TECHNICAL PROPOSAL

Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California

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Statement of Significance

The Global Warming Solutions Act of 2006 (AB 32) calls for California's greenhouse gas (GHG) emissions to return to 1990 levels by 2020. The transportation sector produces 38% of greenhouse gas emissions in California and passenger vehicles are the source of 74% of the emissions within the sector. Emissions reductions can be achieved through a combination of approaches, including: improved vehicle technology, shifts to alternative fuels, and reduction in vehicle miles traveled. The Air Resources Board (ARB) is charged with the responsibility of evaluating and implementing regulatory policies to bring about these changes. California has passed legislation (Pavley AB 1493) requiring improved vehicle technology to reduce GHGs. California applied for a waiver as required under the Clean Air Act but the application was denied by the EPA. California and other states are challenging a U.S. EPA decision preventing implementation of the Pavley standards and expect to prevail. Yet AB 32 requires that if Pavley does not remain in effect, ARB shall implement alternative regulatory options to achieve equivalent or greater GHG reductions. (HSC §38590) ARB plans to pursue a feebate program to backstop the Pavely regulations if they cannot be implemented or to complement them if additional cost-effective emissions reductions are available. Should the Pavley waiver be granted during the course of this research, it would not affect the assessment of lessons learned or the development of the feebate analysis model. However, it would shift the emphasis of the focus groups, survey and stakeholder interviews to give greater emphasis to feebates as a complement to the Pavley regulations.

Feebates are a market-based policy for encouraging GHG emission reductions from new passenger vehicles by levying fees on relatively high-emitting vehicles and refunding the revenue generated to purchasers of lower-emitting vehicles. Feebates may serve as a complement to California's Pavley standards by providing a continuing economic incentive for manufacturers to adopt technologies that reduce GHG emissions as well as a continuing economic incentive to consumers to purchase cleaner vehicles. Feebates could also serve as a replacement for the Pavley standards in the event that California is unable to obtain a waiver for the Pavley standards under the Clean Air Act because feebates can be designed to achieve cumulative GHG mitigation equivalent to or greater than the Pavley standards.

The purpose of this research project is to provide a comprehensive study of feebates that meets the decision-making needs of ARB by addressing issues essential to the practical design and implementation of a feebate program for California. Specific options for possible California feebate systems will be developed based on previous work and studies in the literature, insights from investigating currently functioning feebate programs, and through consultation with ARB staff. A rigorous, quantitative model of vehicle market behavior will be developed to provide a tool for evaluating alternative feebate programs under various market scenarios. The model will represent manufacturers' decision making with regard to in-use vehicle GHG emissions, estimate the impacts on consumers' decisions about new and used vehicle choices, vehicle ownership and use, and provide the data necessary for calculating the impacts on GHG emissions over time. In addition, implications for revenue flows and management of the feebate programs, administrative costs, potential unintended consequences, equity concerns, and interactions between feebates and other possible AB 32 programs will also be investigated. Federal fuel economy standards as specified by the Energy Independence and Security Act of 2007 and implemented by rulemakings of the National Highway Traffic Safety Administration (NHTSA) will be assumed to be in force. The NHTSA is expected to issue a final rule on passenger car and light truck standards through 2015 by the end of calendar year 2008. Specific designs of feebate systems and specific implementation strategies to be analyzed will be determined after consultation with ARB staff. Market research will be conducted to better understand how consumers, auto dealers, manufacturers and other stakeholders are likely to respond to alternative feebate program designs. Based on these activities, and in consultation with ARB staff, the project will synthesize these research results into an overall evaluation and characterization of candidate feebate program options for ARB's consideration.

Abstract

The objective of the California feebate research project is to provide a California specific assessment of two options: (i) a feebate program implemented in place of the Pavley standard to achieve equivalent or greater GHG reductions and (ii) a feebate program in combination with Pavley to achieve additional reductions beyond those expected by the Pavley program. The study will assess options for elements of the design of the feebate program including fee and rebate levels, structure of benchmarks, implementation strategies, point of regulation, consumer and manufacturers responses, and interactions with other AB 32 programs. The information provided will be structured to guide ARB in a potential rulemaking on a feebate system for the State.

Task 1 will infer lessons learned from past and current real world experience with feebate and feebate like systems. The cases evaluated will include France's experience with its current feebate system, the Canadian government's experience with its briefly implemented feebate system, and the Province of Ontario's experience. Other countries reported to have tried feebate (e.g., Denmark and Austria) will be investigate. The U.S. gas guzzler tax (the fee half of a feebate system) will also be examined.

Consumers' perceptions of alternative feebates systems are likely to strongly influence their effectiveness. Task 2 will conduct two sets of focus groups to learn how consumers are likely to react to different feebate programs. The first set will explore consumer's attitudes toward vehicle GHG mitigation policies and feebates in general. The second set will present consumers with specific alternatives.

Feebates can be formulated in many different ways. Task 3 will develop specific formulations to be evaluated by this research project and define the context in which they will be evaluated. The principal investigators will conduct a half-day workshop for ARB staff to explain the key options and their implications, and discuss the pros and cons of alternatives with ARB staff. The outcome will be a set of alternative structures (feebate rates, pivot points and points of regulation) and implementation strategies to be analyzed.

In task 4, a comprehensive feebate analysis model for the present to 2020 will be developed and tested. The model will integrate manufacturer decision making about vehicle design and technology adoption at a national and regional scale with California consumers' decisions about vehicle choice, ownership and use. A detailed, disaggregated model of California households' vehicle choice, ownership and use behavior will be developed to predict the impacts of the feebate systems, given manufacturers' design and product introduction decisions. The model will estimate impacts on new passenger vehicle GHG emissions, changes in the mix of vehicles sold, consumers' surplus by demographic and income group, manufacturers sales and revenues, and feebate revenue flows.

In task 5, the comprehensive feebate model will be used to analyze the impacts of the feebate policies formulated in task 3. The impacts of feebates will be assessed both as a replacement and as a supplement for Pavley. Should the Pavley waiver be granted during the course of the research, greater emphasis will be placed on feebates as a complement to the Pavley regulations. Preliminary results will be presented to ARB staff in a formal briefing by the principal investigators. Final adjustments to the policy strategies will be made, if necessary, and a final assessment completed.

Task 6 will assess policy implications, administrative costs, impacts on state revenues, potential unintended consequences, interactions with other AB 32 measures, and implications for the incidence on different demographic and income groups of program impacts.

Task 7 will carry out a state-wide survey of consumers to determine the perceptions, preferences and concerns of California households with respect to various state feebate programs.

Project objectives

The main objective of this project is to provide the ARB with a California-specific assessment of feebate programs for new vehicles as a replacement for the Pavely standards or as a complement to the Pavley standards.

This study of feebates is needed to insure that the maximum feasible and cost-effective reduction of GHG emissions from new passenger vehicles is achieved. In 2004, the ARB approved regulations to reduce the GHG emissions from new passenger vehicles beginning in model year 2009 and phasing in through the 2016 model year. The regulations apply to four GHGs: carbon dioxide, methane, nitrous oxide and hydroflourocarbons. As required by the Clean Air Act, California applied for a waiver before implementing vehicle tailpipe emissions standards but the U.S. EPA denied the waiver. Although California and other states are challenging the denial in court and expect to prevail, AB 32 Section 38590 requires that the State implement alternative measures to achieve equivalent or greater reductions in GHG emissions should Pavley not remain in effect. A feebate program has been identified by ARB as a key alternative measure that could achieve equal or greater reductions in GHG emissions. A feebate program would combine rebates for low-emitting vehicles with fees for high-emitting vehicles. Fees and rebates would be determined based on the difference between a vehicle's emissions rate and a reference rate, or benchmark. The objective of the feebate program would be to cost-effectively achieve GHG reductions equivalent to the Pavley reductions of 31.7 $MMTCO_2E$. ARB is also considering a feebate program as a complement to the Pavley standards to achieve maximum feasible and cost-effective GHG reductions. Should the Pavley waiver be granted, it would still be useful to ARB to understand how a feebate system would function in the absence of the Pavley regulations but with other federal programs in place. The emphasis of the research, however would shift towards understanding the potential role of feebates as a complement to Pavley and determining whether and how much additional reduction in GHG emissions might be cost-effectively achieved by the addition of a feebate program.

Because of the differing contexts, it is very likely that feebate programs to replace Pavley and to complement Pavley would be designed differently. This study will assess options for program design including fee and rebate rates and structures, alternative designs for benchmarks, alternative points of regulation (manufacturer versus consumer/dealer), and alternative implementation strategies. It will extract lessons to be learned from real world experience with feebate and feebate-like programs. Consumers' perception and likely response to alternative feebate systems will be studied. Views of manufacturers, car dealers and other stakeholders will be solicited and considered. Alternative design strategies will be meticulously defined in consultation with ARB. Rigorous analytical tools will be developed to estimate the impacts of alternative designs on new passenger vehicle GHG emissions, consumer welfare, manufacturer sales and revenues, feebate revenue streams (especially achieving revenue neutrality), administrative costs, State finances and economic impacts.

The resulting information will be organized and presented so as to successfully guide ARB in a potential rulemaking on feebate systems for the State.

Technical plan

1. Research methods

This research project will comprehensively design and assess two general options for a California GHG feebate program. The first will be a feebate-only program to replace the Pavley standards. The second will be a feebate program implemented in combination with the Pavley standards. In both cases the federal CAFE standards as mandated in the Energy Independence and Security Act of 2007 will be assumed to be in effect. The study will address the design of the feebate system, strategies for implementing it over time, its effects on consumers and automobile manufacturers and their responses to it, and interactions with other AB 32 programs.

The complexity of this research calls for an array of research methods. Determining the lessons to be learned from previous experience with feebate or feebate-like policies will require interviewing the key personnel responsible for designing, implementing and managing the programs, collecting data on program impacts, revenue flows and related information, as well as drawing on evaluation studies.

Developing an understanding of consumers' perceptions of feebate systems will be based primarily on facilitated focus group interviews and a sample size 3,000 (completed) statewide survey using standard methods of market research. Focus group protocols will be carefully designed, pre-tested, and cleared by the University of California Institutional Review Board (IRB)/Office for the Protection of Human Subjects, as will be the statewide survey "instrument." The focus groups will take place in two rounds – early and later in the project – and will be conducted in both English and Spanish.

Modeling manufacturers' and consumers' responses to feebate systems is undoubtedly the most complex research task. Manufacturers seek to maximize profits, given the cost and potential of technology for mitigating vehicle GHG emissions, their own product lines and future product plans, fuel economy and GHG emissions standards, and the financial incentives created by the feebate program. We will employ rigorous methods of mathematical programming, together with detailed data on manufacturers' product offerings and the costs and potentials of mitigation technologies to create a model simulating manufacturers' decisions, over time, in response to a feebate program and related policies. Technology and cost data are available from a number of sources, including the ARB, NESCAFF, EPA, NAS and Energy and Environmental Analysis, ICFI, Inc., a key subcontractor to this project. EEA, ICFI will also supply a detailed database of vehicles offered for sale in the U.S. in the base year, their prices and technical attributes, their expected date of major redesign, and their base-year use of GHG mitigation technologies. Detailed data on vehicle sales for California and GHG emissions rates will be obtained from the ARB, while sales data for the Northeast States and Rest of US will be purchased from R.L. Polk & Co or other reliable source. Manufacturers will be assumed to optimize an objective function subject to technology and regulatory constraints.

Importantly, there will be considerable interaction among key project tasks, particularly including the lessons learned, consumer research, and policy formulation tasks (Tasks 1, 2, 3, and 7). Information from the lessons learned assessment and an early round of focus groups will help to shape both the types of policies that will be examined in the policy formulation task and the design of the statewide survey. The statewide survey results will further inform the final selection of feebate policy structures for the analysis, and then a final round of focus groups will help the team to understand how the "downselected" set of potential feebate policy structures may be perceived by the general public, also based on insights gleaned from the statewide survey results.

