and what makes one commodity more attractive than another. Applying these models to assess the attractiveness of alternatively fueled vehicles, especially among the next generation of consumers, was suggested as a research topic. Examining how this information is used in more traditional planning was also suggested.

- Participants discussed the economic aspects of the infrastructure needed for electric and natural gas vehicles. Issues related to the dominance of one or two biofuels, the obsolescence of others, and retail effects were discussed. It was noted that most vehicle manufacturers are using a diversity of parallel approaches. Potential benefits of this diverse approach were discussed, as there could be regional advantages associated with different fuels and approaches.

- The potential for synergies between otherwise competing pathways, the economic benefit of alternative fuels, and the effect on infrastructure were also identified by participants as areas for further research. Assessing the long-term benefits and costs associated with different technology paths represents another research area. There was an extensive discussion on biofuels in one group. Examples of topics included whether the blend wall can increase as biofuels production ramps up, whether the renewable fuels standard will stand, the cost and development of drop-in fuels, the effect of national low-carbon fuel standards, and the uncertainty of the life-cycle GHG footprint for feedstock production.

- Participants discussed models and data needs. The movement toward performance-oriented planning as outlined in MAP-21 leads to more sophisticated and more robust models and the data to support those models. The relationship between micro-, meso-, and macroscale integration was discussed. Many of the energy emissions effects can be examined in detail at the microlevel; however, performance issues are frequently examined at the macroscale. Research on how these levels come together could be beneficial. Some participants noted that new technologies provide a wealth of data that can be overwhelming for potential users. They suggested that research on collecting, reducing, analyzing, and maintaining these large data sets would be beneficial. They further noted that this “big data” issue has been discussed at other conferences. Research on consumer behavior modeling, including surveys linked to actual sales data, was also suggested as a research need. Research on how to consider uncertainty in forecasts and questions relating to generational behavior characteristics were also cited.

- Other data research needs included assessing disaggregate data needs from tracking systems, examining energy consumption by mode, and better understanding cobenefit relationships such as safety, emissions, and energy. Additional areas for research included trade-off analyses of traffic smoothing and safety, obtaining better data on teleworking, modeling interactions between different factors, and examining the effects of other policy sectors’ facility location decisions, such as for hospitals and schools. Obtaining data on freight movement, the distribution of urban fleets, commodity flows, and emissions and energy data was noted by many participants as a key need.

- A number of potential research topics related to eco-driving were identified. Research topics included quantifying the benefits of eco-driving on a larger scale, identifying requirements for dynamic traffic information with advanced eco-driving, and assessing technology versus behavior and convincing drivers to follow advice.

Other research topics are the potential for driver distraction with eco-driving and the role of government, automakers, and researchers. Research that explores establishing CAFE credits to automobile manufacturers for installing eco-friendly technology was also suggested.

Research on Implementation

- Participants discussed different implementation approaches, including the best strategies for phased implementation of infrastructures and the transition to new forms of revenue generation. Identifying potential strategies for states to “opt in” was suggested as beneficial research. Participants discussed the need for research identifying key institutional issues associated with implementation and strategies to overcome barriers.
- Pilot demonstrations to test different approaches, techniques, and technologies were stressed by some participants, with public fleets being considered for such demonstrations. These pilot demonstrations would also serve a public outreach and education function.
- Research on the institutional arrangements for monitoring, collecting, and distributing revenues was identified as a need. Participants noted that the institutional issues are often more difficult to address than the technology issues. It was suggested that research examining the institutional arrangements used in the pilot projects and those used in related activities would be beneficial.
- Participants suggested a potential role for research in public perceptions and preferences; rather than telling the public what the problems and the solutions are, begin by asking members of the public to help define the problems and use their cues to explore possible solutions with them. It was suggested that the public may become more receptive to pricing and financing reforms that meet multiple goals and have multiple cobenefits. These cobenefits can be important in the context of implementation. The Blueprint Plan in Sacramento showed many such cobenefits, including congested VMT per household being reduced, \$15 billion in reduced infrastructure costs, and a 33% reduction in urban water demand. Other benefits were large reductions in farmland and natural resource land conversion to urban uses, reductions in total transportation costs, and increased fare box recovery rates for transit.

STATE DEPARTMENT OF TRANSPORTATION PERSPECTIVE

Paula J. C. Hammond

Paula J. C. Hammond provided comments from the perspective of state DOTs, as well as metropolitan planning organizations (MPOs), cities, and counties. She outlined key areas for additional research. She also thanked Daniel Sperling, the planning

committee, and the speakers for an excellent conference. Hammond covered the following topics in her presentation.

- She said that one critical issue is to realize the real-time changes transportation agencies are facing and the research and data needs associated with policy and investment decisions to address those changes. Some conference speakers noted that individual policies cannot address the multitude of issues associated with the transportation system. Aligning policies—such as those associated with pricing for transportation, reducing emissions from vehicles, and managing the transportation system to lower emissions and improve traffic flow—represents one approach.

- Hammond noted that the loss of revenues through traditional sources is very real to state DOTs. In transitioning to new sources of revenue, it is important to consider how to accomplish other goals, including reducing emissions, managing demand, and influencing driver behavior. She suggested that the performance measures in MAP-21 provide both an opportunity and a threat. There is a lot of interest at the national level in creating performance measures to assist with investment decisions and congestion relief. There is an opportunity in the performance measure development process to consider the mutual goals of moving people, freight, and commerce efficiently, effectively, and with the lowest emissions in major travel corridors. Identifying the data needs and short-term research to assist with developing these performance measures would be beneficial.