With regard to the key market simulation modeling task, past studies have specified objective functions representing cost minimization and consumer, or consumer and producer, surplus maximization. The manufacturer decision model will require a representation of manufacturers' perception of how consumers will respond to changes in vehicle prices, feebates and induced changes in fuel costs. Previous studies have successfully employed representative consumer nested multinomial logit (NMNL) models to represent consumers' demands in regions with and without feebate systems. Based on what has already been documented in the scholarly literature, we are confident that a multi-period, multi-region manufacturer decision model can be successfully developed that will make credible changes to existing vehicle designs to incorporate proven and near-market-ready GHG mitigation technologies. These changes can be handed off to a model of vehicle choice in California to estimate the impacts of alternative feebate programs in California.

A detailed, disaggregated model of consumers' choices among vehicle types, ownership and use levels is required for assessing the impacts of feebate programs in California. Professors Bunch and Brownstone have extensive experience in specifying and estimating such models in general and for California in particular. The models are rigorously grounded in consumer utility theory and make use of state-of-the-art random utility modeling and econometric estimation methods. Disaggregating households by demographic and income attributes not only enables more precise predictions but also permits impacts on different population groups to be assessed. By integrating vehicle choice with ownership and use, impacts of feebate programs on used vehicle markets and overall vehicle travel can be quantitatively estimated. The representative consumer model for California used in the manufacturer decision model will be calibrated to serve as a reduced form version of the full California vehicle choice model. Representative consumer models for the Northeast states and Rest of US will either be calibrated based on the existing literature on vehicle choice or, if possible, to regional models estimated using the same methods used to develop the California vehicle choice model. The will chiefly depend on the availability of appropriate data for all three regions.

Beyond the sequential decision making approach described above, it may be possible to create an integrated model that simultaneously determines manufacturer design, and production decisions, consumers' choices and market equilibrium prices. However, such a model has not been developed before at the level of detail and complexity required for this study. Several difficult issues remain that may or may not be solvable. For example, profit rates and production costs for individual makes, models and configurations of vehicles are deemed highly proprietary by manufacturers and are therefore generally unavailable. Furthermore, in reality manufacturers do make design decisions two or more years in advance of production, suggesting that a sequential modeling approach may be more realistic. Thus, whether or not it is possible or even desirable to construct a full equilibrium model remains an open research question. The question will be decided in the course of the research based on the adequacy of historical data for calibrating a simultaneous market model for three U.S. regions and the degree to which valid simulations can be made in the absence of information on the cost and profit functions for individual makes, models and configurations.

2. Task Descriptions

The research will be carried out in seven tasks. These are: Task 1: Lessons Learned; Task 2: Focus Groups and Interviews; Task 3: Policy Formulation; Task 4: Feebate Analysis Model; Task 5: Policy Analysis; Task 6: Policy Implications; Task 7: Statewide Survey.

Figure 1, below, shows how tasks will interrelate in the context of the overall project.

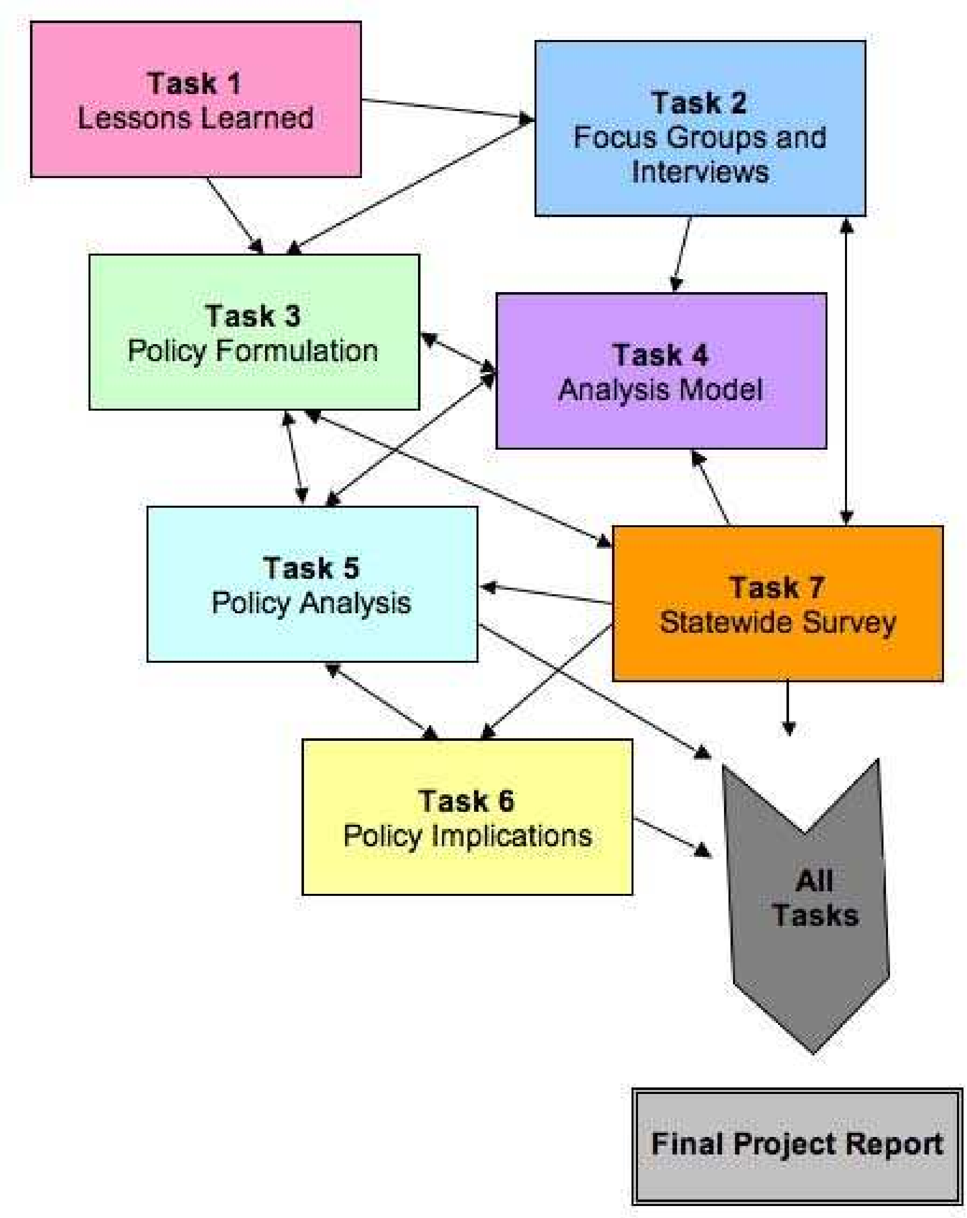


Figure 1: Task Influence Diagram

Task 1: Lessons Learned

This task includes eight to twelve interviews with experts involved in current feebate and "gas guzzler tax" programs around the globe (e.g., in Ontario, Canada; France; Denmark; Norway/Northern EU; etc.), as well as those involved in feebate dialogues in the past in the United States and California (e.g., automobile manufacturers, advocacy groups, governmental agencies, legislature, academics, etc.). Representatives of major auto companies will also be interviewed to get their impressions of how feebate programs and other vehicle pricing strategies have worked in the past, and how they might respond to a new feebate program in California and other states. Published studies and publicly available reports will also be drawn upon. Of particular interest are experts familiar with AB 493 (the California Clean Car Discount bill), which expired without passing in February 2008 and the Drive+ program (ca. 1990) that also failed to pass, despite a great deal of support. A key goal is to understand barriers to feebate deployment and successful implementation, particularly in terms of how the public has reacted to the programs. Additional key areas of investigation will include assessment of the policy and administrative issues and considerations that have come up as the programs have been proposed and implemented, and any lessons that can be learned from past use of differential vehicle registration fees, for example to encourage purchases of cleaner or more efficient vehicles.

The expert and automaker interviews will be conducted primarily by telephone, except where in-person meetings can be arranged within the project travel budget. No international travel is included in this task. This task will be co-led with UC Davis by Dr. Susan Shaheen and Dr. Tim Lipman of UC Berkeley's Transportation Sustainability Research Center (TSRC). Human subject's approval must be granted by both the UC Berkeley and Davis campuses prior to proceeding with the interviews. Results of this task will help to inform the efforts in Task 3 - "Policy Formulation," Task 4 - "Feebate Analysis Model," Task 6 - "Policy Implications of Program," and Task 7 – "Statewide Survey."

Deliverables:
-- Summary report on lessons learned, to be included in the final report.

Task 2: Focus Groups and Dealer/Salesperson Interviews

This task is focused on assessing the potential consumer perceptions and response to the feebate schemes developed in earlier tasks, as well as dealer perceptions. Responses will be studied on potential public support for feebate schemes, if enacted. This task will be led by Dr. Susan Shaheen of UC Berkeley's TSRC. It consists of two key steps: 1) focus groups and 2) interviews with new vehicle dealers and salespersons. Human subject's approval must be granted by both the UC Berkeley and Davis campuses prior to proceeding with these steps.

Focus Groups:
Consumer response to feebates will be explored via a total of twelve (12) focus groups (including four (4) urban, four (4) suburban, and four (4) rural groups). Six exploratory focus groups will be held at the start of the study, and another six will be conducted toward the end of the study to evaluate policy options developed as part of earlier study tasks. Of these, two (2) of the twelve will be conducted in Spanish and ten (10) will be conducted in English.

The six (6) initial study focus groups (including two (2) urban, two (2) suburban, and two (2) rural groups) will be conducted with consumers that intend to purchase a car within the next year or two or have purchased a new car in the past two years. Recruitment for the focus groups will be performed by a well-regarded market research firm, using web-based recruitment tools and other recruitment techniques available to the firm (e.g. existing databases of potential study participants to draw from). Study participants will be offered an incentive of $100 to participate in a focus group.

The focus groups will begin with an overview of GHG emission standards and feebates to provide participants with background information for the discussion. The exploratory discussion will include:

- Vehicle GHG emission standards (Pavley program) vs. feebates;
- Vehicle GHG emission standards (Pavley program) in conjunction with feebates;
- Are feebates viewed as a "tax" or as an opportunity to purchase a cleaner or more desirable (to the buyer) vehicle?
- Manufacturer-level applied feebate vs. consumer level feebate;
- Discussion of additional feebate structures/issues, including feebate per manufacturer fleet or per vehicle class;
- Discussion of clean fuels/advanced technology vehicles in relation to feebates;
- Potential social stigma and "halo" effects resulting from the feebate program; and
- Hypothetical responses to different consumer feebate structures based on input from study tasks (described above).

Initial focus group results, along with lessons learned from expert interviews, will then be used to develop a statewide survey (described below), and to inform the design of feebate policies in task 3.

A second set of six focus groups (including two (2) urban, two (2) suburban, and two (2) rural groups) will be conducted midway to two-thirds of the way through the project, with exact timing to be determined depending on when the researchers feel they would be of most use (i.e., just before or after the statewide survey). This second set of focus groups will also be conducted with consumers that might be about to purchase or have recently purchased a new car to evaluate participant response to feebate policy options.

<u>Interviews with New Vehicle Dealers and Salespersons:</u>
If consumer feebates are implemented, the role of explaining the fee or rebate associated with different vehicle choices will fall primarily to new vehicle dealers/salespersons. Eight to ten interviews will be conducted with new car dealers/salespersons to gain a stronger understanding of their perceptions/opinions regarding feebates, how they think their customers might respond, and what message/language regarding feebates would be useful for consumers. Interviews will be approximately 30 minutes and will likely be conducted via telephone. In-person interviews could be conducted, if appropriate. Note that the success of this research step is dependent on the willingness of car dealers to participate in the interviews. To this end, the researchers will seek the cooperation of the California Automobile Dealers Association in recruiting and scheduling interviews. Interview topics include:

- Awareness of AB 493?
- Overall opinion of feebates (once explained);
- Potential impact on consumer choice of vehicle GHG emission standards (Pavley program) vs. feebates;
- Are feebates likely to be viewed as a tax or as an opportunity to purchase a more desirable vehicle by their customers?
- Anticipated impact on individual sales representatives and the business; and
- Hypothetical responses to different consumer feebate structures based on input from economic analysis.

<u>Deliverables</u>:
-- Summary of focus group results, which will be included in the final report.

-- Summary of interviews with new vehicle dealers and salespersons, which will be included in the final report.

Task 3. Policy Formulation

While design details can vary greatly, all feebate systems share certain structural elements. One key element of any feebate program is the pivot or benchmark point: vehicles with emission rates above the benchmark are subject to fees, whereas vehicles with emission rates below the benchmark obtain rebates. There may be one or many benchmarks (e.g., for different vehicle classes) or benchmarks may defined as a function of vehicle attributes (e.g., weight or footprint). A second critical design element is how fees/rebates vary as a function of distance away from the pivot point. The most commonly analyzed functional form is linear: the fee (or rebate) is equal to a constant multiplied by the difference between the vehicle's emissions rate and the benchmark rate. The feebate rate determines the marginal value of reducing a vehicle's GHG emissions and is therefore the principal driver of manufacturers' responses to a feebate system. A third essential design question is the point at which feebates will be transacted. Feebates may be enforced at the level of the vehicle manufacturer, in which case there will be a small number of parties involved and most "transactions" will be internal to the firm. Under such a system feebates may be reported to car buyers via a label on the vehicle or other means, but the State would deal directly with manufacturers for the payment of rebates or collection of fees. Alternatively, feebates can be made a part of the transaction between dealers and customers. This would greatly increase both the number of transactions and the volume of revenue flows but might possibly have a greater impact on consumer decision making.

There will very likely be differences in the design of a feebate program intended to replace and provide equal or greater GHG reductions than the Pavley standard and a feebate program designed to supplement the Pavley standard. A feebate program replacing Pavley would almost certainly have to be comprehensive and might call for a greater feebate rate than a complementary feebate program. Feebates can be interpreted as a charge on future GHG emissions, capitalized at the time of vehicle purchase. By shifting the incidence of these costs from the future to the present feebates, like emissions standards can remedy failures in the marketplace (e.g., Greene et al., 2009). Employing this insight, feebates as a complement to Pavley could be designed to reflect the price of carbon (equivalent) emissions and could be harmonized with other GHG policies, such as carbon cap-and-trade systems. Other potential design differences between replacement and complementary feebates might also be desirable and will be investigated.

Other practical questions for policy makers include how to manage revenue flows generated by the program and how to adjust the program to cope with the uncertain future energy prices, or changes in the preferences of consumers and use of technology by manufacturers, as well as economic conditions in general.

Design and implementation issues will be examined in depth in a workshop conducted by the University of California research team for ARB staff. The UC research team will present options, pros and cons for each of the following feebate program design issues.

- Specification of benchmark(s)
- Magnitude and functional form of the feebate rate
- Domain of vehicles included in the program
- Point of regulation
- Implementation and management

The policy formulation task will also decide on the general context in which future feebate systems are to be evaluated. This will likely require selecting one or more projections of future population, economic growth, energy prices and other key factors. It will also require deciding on external "surprises" that could alter the effectiveness of the feebate program, the revenue flows it generates or its economic impacts. Surprises could include large changes in the price of oil, severe economic downturns, drastic reorganization of the automobile industry, or more rapid than expected development of key technologies, such as batteries or fuel cells.

Following a thorough discussion of the alternatives, ARB staff and the UC research team will select a feasible number of feebate structures and implementation strategies to evaluate under each of the two policy options (without and with Pavley standards). A memorandum will be prepared by the UC Davis principal investigators documenting the conclusions of the workshop. This task will be led by Dr. Greene.

Deliverables:
-- Workshop and memorandum detailing the policy structures to be analyzed.

Task 4. Feebate Analysis Model

The UC research team will construct a rigorous model of consumers' vehicle choices and manufacturers' decisions concerning the use of technology to reduce vehicular GHG emissions. This task will be led by Dr. Greene and Professor Bunch. The model will be used to analyze feebate alternatives and provide the information needed to guide ARB in a potential rulemaking on a feebate system for California. The model will be capable of representing the constraints imposed on manufacturers by the federal CAFE standards and the California Pavley standards, as well as the incremental impacts of a California feebate system. The model will focus in detail on the state of California but will include separate representations of the Northeast states likely to opt in to California's standards and the rest of the U.S. (3 regions). The model will represent annual decision making by vehicle manufacturers and consumers from the present to 2020. It will be capable of analyzing a wide range of feebate system designs and implementation strategies.

Previous studies provide a variety of insights into how feebates systems and their impacts can be successfully modeled. On the manufacturer decision side, models have been constructed making use of the full detail of EPA's test car list (approximately 1,000 makes, models and drivetrain combinations) and representing every major car manufacturer individually. Vehicle class-specific technology/cost cost models for GHG mitigation as well as fuel economy improvement have been developed. Models have been constructed simultaneously representing different regions with different policies and different preferences. Models have been constructed representing multiperiod decision making, taking into account the normal redesign cycles for individual makes and models. On the consumer side, detailed, disaggregate models of vehicle choice, use and ownership have been developed capable of predicting impacts in new and used car markets and the behavior of and economic impacts on different demographic and income groups. Yet to date, no model has combined all the features necessary to comprehensively evaluate alternative feebate programs and adequately address the requirements for implementing a feebate program in California. However, existing research does demonstrate that such a model can be constructed and can be supported by existing information resources.

Lessons learned from previous research

Existing models of feebate systems have utilized differing but related designs to address a variety of issues (e.g., Greene, 2008; McManus, 2007; Dumas et al., 2007; Johnson, 2006; Greene et al., 2005; Davis et al., 1995). The best model formulation for analyzing a California feebate program will not be clear until the policies to be analyzed have been specified. However, a great deal has been learned from the models developed by previous studies about how manufacturer decisions can be realistically represented at a high level of detail and how consumers' responses and economic impacts can be estimated.

Nearly all previous studies have considered feebates as a fuel economy rather than greenhouse gas mitigation policy (DRI, 1991 is an exception). Davis et al. (1995) examined a wide variety of definitions and forms of feebates. Their model combined an algorithmic representation of manufacturers' decisions to adopt fuel economy technologies based on their cost-effectiveness with a random utility model of consumers' vehicle choices. The manufacturer decision model ranked technologies by cost-effectiveness and then adopted them sequentially (taking into consideration engineering constraints) until the retail price equivalent of the last technology exceeded the sum of its feebate and fuel savings benefits. Market solutions were found by maximizing the sum of consumers' and producers' surplus. This formulation allowed Davis et al. to simulate market responses to feebates over time, from initial implementation to full impact. The manufacturer decision model used by Davis et al. (1995) assumed that consumers would undervalue fuel savings relative to expected full lifetime discounted present value. In the vehicle choice model, on the other hand, consumers were represented as placing a much higher value on fuel savings. As a consequence, the study found that feebate systems generally increased social surplus.

Greene et al. (2005) developed a model that represented manufacturers' decisions and consumers choices at the level of make, model and drivetrain (approximately 1,000 vehicles) for a single year in the future. Manufacturers were assumed to have the opportunity to redesign all their product lines to respond to the feebate system. Vehicle choice was modeled using a representative consumer nested multinomial logit model. Technology was represented by quadratic cost curves fitted to fuel economy cost data developed by the NRC (2002). Solutions were found by maximizing consumers' surplus. With the high level of vehicle detail, Greene et al. (2005) were able to estimate sales and revenue impacts by manufacturer. The impacts on vehicle manufacturers of a single unified feebate schedule with one pivot point for all vehicles versus feebate systems with pivot points for 2 to 11 vehicle classes were studied. The results indicated that class based systems would produce more equitable impacts on manufacturers. Assuming that consumers undervalued fuel savings, Greene et al. (2005) found that feebate programs would produce a small decline in vehicle sales but a small increase in revenues received by manufacturers. The relative increase in vehicle price exceeded the relative decline in sales because the value of fuel savings offset a portion of the vehicle price increase. If the full lifetime value of fuel savings were taken into account, feebate systems were found to produce net economic benefits even without considering the value of reduced external costs.

Using a methodology similar to Greene et al. (2005) Dumas et al. (2007) considered the impacts of feebates implemented in Canada but not the entire North American car market. The results of the modeling indicated that if only Canada implemented a feebate system the impacts on fuel economy would be smaller than if the same system were implemented throughout North America and a greater proportion of the fuel economy gain (on the order of 50%) would come from sales mix shifts. This appears to be the first study explicitly representing manufacturers' responses when a feebate program is implemented in only a portion of the North American market. HLB (1999) carried out a feebates analysis for Canada but incorrectly changed the technology cost function for the Canada-only program, rather than the demand function faced by manufacturers.

McManus (2007) analyzed the impacts of a feebate program applied to California for the year of 2016, separately and in combination with the Pavley GHG standards. Similar to Greene et al. (2005) McManus' manufacturer decision model assumed manufacturers would make adjustments to a base year (2002) set of product offerings in response to the feebate policy. Consumer demand was modeled using a representative consumer nested multinomial model that included a vehicle class market structure. Makes and models with similar features were assigned to vehicle classes (e.g., Small Cars, Luxury Cars, Minivans, Midsize SUVs) based on the notion that they are "substitutes," i.e., makes and models within the same vehicle class are more likely to compete with one another than they are with makes and models from other vehicle classes.

McManus' demand model was implemented as a "representative consumer model," i.e., consumers are considered to be part of a population that can be characterized by a common utility function that represents the population's "average" utility for each vehicle, plus a random error term to capture individual differences across consumers. Vehicle choices were assumed to be a function of: vehicle price ($), performance (horsepower per ton), size (weight in pounds), and fuel economy (fuel cost per mile). Fuel economy is assumed to be valued on the basis of miles driven over the lifetime of the vehicle, which in turn relies on specific behavioral assumptions (14 year lifetime, with a decline in miles driven as a function of age, and an assumed discount rate). Substitutability within vehicle classes was captured by assuming that vehicles *within* the same class have random errors representing unobserved (to the analyst) similarities in preference or excluded attributes. Model parameters were estimated using hedonic price regression on aggregated sales data from 2002. Demand elasticities for the vehicle attributes were assumed to vary by vehicle class, and are a function of the correlation parameters.

The supply side was modeled using seven vehicle manufacturers (the six largest, plus a seventh "composite"), and the vehicle choice set included all makes and models offered for that model year. Using the level of detail offered by the EPA Fuel Economy Guide (which represents technological choices affecting fuel economy for vehicle series, but does not include details like trim level), yields approximately 1,000 vehicle choices in any given model year. To perform the simulation, the manufacturers were assumed to offer the same makes and models as in the base year. In response to a regulation scenario, they have two decision variables under their control: the amount of improvement (if any) in emissions for each model, and the price. (The decision of how many vehicles to produce is interdependent with price, as discussed below.) Improvements in emissions control increase the unit cost of a model according to a specified cost curve. Each manufacturer was assumed to minimize costs, subject to any constraints that might be in force (e.g., Pavely). Prices and vehicle emissions characteristics are varied in an iterative process to reach market equilibrium, which in turn determines the quantity manufactured.

Like Davis et al. (1995), McManus' model assumes that manufacturers believe that consumers undervalue fuel economy improvements but that consumers actually fully value the expected, discounted lifetime fuel savings. As a consequence, McManus' model estimates net economic benefits for a feebate program, even excluding the value of reduced external costs.