- Hammond characterized public outreach and public engagement on pricing and transportation funding as critical. Research on the factors that influence travelers' behavior in response to pricing and what the public will accept would be beneficial. Washington State has made a commitment with the legislature to “toll at the pace the public will accept.” Tolling is being implemented on a corridor-by-corridor basis to help develop public understanding and acceptance, especially on aspects related to security, pricing levels, and the value of a trip. Hammond noted that there is a need to know more about public attitudes, preferences, and responses. Additional research on these topics would help decision makers address key issues.

- Infrastructure needs for alternatively fueled vehicles and the roles of government and the private sector in providing facilities and services represent another research area. Hammond cited the West Coast Electric Highway as an example of a multistate approach. Washington, Oregon, California, and British Columbia are partnering to develop charging stations at key locations. Research on different models to implement and operate charging facilities and other support networks for alternatively fueled vehicles would be beneficial, she added.

- Hammond suggested that there are numerous topics related to freight that need further research. Examples of these topics include short-haul urban freight trips, the use of EVs at ports, and techniques to reduce emissions from trucks. State DOTs are focusing on implementing strategies to provide efficient freight movements in major travel corridors. Moving freight and people in mutually beneficial ways is a key challenge for transportation agencies.

- She observed that encouraging participation in the University Transportation Center (UTC) Spotlight Conference by representatives from additional state DOTs, MPOs, cities, and counties would be beneficial. There is much to be gained by universities and transportation agencies working together to address critical issues. While transportation agencies are focused on current concerns, there is also interest in long-term issues and opportunities.

U.S. DEPARTMENT OF TRANSPORTATION PERSPECTIVE

Kevin Womack

Kevin Womack provided a perspective from the U.S. DOT and the Research and Innovative Technology Administration (RITA) on the topics discussed at the conference. He noted his long-time interest in sustainable energy as a spotlight conference theme. Womack thanked everyone involved in organizing the successful conference, including his colleagues at RITA, the planning committee, TRB staff, the speakers, and the breakout group leaders. Womack covered the following topics in his presentation.

- Global warming is a critical issue today, and it will continue to be a critical issue for the next generation. Increasing vehicle energy efficiencies and reducing GHG emissions are essential to attacking the issue, Womack noted. President Obama stated the importance of this issue in his acceptance speech. As a federal agency, the U.S. DOT will assist the president in attacking global warming. Research in this area is very broad and can be linked to any of the U.S. DOT five goals. Gregory D. Winfree, RITA Deputy Administrator, mentioned the link to ITS and the connected vehicle research in his comments at the conference opening session. Automated vehicles represent a next step in that area. Technologies are available to increase throughput, reduce congestion, and improve safety, which is U.S. DOT Secretary La Hood's Number 1 goal. Upgrading the infrastructure for these technologies relates to the state-of-good-repair goal. New pricing scenarios and revenue options can help stabilize funding and maintain the system in a state of good repair. The goals related to livable communities, environmental sustainability, and economic competitiveness are also addressed by sustainable energy research.

- Womack observed that the research needs discussed at the conference are appropriate for UTCs. The implementation of research is also critical, he said. Deployment of research results may take many forms, including introducing new methods into practice, providing key information to decision makers, developing new policies, helping change behavior, supporting state DOTs' enhanced operations, and bringing new technologies into the marketplace. According to Womack, short-term research, applied research, and long-term basic research are needed. Addressing climate change is a daunting task. The ideas and research discussed during the past 2 days of the conference provide numerous opportunities for addressing climate change, GHG emissions, and energy efficiency.

- Reflecting on the discussion and identifying and embarking on a path that matches individual talents and organizations represent one important next step. In concluding his comments, Womack stressed the importance of working together to meet the challenge outlined by President Obama of ensuring that future generations do not have to address the issues being faced today related to climate change, GHG emissions, and energy efficiency.

CONCLUDING REMARKS

Daniel Sperling

Daniel Sperling provided closing comments. He thanked the speakers, poster authors, sponsors, and participants for making the conference a success. Having just returned from an Intergovernmental Panel on Climate Change (IPCC) conference in Spain, which included experts from around the world working on the next IPCC report on climate mitigation, he noted that the discussion on the need to address climate change was very timely. Sperling covered the following points in his closing comments.

- He suggested that the science on climate change is becoming stronger, focusing the need and the urgency to take action on climate change. IPCC is suggesting that an 80% reduction in GHG emissions in advanced countries, including the United States and the Organisation for Economic Co-operation and Development countries, is needed along with a 20% reduction for developing countries. According to Sperling, meeting an 80% reduction in GHG emissions in the United States will require a transformation in transportation, and a tremendous amount of innovation will be needed to accomplish that transformation.
 - He observed that developing a stronger research foundation is needed to support the public and private sectors moving forward. Flexibility is needed to be responsive to the uncertainties and to the complicated interrelationships associated with reducing GHG emissions. He noted that the freight session highlighted many of these interrelationships. No one group, industry, or agency can address the situation alone. Freight shippers and carriers, automotive companies, electric utilities, biofuel manufacturers, and government agencies at all levels have roles to play.
 - Sperling noted that continuing the dialog initiated at this conference as well as the ongoing involvement of the participants is needed to address these complex challenges. He emphasized that simple solutions or simple actions will not meet the complex challenges. The conference was organized around the four topics of vehicles and fuels, VMT and land use, system operations, and freight and passenger needs. He closed by encouraging the transportation community, the research community, and their partners to deepen and broaden their engagement in addressing energy and climate issues.

APPENDIX

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