Greene (2008) studied the effect of manufacturers' redesign schedules for individual makes and models in estimating the application of fuel economy technologies over time in response to a feebate system. Manufacturers were assumed to optimize one year at a time, an acceptable method provided that feebate rates are constant. The results indicated that the impacts of a feebate system change significantly over the first five years, indicating a possible need for a phase-in strategy to address the fact that manufacturers cannot change the design and technological content of all the vehicles they manufacture in a single year.

Other studies have shown that feebate benchmarks can be readily defined as functions of vehicle attributes. Johnson (2006) compared weight-based feebates with single pivot point systems and found strongly differing impacts on manufacturers. Greene (2008) analyzed the feasibility and impacts of a footprint (wheelbase time track width) based feebate system (similar to NHTSA's reformed Corporate Average Fuel Economy {CAFE} system) and found its impacts on manufacturers to be similar to a multiple-class system.

Manufacturer Decision Model

Manufacturers will respond to a feebate program chiefly by incorporating additional GHG mitigation technologies in the vehicles they produce. A realistic representation of manufacturers' responses requires a detailed knowledge of each manufacturers current product lines, future product plans, and technology status, as well as comprehensive information on the costs and potentials of mitigation technologies. Vehicles must therefore be represented at a fine level of detail equivalent to the Environmental Protection Agency's test car list (approximately 1,000 makes, models and drivetrain configurations). The technical potential to reduce GHG emissions will be represented by technology/cost relationships that take into account base year implementation of mitigation technologies as well as future potential applicability. The representation of manufacturer decision making will be dynamic, considering normal redesign cycles and their interaction with the feebate implementation strategy. Manufacturers will be assumed to be designing vehicles for sale in three regions (California, Northeast States and Rest of US) that may have differing GHG policies.

There is considerable experience and success in modeling the uptake of proven technologies to reduce vehicle emissions or improve fuel economy. The ability to predict the introduction of novel technologies, especially at the level of detail required for this study, is lacking. Instead, we propose to use scenarios to specify alternative assumptions about the timing and make/model details of introductions of new technologies such as plug-in hybrid vehicles (PHEVs), battery electric vehicles (BPEVs) and hydrogen fuel cell vehicles (FCVs) over the 2009-2020 timeframe.

For a competitive manufacturer, profit maximization is equivalent to cost minimization, assuming the quality of the product remains constant. When a feebate system is introduced, the manufacturer faces a new market demand that alters the previous relationship between a vehicle's GHG emissions and the cost of manufacturing it. All else equal, reducing a vehicle's GHG emission rate will add to the cost of manufacture, improve its feebate, and very likely reduce it's energy costs. Reducing energy costs, other things equal, increases the value of the product. Assuming a manufacturer can estimate the value of reduced energy costs to its customers, cost minimization is equivalent to minimizing the change in net cost to the consumer. Let $f(e, e_o)$ be the change in feebate associated with a change from emissions rate e_o to emission rate e, let $V(e, e_o)$ be the change in energy costs as perceived by the customer, and let $c(e, e_o)$ be the change in the full cost of the vehicle, including returns to capital (i.e., the retail price equivalent or RPE). As a convention, it is assumed that rebates and fuel savings are negative, fees and prices are positive. For any given vehicle, the manufacturer will maximize its profits by minimizing the following.

Equation 1

$$Min \quad NetCost = c(e,e_o) + f(e,e_o) + V(e,e_o)$$

$$\frac{dc}{de} + \frac{df}{de} + \frac{dV}{de} = 0$$

The first order conditions for optimization shown in equation 1 require that the marginal cost of reducing emissions equal the negative of the sum of the marginal changes in feebates and energy costs. That is, a marginal increase in manufacturing cost to reduce emissions is just offset by the marginal increase in the benefits of an improved feebate and lower energy costs. It is important to note that equation 1 applies independently to each vehicle, assuming a competitive market. That is, a competitive manufacturer's optimal strategy is to minimize the net cost (maximize the net value) of each and every vehicle. This principle applies even though a manufacturer's product lines compete with one another, to some degree. As long as the manufacturer faces other competitive producers, it has no choice but to minimize the net cost of each and every one of its product lines. In a less than perfectly competitive market this simple rule must be modified. We will address the question of whether or not such deviations from perfect competition could have important implications for feebate policies in real world automotive markets.

Acceleration performance and weight can also be traded-off for fuel economy improvement and GHG emissions reductions. In general, weight reduction via materials substitution (while maintaining the size of a vehicle) is included as a technology in technology/cost curves. Thus, the only opportunity for further weight reduction would be downsizing, which would fundamentally change vehicle design, in effect creating a new make and model. Since a wide range of sizes of makes and models are already available for consumers to choose from, we propose to handle weight reduction by downsizing via sales mix shifts as predicted by the NMNL vehicle choice model. We propose to experiment with including the option to trade-off performance (measured by the ratio of horsepower to weight) for fuel economy. This may or may not be successful due to a lack of consensus in the literature on the value of horsepower and its impact on fuel economy.

Manufacturers have other options they may use to change their product offerings in California. One option is to modify a design currently sold in other countries to meet U.S. and California regulatory requirements. Another is to acquire or merge with a foreign manufacturer to acquire new product lines. With the assistance of EEA, ICFI, Inc. we will explore such options and incorporate them in the analysis as appropriate.

For the manufacturer decision model, we propose to develop an aggregate, representative consumer, vehicle market simulation model, implemented as a non-linear, multi-period optimization model. Market equilibrium solutions will be determined by maximizing social (consumers' plus producers') surplus, thereby simulating a competitive market equilibrium. Vehicle choices will be represented by a nested multinomial logit function of vehicle and consumer attributes. Choice alternatives will be represented in detail, by make, model, engine and transmission type, at a level of detail equivalent to EPA's test car list. This will result in on the order of 1,000 choice alternatives per year. Consumer demand will be represented in three distinct regions: California, the Northeast States and "Rest of U.S." To the maximum extent possible, the aggregate choice model will be calibrated to mimic the behavior of the California Vehicle Market Model described below.

Each regional NMNL vehicle choice model can be calibrated to exactly fit the base year make, model and drivetrain market shares by calculating intercept terms in two steps. First, make and model intercepts (A_{ij}) are calculated using the following equation, in which s_{ij} is the base year share of make and model i, in class j, n_j is the number of makes and models in class j, and N is the number of vehicle classes. These intercepts represent the net utility of each vehicle in the base year, before design changes are made in response to the feebate program. Vehicle classes can be defined in many different ways. The vehicle classes used will depend on the feebate structures to be analyzed, among other factors.

Equation 2

$$A_{ij} = \ln(s_{ij}) - \frac{1}{\sum_{j=1}^{N} n_j} \sum_{j=1}^{N} \sum_{i=1}^{n_j} \ln(s_{ij})$$

Second, vehicle class intercepts (a_j) are calculated, given values for the class price coefficients (B_j) and overall price coefficient (b). Since the class shares, S_j , must sum to one, an arbitrary constraint is required to produce a unique set of coefficients. Assuming that the sum of the class intercepts is zero, the intercept for class 1, a_1 , is the following.

Equation 3

$$a_1 = \frac{b}{B_j}\ln\left(\sum_{i=1}^{n_j} e^{A_{ij}}\right) + \frac{1}{N}\left[\sum_{j=1}^{N}\ln\left(\frac{S_1}{S_j}\right) - \sum_{j=1}^{N}\frac{b}{B_j}\ln\left(\sum_{i=1}^{n_j} e^{A_{ij}}\right)\right]$$

In equations 3 and 4 e represents the base of the naperian logarithms. Intercepts for the remaining classes are obtained from the following equation.

Equation 4

$$a_j = a_1 - \ln\left(\frac{S_1}{S_j}\right) + \frac{b}{B_1}\ln\left(\sum_{i=1}^{n_1} e^{A_{ij}}\right) - \frac{b}{B_j}\ln\left(\sum_{i=1}^{n_j} e^{A_{ij}}\right)$$

The above calibration insures that before any GHG mitigation technology can be implemented and before any feebate system is imposed, the model will predict exactly the base year market shares for every class and every make and model, in each of the three regions (California, Northeast States, Rest of US).

Manufacturers' decisions concerning the use of technologies to reduce greenhouse gas emissions will be represented by technology cost curves that estimate the change retail price equivalent (RPE) per vehicle as a function of the relative reduction in GHG emissions. At a minimum, vehicle class-specific cost functions will be used. If possible, we will develop manufacturers and class-specific or even vehicle specific costs curves to more accurately reflect the current status of technology implementation. Manufacturers' planned redesign schedules and announced product introductions will be used through 2016, at least. Curves describing the total cost of fractional improvements in fuel economy from a base level have been constructed by numerous researchers over the past three decades (see, e.g., Greene and DeCicco, 2000, for a review of this the topic). Data developed by EEA, ICFI, Inc. for Transport Canada showed that the same methods can be used with equal effectiveness for GHG mitigation. When technologies are ranked by decreasing cost effectiveness (change in GHG emission rate divided by cost, taking into consideration a logical engineering implementation sequence) total cumulative cost (RPE) as a function of cumulative fractional change in GHG emissions (Δ) can be very closely fitted by a quadratic curve with zero intercept (figure 1).

Equation 5

$$\Delta = \frac{e - e_0}{e_0}$$

$$RPE(\Delta) = b\Delta + c\Delta^2$$

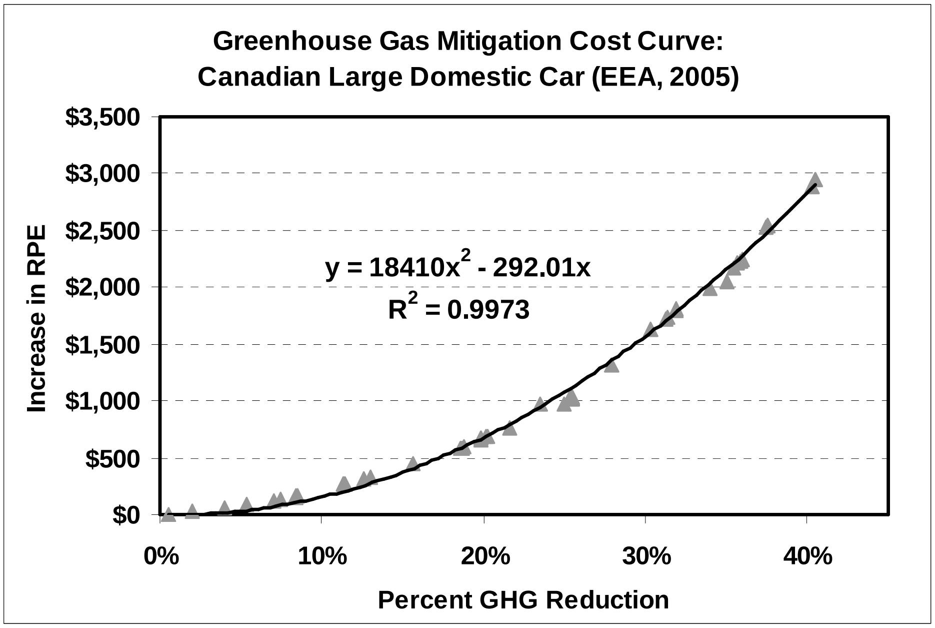


Figure 1. Greenhouse Gas Mitigation Cost Curve for a Large Canadian Domestic Car Derived from Data Presented in table 1-4 in EEA, 2005.

In figure 1 cost is measured in terms of retail price equivalent, an estimate of the incremental price the purchaser of a car would pay based on fully burdened manufacturing costs plus manufacturer's profit and retailing cost and profit.

Many technologies that reduce GHG emissions also improve energy efficiency and fuel economy. Thus, a fuel economy improvement function corresponding to the GHG mitigation cost function must also be created. How consumers are assumed to value fuel economy improvements is key to both the impacts on GHG emissions and economic welfare. Economically rational consumers would measure the value of fuel savings by the expected discounted present value of fuel saved over the full life of the vehicle. There is evidence that very few consumers actually make such quantitative assessments (Turrentine and Kurani, 2007). Greene et al. (2008) show that typical consumer loss aversion combined with the uncertainty of future fuel savings could lead to a significant undervaluing of future fuel savings relative to their expected present value. On the other hand, some econometric studies indicate that car buyers appear to value fuel savings in accord with rational economic principles (e.g., Espey and Nair, 2005). The subject remains controversial and has very significant implications for the costs and benefits to consumers of fuel economy policies (e.g., Fischer, 2007). Reflecting this controversy, the NRC (2002) fuel economy study considered two alternative methods of valuing fuel savings, full lifetime discounted fuel savings (equation 6) and a 3-year simple payback (equation 7). Greene et al. (2008) showed that the 3-year simple payback produces approximately the same effect as loss aversion plus uncertainty.

Equation 6 Lifetime Discounted Present Value

$$V_L = \int_{t=0}^{L} P(t) M_0 e^{-\delta t} \left(\frac{1}{G_0} - \frac{1}{G_0(1+\varepsilon)} \right) e^{-rt} dt = \frac{1}{\delta + r} \left[1 - e^{-(\delta + r)L} \right] P_0 M_0 \left(\frac{1}{G_0} - \frac{1}{G_0(1+\varepsilon)} \right)$$

Equation 7 Simple 3-year Payback

$$V_3 = 3P_0M_0\left(\frac{1}{G_0} - \frac{1}{G_0(1+\varepsilon)}\right)$$

P(t) = price of fuel, for simplicity of exposition only assumed to be P_0 for all t
M_0 = annual miles traveled for a new vehicle
e = base of naperian logarithms
-δ = rate of decline in vehicle use per year (-0.04)
G = base year fuel economy
ε = fractional increase in fuel economy
r = consumer discount rate
L = vehicle lifetime, in years

Solving the Manufacturer Decision Model

The manufacturer decision model is solved by maximizing consumers' surplus subject to federal CAFE standards and with and without California Pavley constraints, with the decision variables being the change in GHG emissions for each vehicle eligible for redesign in the year in question. Consumers' surplus in the NMNL model is a function of the calibrated constant terms, the price slopes, and the changes in vehicle price, P, present value of fuel savings, V, and the feebate, f. The utility of vehicle i in class j, u_{ij}, is the sum of its constant A_{ij} and the class j price slope times the changes in P and V, and f.

Equation 8

$$u_{ij} = A_{ij} + B_j\left(\Delta P_{ij} + \Delta V_{ij} + f_{ij}\right)$$

The change in consumers surplus per vehicle (ΔU) is calculated using the expected utilities of each class (u_j) with (u) and without (u^*) the feebate system, and the price slope for choice among vehicle classes, b (equation 8).

Equation 9

$$u_j = \frac{1}{B_j}\ln\left[\sum_{i=1}^{n_j} e^{u_{ij}}\right]$$

$$\Delta U = \frac{1}{b}\ln\left[\frac{\sum_{j=1}^{N} e^{a_j + bu_j}}{\sum_{j=1}^{N} e^{a_j + bu_j^*}}\right]$$

Note that, all else constant, in the absence of the feebate program there would be no motivation to change vehicle designs and so $u^* = A_{ij}$.

The manufacturers' optimization problem is to choose the change in GHG emissions (implying changes in the price, fuel savings and feebate) for each vehicle that maximizes the change in consumers' surplus. Because feebate structures (e.g., rates, benchmarks) may change over time, multi-period optimization will, in general, be required. This will require the researchers to address questions of myopia versus perfect foresight versus various representations of expectations, uncertainty, and discounting of future costs and benefits. The modeling framework, however, is well suited to multi-period optimization methods.

CAFE standards are represented as equations constraining, by year, the sales-weighted harmonic mean fuel economy (G) of a manufacturers vehicles to be greater than or equal to the required levels (G^*). In equation 10 Q_{ijt} is the number of vehicles of type j sold by manufacturer i in year t. NHTSA's new CAFEE standards are based on a footprint metric, which results in a unique standard for each manufacturer.

Equation 10

$$G = \left[\sum_{j=1}^{N_{it}} \frac{Q_{ijt} / Q_{ji}}{G_{ijt}} \right]^{-1} \geq G_{it}^*$$

The greenhouse gas constraints in California (Pavley standards) require that the sales-weighted mean emissions rate is less than or equal to the standard. Since manufacturers have alternative compliance methods, the actual constraints may be more complex than shown in equation 11. In particular, banking and trading of credits is permitted. Note that in equation 11, e represents an emissions rate.

Equation 11

$$\sum_{j=1}^{N_{it}} \frac{Q_{ijt}}{Q_{it}} e_{ijt} \leq e_t^*$$

The federal gas-guzzler tax also remains in effect and will be represented in the manufacturer decision model.

California Vehicle Market Simulation Model

A major task in this project is the development of a Vehicle Market Simulation Model to support the evaluation and assessment of alternative feebate policy scenarios. The entire premise of a feebate approach is that desired policy outcomes (e.g., reduction in greenhouse gas emissions) can be brought about through the effect of economic incentives on the general market behavior of both consumers and vehicle manufacturers, rather than by, e.g., direct governmental regulation of specific vehicle choice offering performance standards. [Note: Some policy scenarios to be considered in this project involve a combination of both types of regulations. However, the emphasis in this discussion is on the modeling requirements imposed by the goal of addressing feebates.] Evaluating alternative policies therefore requires a means of analyzing the effect of these policies on market behavior. In the case of feebates, the distribution of demand across vehicle types, as well as their emissions characteristics, directly determines the bottom-line effect not only on the desired policy outcome (emissions) but also on the total program budget (total costs from rebates and administration, minus revenues from fees).

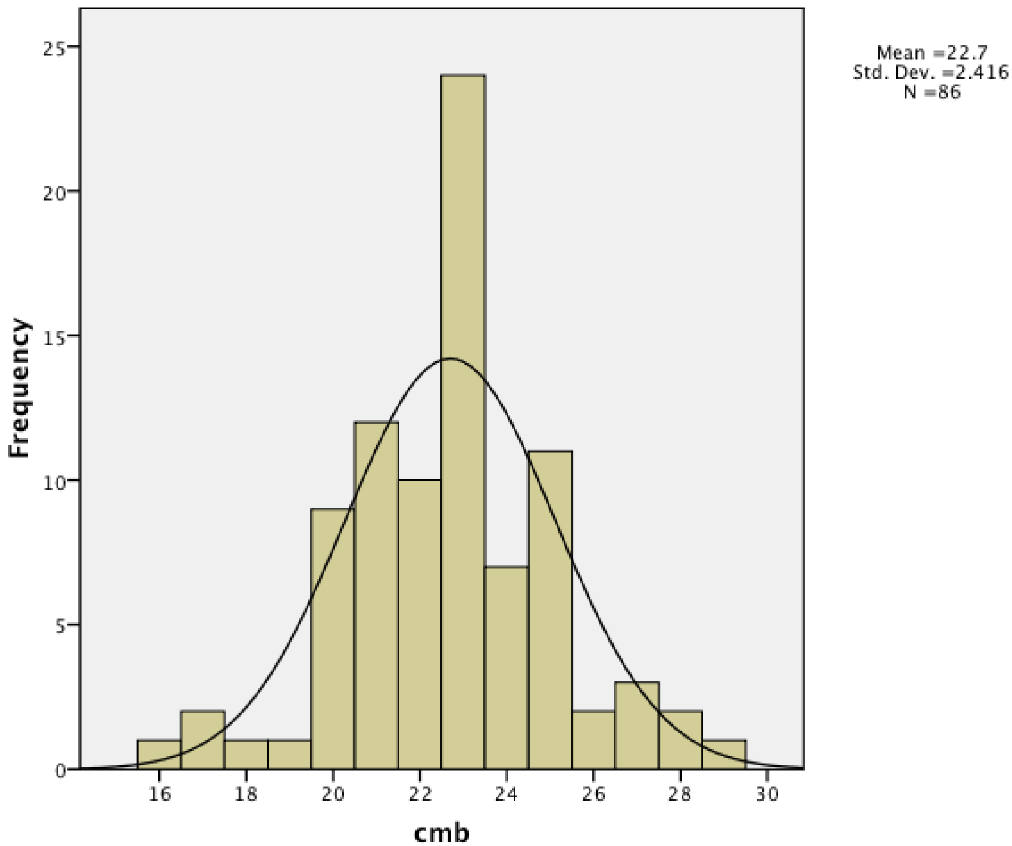
As discussed in Bunch and Chen (2008), the choice of specific methods and techniques for vehicle demand modeling are determined by the purpose to which the results will be applied. For example, methods used for short-run decision making by automobile manufacturers will generally be different from those used for medium-to-long run policy analysis by public agencies (although there will be many similarities). Manufacturers will typically be concerned with preferences by consumers for highly detailed vehicle characteristics within any one of a number of segments. In contrast, policy analysts are more concerned with large, general impacts on total fuel consumption and emissions from the entire fleet over a medium- to long-term time horizon. Automobile manufacturers are typically focused on *sales* in the new vehicle market, whereas policy analysts are concerned with the full life cycle and distribution of the entire fleet, as well as how the vehicles are actually driven, since these are the direct determinants of fuel use and emissions. Policy makers may also be concerned with the impact of their decisions (both economic and environmental) on specific demographics groups (e.g., low income households). To provide context, we briefly review two different types of modeling approaches to illustrate previous discussion, and then discuss in more detail the requirements for this project.

The first type of approach relies on aggregate-level demand models of the type described in the previous section. McManus (2007) is such an example. The model includes a high level of detail in product offerings (i.e., down to the make-model level), which would seem to be a requirement because under feebate programs consumers would face tradeoffs for purchase price versus emissions characteristics when choosing among vehicles in the same vehicle class (e.g., subcompact cars). However, this approach focuses exclusively on the new vehicle market, and analyzes manufacturer decisions based on a one-period simulation and optimization. This ignores two potentially important effects, namely, the interaction between the new and used vehicle market, and how these affects affect both sales and manufacturer decision making over time (as discussed in more detail below).

By way of contrast, many policy analyses use models with a different set of features. Two examples are the CalCars model of the California Energy Commission, and CARBITS of the Air Resources Board. These models are different than the McManus (2007) approach in the following respects:

1. The models simulate market behavior over a many multi-year time horizon, and attempt to incorporate dynamic effects (to the degree possible).
2. Consumer choice models are formulated at the individual household level, and are estimated using actual household choices and behavioral data collected using large-scale surveys. Utility functions are based on behavioral theory that posits a more detailed set of preference effects, including those due to demographic differences across households (e.g., income, age, household size).
3. As part of the market simulation, temporal changes in the demographic makeup of the market can also be incorporated if necessary. These typically rely on demographic forecasts from a sanctioned source.
4. Models simulate household-level choices for the entire vehicle fleet, including how many vehicles to own, which types, and how much to drive them. The models include choice of both new and used vehicles. In some cases, vehicle scrappage effects are also modeled.
5. Vehicle choices are characterized at the vehicle *class* level of detail (e.g., subcompact cars, large SUVs), i.e., choices are not simulated at the individual make and model level. New vehicle offerings (and their characteristics) are treated as exogenous and are part of the evaluation scenario to be determined by the analyst.

The above two examples illustrate various potential requirements for a vehicle market simulation model to evaluate feebate policies. For example, in order to adequately model consumer response to feebates, choice of new vehicles may require a level of detail similar to McManus (2007), so the level of detail typically included in vehicle-class-based models such as CalCars and CARBITS may be inadequate. As further illustration, the following histogram shows the distribution of EPA combined fuel economy (combined MPG, or cmb on the x-axis below) for Compact Cars in 2003:



There are 86 data points representing available vehicle technologies at the level of make-series-engine–transmission-drive train. Specifically, for a give make-series (e.g., Toyota Corolla), details that affect fuel economy and performance for a series are included, but details related to trim package are not. Fuel economy for this vehicle class covers a relatively wide range (from 16 to 29 MPG), roughly corresponding to a range of 550 grams-per-mile to 300 grams-per-mile CO_2 equivalent. This is comparable to the ranges used as examples by McManus (2007, section 2.4), where lower bound could incur a fee of, e.g., $2,500, and the upper bound a rebate of, e.g., $1,300. In other words, a typical feebate program would seek to influence vehicle demand over ranges that currently fall entirely *within* a typical vehicle class. In this instance, the McManus (2007) approach includes the required level of detail in the consumer model, whereas a vehicle class-based model does not.

At the same time, features of CalCars/CARBITS models are also potentially important. The McManus (2007) focuses only on new car purchases, and performs a myopic one-period market simulation. Such an approach cannot capture the total effect of a policy for an evolving vehicle market in which last year's new vehicles become this year's used vehicles. The effect of the policy on the entire market is extremely important, and ignoring the dynamic effects for the entire market system could lead to erroneous results. The vehicle market simulation model for this project must adequately address all of these issues.

With this as background, we now formulate a mathematical framework for vehicle market simulation that will form the basis for developing a model for this project. Note that the framework is intended to be rather general: For any specific model implementation certain elements may be simplified or eliminated, depending on the nature of the assumptions. The basic issues are: Modeling consumer demand given available vehicles, and modeling the decisions made by automobile manufacturers. In what follows, we make use of the following notation:

m is an index of manufacturers from 1 to M
s is an index of household/consumer segments from 1 to S
Z_s is a vector of consumer characteristics for segment s
Z = $\{Z_s, s = 1, \ldots, S\}$ = the collection of characteristics for all segments
j is an index of vehicle *models* (for a given make) from 1 to J_m
y is a time-related index used to denote a vehicle *model year*
t is a time-related index used to denote a *calendar year*
jy denotes a vehicle type of model j and model year y
O_{my} denotes the set of vehicle models offered by manufacturer m for model year y
W_{st} is the size of consumer segment s at time t
W_t = $\{W_{st}, s = 1, \ldots, S\}$ = the collection of segment weights for time t
X_{jy} denotes vehicle attributes for vehicle jy
e_{jy} is the emission rate for vehicle jy (and is therefore one of the X_{jy}'s)
c_{jy} is the marginal cost for producing jy (generally not observable)
$c_j(e, e_0)$ is an incremental cost function.
= the cost of improving a vehicle model's emission rate from e_0 to e.
$p_{jy,t}$ is the market price for vehicle jy in calendar year t
(so $p_{jy,y}$ is the new vehicle price)
$Q_{jy,t}$ is the *quantity* of vehicle jy in the market during year t (a.k.a., vehicle stock)
(so $Q_{jy,y}$ is the number of new model j vehicles manufactured in year y)

Using the above notation, we denote a vehicle choice model by

$H(jy\,|P, X, Z_s)$ = the expected demand for vehicle type jy by a household belonging to segment s in a market defined by the matrix of vehicle characteristics X and price vector P (where we have suppressed the subscript t).

The aggregate demand for vehicle type jy by the consumers in segment s is given is therefore given by

$$W_s H(jy\,|P, X, Z_s)$$

This general form can support a range of model types. In the simplest case, there would be one segment ($S=1$) corresponding to a representative consumer model with a vector of preference parameters and no actual consumer characteristic variables (e.g., demographics). If the market definition were limited to the new vehicle market, this would correspond to an aggregate level demand model of the type used in McManus (2007), where the weight (W) would be the market size. Alternatively, in a policy analysis model such as CalCars, there might be a limited number of segments that are specifically defined by demographic variables such as income, household size, etc. Each segment would be defined by its own set of variables (Z_s). The definition of each segment would not change during the course of a market simulation; however, weights could be changed based on demographic forecasts to represent changes in the population. In the most extreme case the vehicle market could be modeled using pure micro simulation, so that S is large and the Z_s would represent a random draw from a distribution. The distribution could involve demographic variables and/or unobserved heterogeneity in consumer preferences. In this case (depending on the details of the model) the weights might all be equal, and their sum would equal the market size.

Adding in the time dimension t, the total market demand for jy during calendar year y is given by

$$D_{jy,t}(P_t, X_t, Z_t, W_t) = \sum_{s=1}^{S} W_{st} H(jy\,|\,P_t, X_t, Z_s)$$

From the perspective of a manufacturer, total profit during calendar year y is given by

$$\pi_{my} = \sum_{j \in O_{my}} (p_{jy} - c_{jy}) D_{jy,y}(P_y, X_y, W_y) = \sum_{j \in O_{my}} (p_{jy} - c_{jy}) \sum_{s=1}^{S} W_{st} H(jy \mid P_y, X_y, W_y)$$

The standard behavioral assumption is that manufacturers make decisions based on profit maximization, subject to any relevant constraints. However, there are many issues that can affect the details of how models are estimated and used in practice. For example, in many cases it is difficult to obtain accurate data on proprietary items such as costs (e.g., c_{jy}). This issue has been addressed in a variety of ways, as discussed elsewhere. Other cost-related issues include such affects as economies of scale, and synergies across product lines within the same company.

The timeframe raises additional issues. In the short term, manufacturers are constrained to making price changes only, whereas over a longer time frame they can change their vehicle designs. In considering a longer time frame, market dynamics and the role of the used vehicle market can be important issues.

For a dynamic market simulation, define the vehicle stock of vehicle type *jr jv* during calendar year y by $Q_{jr,yv}$ for *r v* = *y* - *wv*, …, *y*, where v denotes vehicle vintage.. For this example, let *v w* denote a parameter used to define the window of allowable vehicle vintages, so that $Q_{jvr,\ y} = 0$ for *r v* < *y* -– *vw*, i.e., all vehicles w+1 years old or older are assumed disappear completely from the market. (Depending on the details of the model, vehicles may be scrapped prior to this, but the window is included to create a well-defined lower bound.) . If we assume that the market is in equilibrium in year t so that supply equals demand, then the following must hold:

$$Q_{jv,t} = D_{jv,t}(P_t, X_t, W_t), \ \text{ for } v = y - w, \ldots, y.$$

For new vehicle purchases, vehicle stock is the same as the demand defined above. For used vehicles, the evolution of vehicle stock can be modeled in a number of ways. However, in a closed system the following must be true: The vehicle stock for a given model year must decline over time (e.g., it cannot go down, and then go back up). It is generally assumed that the used vehicle stock for year t is determined by the vehicle stock from year $t-1$, minus some scrappage quantity.

This framework provides a basis for discussing the following research issues to be addressed by this project. The following were identified in the pre-proposal:

1. Representation of Market Structure
    a. Role of California within a national market
    b. Role of States that “opt in” to the California feebate program
    c. Framework for manufacturer decision-making as a function of market structure
    d. Importance of differentiation of consumer market

2. Consumer Demand
    a. How consumers value vehicle attributes
    b. Nature of demand for fuel economy
    c. Role of heterogeneity
    d. Functional requirements for vehicle choice modeling
    e. Data requirements

3. Manufacturer Decision Making
    a. Role of timing in designing and offering new vehicles
    b. Strategic choices on offering products to a total market system

c. Vehicle technology adoption decisions
d. Manufacturer assumptions regarding consumer response

One challenge in discussing these issues is that they are not independent from one another, as will become apparent.

To begin, consider a "simplified" case where a group of manufacturers is serving a single market, and we seek to evaluate alternative regulation scenarios applied to this market. To support additional discussion about methods and data, assume that the market is California. Also for purposes of discussion, assume that we are modeling household vehicle holdings decisions, that these holding "choices" are made on an annual basis, that every household holds at least one vehicle, but may hold no more than three. In this case, the household-level demand model depicted above:

$$H(jy \mid P, X, Z_s)$$

gives the "expected number" of vehicles of type *jy* held by a household with characteristics Z_s. Note that these are not choice probabilities that sum to one. One research task will be to formulate more detailed "submodels" that are subsumed under *H*. For a holdings model, the vehicle choices involve the choice of (i) how many vehicles to own, and (ii) which vehicles to own, which can be depicted by a tree structure. As noted above, a household's expected choices will be a function of the attributes (X'SX's) of all vehicles available in the market, their prices (P's), and the household's characteristics (already mentioned).

The market consists of available used vehicles from the collected market activities of earlier years, plus the new vehicles that are introduced in the current year by the manufacturers. For every model year, each manufacturer must decide:

1. Which vehicles to offer
2. What characteristics (X's) they should have
3. What price to charge
4. How many to manufacturer

For an operational model using the above framework, the behavior of both consumers and manufacturers must be specified in some manner. Generally speaking, the methods for developing and estimating quantitative behavioral models are much more highly developed for consumer demand than they are for manufacturers. With regard to consumer models, the team will apply its expertise in choice modeling to develop an appropriate model to meet the needs of the project. Using California as an example, developing and estimating choice models makes use of multiple types of data. The following is a list of categories, and our preliminary assessment of specific data sets that can be used.

1. Detailed historical database on Vehicle Technology (X's).
   a. Chrome data on vehicle characteristics.
   b. National Automobile Dealers Association historical data on used and new vehicle prices (broken down by region).
   c. Wards Automotive data on vehicle characteristics
   d. EPA and NHTSA data.
   e. Historical vehicle technology data from KG Duleep.
2. Projections of Vehicle Technology scenarios for future vehicle markets.
   a. Data tables and consulting with KG Duleep.
3. Household-level survey data on vehicle holdings.
   a. 2001 Caltrans Travel Survey

   b. NHTS Travel Surveys
   c. Consumer Expenditure Survey (CES) data
   d. California Vehicle Survey (CVS) data from California Energy Commission
4. Aggregate level sales data for estimation and calibration purposes.
   a. Sales estimates from processing historical data from California DMV
   b. Data from RL Polk (for non-California sales)
   c. Smog Check data?
5. Stated preference data from households on hypothetical future vehicles.
   a. 2001-2002, 2006, and 2008-2009 California Vehicle Survey (CVS) data from California Energy Commission

These data represent the required collection of information on consumer choices (*H*), characteristics (*Z*), market demand (*D*), vehicle characteristics (*X*), and prices (*P*) to support estimation of choice models.

With regard to the decisions of manufacturers, quantitative approaches based on maximizing the profit function, subject to constraints, have already appeared in the literature. For example, one such constraint would be that the sales -weighted mix of vehicles meets CAFÉ CAFE requirements. See, e.g., Goldberg (1998), Bento, et al. (2006), and Jacobsen (2006). These approaches require structural assumptions about market equilibrium between supply and demand in order to simultaneously estimate the parameters of both the consumer demand model and the manufacturer decision model.

However, as mentioned previously, quantitative modeling of manufacturer decisions is much less developed and faces a number of challenges. For example, one problem is the availability of accurate data. Attempting to model manufacturers as profit maximizers nominally requires knowledge of each manufacturer's variable cost of production, but accurate cost data are proprietary and difficult to obtain. This problem has been addressed by the literature in a number of ways, but remains a concern.

A bigger challenge is that the needs of this project go well beyond price and quantity decisions, as evidenced by the list provided above. Issues include the timing and nature of design decisions, the role of multiple markets, etc. For purposes of this project the overall approach to specifying the manufacturers' decision processes was presented in the previous section, and reflects the most current experience available. Our initial approach will be to develop a high-level model of the entire new vehicle market (defined to include the entire United States, comprised of up to three region-based segments) that captures manufacturers' design and pricing decisions over time. Aggregate-level market models will be used for this purpose. The solution of the high-level model will define the market environment scenario to be used as an input to a more detailed model of the California vehicle market. The more detailed model allows a sharper focus on policy-related outcomes such as sales of specific vehicle types in the new vehicle market, the impact on the used vehicle market, vehicle usage, and the affect on emissions. Economic impacts on demographic segments of the consumer market can also be assessed.

The approach is practical, and will support the needs of the project. At the same time, the development of consumer choice models and the implementation of vehicle market simulation for this project provide an opportunity to test and pursue potential new approaches. We Specifically, we plan to explore the possibility of using the above framework to extend the simulation model by including a quantitative, integrated model of manufacturer decision making.

Model outputs

The feebate analysis model will produce estimates of feebate impacts on a wide array of variables at a fine level of detail. Impacts on vehicle GHG emissions rates for both new vehicles and the vehicle fleet, as well as total, on-road light-duty vehicle GHG emissions will be estimated. ARB estimates of emissions rates per vehicle as defined for the Pavley standards will be used. In general, impacts on vehicles will be estimated at the level of make, model, engine and transmission. In addition to GHG emissions, these impacts will include estimated changes in the retail prices of vehicles, their fuel economy and the feebates they will incur. Estimates of manufacturers' changes to vehicle design will be produced for each of the three regions (California, Northeast States, and Rest of U.S.). This will permit estimation of impacts on national and California total light-duty vehicle sales, sales distributions by make and model, changes in manufacturer revenues, and revenue impacts on notional automobile dealerships characterized by brand and sales volume. Estimates of impacts on California consumers will be produced by demographic and income group. All the output variables listed below will be generated for each calendar year.

- New passenger vehicle GHG emissions rates by year, by individual make and model, by manufacturer, by vehicle class and for the new vehicle fleet as a whole
- Vehicle price and fuel economy changes for all subcategories
- Passenger vehicle sales by manufacturer, vehicle class by model year
- Manufacturer sales revenues by vehicle class and model year
- Sales revenue impacts on notional automobile dealerships
- Changes in consumers' surplus by model year and by manufacturer
- Impacts on used vehicle prices and transactions by vehicle class
- Fees and rebate flows, and net revenue to the State
- Total GHG emissions by passenger vehicles in California by calendar year, and cumulative emissions impact
- Passenger vehicle travel, energy use and petroleum consumption by calendar year.

These outputs will provide a comprehensive and detailed basis for policy analysis.

Deliverables:

-- Working, tested model of manufacturer decision responses to feebate systems in an appropriate computer language, with documentation.

-- Working, tested model of vehicle choice, use and ownership for California with documentation.

-- Databases used in model development and calibration, as permitted by data acquisition agreements.

Task 5. Policy Analysis

The design of a feebate system affects its efficacy in reducing GHG emissions, its economic efficiency, its distributional impacts, its administrative complexity, and its revenue risks. Moreover, the number of possible feebate designs is infinite. Feebate systems can be discrete, assigning the same fee or rebate to classes of vehicles, or continuous, basing the fee or rebate on a metric such as grams of CO_2 equivalent emissions per mile. There can be a single benchmark, different benchmarks for different classes of vehicles, or benchmarks defined by a continuous vehicle attribute, such as footprint or weight. The feebate rate parameter can be a constant or can be any number of different functions of distance from the pivot point. Feebates can apply to all light-duty vehicles or only certain vehicles, for example to only the most and least efficient. Based on the results of task 2, Policy Formulation, several alterative feebate strategies will be analyzed using the Feebate Analysis Model. These will embody different assumptions about the key elements of feebate design:

- Functional form: discrete or continuous
- Benchmark definition: single, vehicle class, or attribute-based benchmarks
- Value of emissions: constant or varying $/gm-per-mi feebate rate, and level
- Coverage: universal or segments of vehicle market

- Implementation strategy: changes in rates, benchmarks or coverage over time

Continuous feebate systems avoid boundary effects that could reduce the impact of the system on GHG emissions and also increase uncertainty about revenue streams. Nonetheless, France implemented a discrete feebate system and some argue that such systems may have a greater psychological impact on consumers' purchase decisions by identifying certain vehicles as "the right choice" (Peters et al., 2008). For a given feebate rate, a single benchmark system is likely to have the greatest impact on the mix of vehicles sold, but multiple and attribute-based feebate systems can mitigate inequitable impacts on vehicle manufacturers (Greene et al., 2005). If all vehicles were driven the same number of miles per year, a constant feebate rate ($/gm-per-mi) would insure that every gram of CO_2 equivalent GHG emitted was valued the same, satisfying a key condition for economic efficiency. On the other hand, varying feebate rates can be used to mitigate potentially extreme payments for unusual vehicles or to create special incentives or disincentives. Including all vehicles in the feebate system insures maximum impact on GHG emissions but exempting some vehicles, especially during a phase-in period, can reduce economic costs and revenue flows and may affect public perception of the policy.

The implementation and management of feebate systems has received too little attention from researchers. This is important because feebate systems are likely to have different immediate and long-term impacts. Past analyses indicate that for nationwide feebate systems, 90% or more of the impact on energy use or GHG emissions is likely to come from technology and design decisions made by manufacturers and 10% or less from changes in the mix of vehicles sold (e.g., Davis, et al., 1995; Greene et al., 2005). When the system applies to only a portion of the market, however, salesmix effects can account for half or more of the total impacts (Dumas, Bourbeau and Greene, 2006). Still, manufacturers' engineering decisions are of major importance. In the first year of a feebate system, manufacturers will be able to redesign only 10% to 20% of their product lines. Thus, early on, a greater proportion of the feebate impacts will come from salesmix shifts (Greene, 2008).

Once a feebate system has been implemented, management will be required not only to handle revenue flows but also to adapt to changing market conditions. Sudden, large changes in the price of oil, for example, can significantly change the economics of the feebate program. The scenarios and surprises identified in task 3 will be used to estimate the impacts of important external events on the feebate program. Once impacts have been estimated, strategies for adjusting to changed revenue flows or GHG impacts will be proposed and tested to determine which feebate formulations are most robust to external challenges.

Utilizing the feebate analysis model, the policy analysis task will estimate the impacts of the feebate strategies defined in task 3 on vehicle emissions rates and total GHG emissions from passenger vehicles in California annually and cumulatively from the present to 2020. It will assess the impacts on the mix of vehicles sold in California, on vehicle prices, on fuel savings, and the impacts on consumers' surplus by income and demographic group. Effects on vehicle sales in total and by manufacturer, and impacts on manufacturers' average vehicle prices and total sales revenues will be estimated, as will gross and net revenue flows.

Dr. Greene and Professor Bunch will lead this task.

<u>Deliverables:</u>
-- Workshop presenting intermediate results of policy analysis with opportunity for stakeholder comments.
-- Draft report on policy analysis of a feebate program for California.

Task 6: Policy Implications of Program

This task is focused on assessing the policy implications and social responses to the feebate program structures and features developed in earlier tasks. This task will be led by Dr. Tim Lipman and Prof. Dan Kammen of UC Berkeley's TSRC, with the assistance of Dr. Walter McManus and other UC Berkeley and Davis team members. The task consists of several key aspects, including assessment of:

- Program social incidence/consumer welfare shift analysis;
- Potential program VMT interaction effects and effects on trip-making behavior;
- Program administration costs and secondary effects;
- Possible unintended program consequences to be considered; and
- Potential interaction with other AB 32 measures.

This task would be informed by the results of Task 1 – "Lessons Learned," in terms of drawing in considerations from previous feebate program experiences. The results of this task will help to inform the efforts in Task 3 – "Policy Formulation" and Task 5 – "Policy Analysis."

Social Incidence/Consumer Welfare Shift Analysis

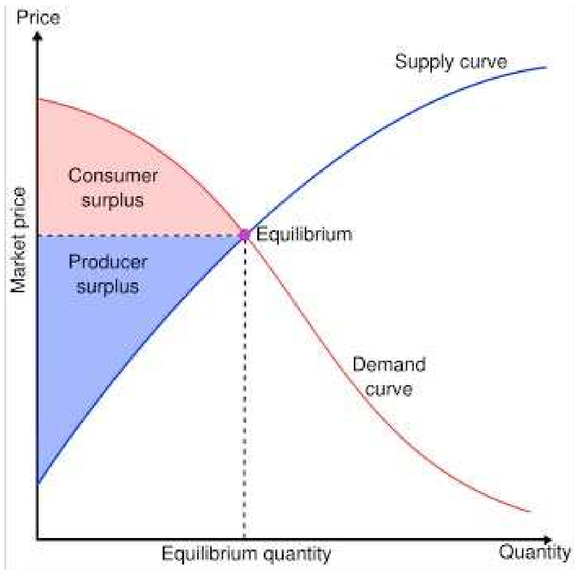
This task will consist of examining the potential shifts in consumer welfare from the feebate program (i.e., Who 'wins' and who 'loses'?), based on the results from the feebate analysis model (Task 4) activity. This task would be led by Walter McManus and Tim Lipman at UC Berkeley's TSRC, with assistance from other team members including David Greene and Dan Kammen.

A key question for any feebate program is the effect that the program will have on vehicle purchasers of different income groups, including potential interactions through the used vehicle market. Discussions among the project team with regard to the type of assessment that will be possible of feebate program social incidence/welfare issue, have concluded that incorporating demographic data into the main feebate program analysis / market equilibrium assessment is vital, so that social welfare shifts can be included. However, the complexity of that analysis limits the number of socio-economic or other demographic strata that can be considered.

In this investigation, the project team proposes to include three to four divisions by household income, and to assess consumer welfare changes that occur through the implementation of the feebate program. The research team will also consider social welfare shift effects within California, including: 1) regional effects on more rural and more urban areas; 2) potential adverse effects on elderly populations; and 3) potential social welfare shifts associated with the implementation of feebate program structures.

As the model output data from Task 4: "Feebate Model" will be highly resolved with regard to vehicle make, model, engine/transmission, etc., and will have an annualized representation in the vehicle stock model, detailed analysis of the consumer welfare shifts between income groups as a result of the potential introduction of a feebate program will be possible. This analysis will also make possible careful assessment of the local and state sales tax and revenue shifts associated with potential feebate program designs, resulting from changes in vehicle sales patterns.

Figure 3: Consumer and Producer Surplus in Microeconomic Theory



The consumer surplus effects of the feebate program within and between income groups can then be assessed by then assessing the inter-group shifts in social welfare when the vehicle purchase data are disaggregated. The team will also include assumptions about whether or not the government derives any government surplus from the feebate program, which would be minimized if the program were designed to be "revenue neutral" but which may be desired to some extent, for example to cover the administrative costs of the program.

There are various methods for aggregating the total social welfare gains and losses associated with this potential economic intervention in the vehicle markets in CA and other states that may adopt California regulations, and the merits of these will assessed early in the project and a more detailed methodology will be developed. Options include a traditional "closed form" representation of consumer welfare, as well as more innovative approaches based on the more detailed understanding that is expected to emerge from this specific market equilibrium modeling exercise. The team also will include the impacts of changes in prices of vehicles in the used car market and/or availability of certain models in the used car market that also would entail gains or losses in consumer welfare by certain groups. This could be particularly important with regard to impacts on lower household income groups, as they purchase new vehicles relatively less frequently and more often on the used vehicle market.

In evaluating the incidence of the feebates program we will distinguish between the effects of changing the marginal "price" of clean vehicles to consumers and the income effects of the feebates themselves. This will tell us how much of the change is due to changing the slope of the feebate curve and how much is due to changing the total spending by the household. This is accomplished with a simulation by "returning" the fee or "taking back" the rebate, but in the form of an income change.

The research team also proposes to engage Catherine Wolfram, PhD, from the UC Berkeley Haas School and UC Energy Institute, to help advise this task activity. The team will involve Dr. Wolfram, who has expressed interest in the project, initially on an informal basis but also will work on a side proposal to generate funding for a more formal collaboration, e.g. to the UC Transportation Center or UC Energy Institute. This would allow for additional aspects of the consumer welfare implications of the feebate program, and potentially other economic impacts of the program, to be investigated somewhat more extensively.

VMT Interaction and Trip-Making Behavior

The assessment of potential shifts in vehicle miles traveled (VMT) and trip-making behavior will examine the potential "rebound effects" that may occur as vehicle consumers were shifting to lower GHG-emission and more fuel-efficient vehicles. This effort would be led by Tim Lipman and Walter McManus, with assistance from Caroline Rodier, Susan Shaheen, and other project team members.

With regard to potential VMT shifts in response to a lower GHG-emission (and higher fuel economy) vehicle stock, a recent study by Small and van Dender (2005; 2007) found that price elasticities for fuel consumption with regard to fuel price have declined over time due to rising incomes, and the progressively smaller contribution of fuel costs to overall purchasing power. In a study of 1966-2004 data, Small and van Dender found a short-term elasticity for changes in fuel consumption relative to fuel prices of -0.074 in the full period from 1966-2004, but only a -0.041 elasticity from the most recent 2000-2004 period. Provided that the trend of increasing wealth continues, this trend might be expected to continue, but with the impact of fluctuating fuel prices (in real terms, relative to real incomes and purchasing power) complicating the story.

Furthermore, shifts to some types of lower GHG emission vehicles, such as electric and natural gas vehicles, may involve shifts to vehicles that have different attributes that could affect how they are used. For example, battery electric or plug-in hybrid vehicles may be attractive choices for some consumers, especially if they can link them with the supplementary use of transit.

This task would assess these two potential implications of the feebate program, by using elasticity values derived from previous studies and examining the effects of VMT increases as a function of decreasing effective fuel prices for consumers, developing ranges of potential VMT rebound effects and potential transit system interactions, and then assessing the impacts of those effects on feebate program effectiveness, public perception/response, and overall AB 32 program goals. The results of the investigation will help to inform the broader assessment of potential program effectiveness, as well as potential side benefits or detriments from the program.

Tax Revenue Impacts and Effects on Auto Dealers

In addition to potential impacts on consumers, this task would consist of assessing the impacts of feebate programs on tax revenues as well as potential impacts on automotive dealers. Based on output from the market equilibrium model, shifts in vehicle sales will be assessed with regard to the number of sales on an annual basis and the values of the vehicle sold. These data will then be used to assess sales tax revenue changes and potential effects on the revenues generated by auto dealers. The auto dealer effects will be assessed for several "generic" auto dealers of different sizes and with different offerings of vehicle models, to get a sense of the types of impacts that can be anticipated. Assessing the impacts on specific auto dealerships (there are approximately 2,000 in California alone) would be outside the scope of the project.

Program Administration Costs and Secondary Effects

This aspect of Task 6 would consist of estimating the administration costs of the feebate program, as implemented in different ways, as well as potential additional secondary effects or "unintended consequences." For example, the administrative costs would be significantly different if the feebate were applied at the manufacturer or dealership level, and this could also affect a key secondary effect – the level of positive or negative public reaction to the program. This effort will be led by Tim Lipman and Walter McManus, with assistance from Rachel Finson, Susan Shaheen, David Greene, and other members of the project team.

In assessing the potential program administration costs, information would be drawn from the Task 1 – "Lessons Learned" activity, as well as additional information specific to a California policy setting. This would include examination of estimates of the potential administrative costs of the proposed *AB 493* legislation, as well as consultations with the California Legislative Analysts Office (LAO). Factors considered will be the structure of the feebate program, options for administering it through different state agencies, costs of public education campaigns to make sure the program is understood by the public, etc.

In addition to the potential VMT rebound effect and transit system interaction assessments discussed above, additional secondary impacts of the feebate program would also be examined and assessed. These include:

- How to predict and potentially calibrate incentive levels to ensure revenue neutrality?
- Fluctuating gas prices and the resulting uncertainty in program effectiveness and impacts;
- Interactions with the used vehicle market and the resulting impacts on society;
- Impacts on different automakers, foreign and domestic, and the resulting economic implications for California and the U.S.; and
- Interaction with other *AB 32* measures:
    - Low carbon fuel standard (LCFS)
    - Cap and trade program
    - SB 375 – land use and planning restrictions
    - Electricity sector interactions with BEV/PHEV
    - Potential double counting issues
    - How to assess feebate program effectiveness relative to other programs
- Manufacturer gaming/vehicle shuffling, emissions leakage

These issues will be investigated with discussions with feebate stakeholder groups and ARB staff, discussions among the project team, and consultation with other knowledgeable individuals. UC Berkeley and UC Davis have several complementary assessments completed or underway around various aspects of *AB 32* program implementation that will help to inform the efforts of this task.

<u>Deliverables</u>:
-- Several report sections that document the findings of each element of the assessment of the policy implications of potential feebate programs

Task 7: Statewide Survey

Based on the focus group results and expert interview (lessons learned), researchers will develop a telephone survey that addresses the following questions (at a minimum):

- Are feebates viewed as a tax or as an opportunity to purchase a more desirable vehicle?
- Do respondents prefer a manufacturer feebate vs. consumer feebate?
- Equity concerns regarding feebate approach;
- Interest in clean fuels/advanced technology vehicles in relation to feebates; and
- Hypothetical responses to different consumer feebate structures based on input from economic analysis.

The objective is to obtain 3,000 residential interviews completed by a telephone survey of 15 minutes in length throughout the state of California (e.g., five key regions including Sacramento, Bay Area, San Diego, Central Valley, and Los Angeles). A random digit dialing sample will be used. The large sample size will enable the results to be disaggregated by location and by demographic groups with a 95%

confidence interval. The sample will be stratified to reflect the population characteristics of the five key regions of the state, allowing the sample to be broadly representative of the state as a whole. An outside organization will administer the survey. Researchers will collaborate on the content and implementation of the survey to ensure that the project objectives are met. Researchers will analyze survey results and report findings.

<u>Deliverables</u>:
-- Report section with synopsis of statewide survey results and interpretation/analysis of results

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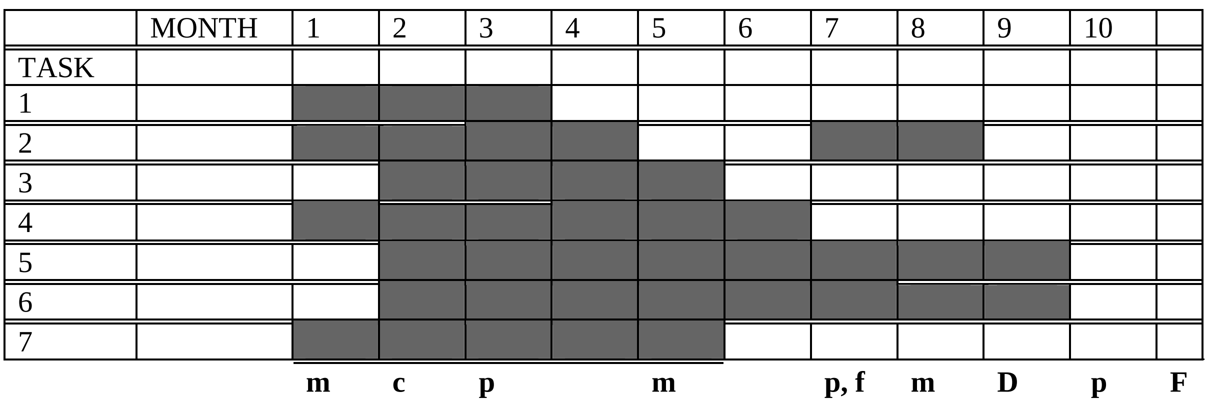
II. Project Schedule

A kick-off meeting at ARB will be held prior to the initiation of the project. The scheduling of Tasks 1-7 is shown in figure N below in terms of months from the start of the contract. The major product of this research project will be a final report describing the research methods and data, and presenting the results of the feebate analyses described above. The computer model developed by this research project and the data used (to the extent that the data are not proprietary) will be documented in detail in an appendix to the final report, and the model and data will be provided to the ARB for use by their staff. A draft final report will be delivered not more than 10 months after the start of the project. The project principal investigators from Davis and Berkeley will present a full reporting on the project at a Chairman's Seminar at the conclusion of the project.

Task 1: Lessons Learned
Task 2: Focus Groups and Interviews
Task 3: Policy Formulation
Task 4: Feebate Analysis Model
Task 5: Policy Analysis
Task 6: Policy Implications
Task 7: Statewide Survey



m = Meeting with ARB staff
c **= Public consultation meeting to discuss policy formulation**
p = Quarterly progress report
f **= Presentation of interim study findings**
D = Deliver draft final report
F = Deliver draft final report and Chairman's Seminar

The project leaders (and senior researchers as needed) will meet with ARB staff to report on the progress of the research on three occasions during the course of the research, at specific times and places to be jointly agreed. Progress reports will be submitted in the third, seventh, and tenth month of the project. A public consultation will be held in the second month of the project to present a preliminary plan and options for structuring the policy analysis and to obtain input. Interim study findings will be presented at the end of the seventh month in an appropriate venue to be determined by the ARB staff. The draft final report will be submitted for formal review. A final project briefing will also be made no later than 10 months after the start of the project as a Chairman's Seminar.

III. Project management plan

The UC Research Team has extensive experience in analyzing policies for transportation greenhouse gas mitigation at state, national and international levels, and in conducting surveys of consumer attitudes and perceptions. Personnel are professors, researchers and graduate students in the UC system with the exception of K.G. Duleep, an internationally renowned expert on automotive technology, cost and energy efficiency potential. Members of the research team have constructed feebate analysis models similar to the one that will be built for this study, have carried out numerous consumer research efforts, and have published extensively on these subjects in the peer-reviewed literature. The team possesses strong expertise in modeling and policy analysis of motor vehicle and environmental policy issues in California and the United States.

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Curricula Vitae

DAVID L. GREENE

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EDUCATION

THE JOHNS HOPKINS UNIVERSITY

Ph.D., Geography and Environmental Engineering, 1973–78

UNIVERSITY OF OREGON

M.A., 1972–73

COLUMBIA UNIVERSITY

B.A., 1967–71

EMPLOYMENT

OAK RIDGE NATIONAL LABORATORY (ORNL) 1977–PRESENT

1999–Present *Corporate Fellow, Oak Ridge National Laboratory*
1989–1999 *Senior Research Staff Member II and Manager of Energy Policy Research*

Programs, Center for Transportation Analysis
1988–1989 *Senior Research Analyst, Office of Policy Integration, U.S. Department of Energy (On assignment from ORNL)*
1987–1988 *Head, Transportation Research Section*
1984–1987 *Senior Research Staff Member I*
1982–1984 *Research Staff Member*
1980–1982 *Leader, Transportation Energy Group*
1977–1980 *Research Associate*

AWARDS AND HONORS

2008 Science Communicator Award, UT-Battelle
2007 Department of Energy Hydrogen Program R&D Award (with P.N. Leiby)
Society of Automotive Engineers, Barry D. McNutt Award for Excellence in Automotive Policy Analysis, 2007
Member Emeritus, Transportation Research Board Committee on Alternative Fuels, 2006
Barry D. McNutt Award for best paper of 2004, Energy Committee, Transportation Research Board Lifetime National Associate of the National Academies, 2002
UT-Battelle Award for Excellence in Science and Technology, 2001
Oak Ridge National Laboratory Significant Event Award, 2001
Designated Corporate Fellow of Oak Ridge National Laboratory, 1999
Outstanding Paper of 1999, *The Energy Journal*, International Association for Energy Economics

Lockheed-Martin Significant Event Award, 1999
Member Emeritus, Transportation Research Board Committee on Transportation Energy, 1998
Lockheed-Martin Significant Event Award, 1996
Distinguished Service Certificate, Transportation Research Board, 1993
ORNL Special Achievement Award, 1991
Distinguished Service Certificate, Transportation Research Board, 1989
Energy Specialty Group Paper Award, Association of American Geographers, 1986
ORNL Special Recognition Award, Oak Ridge National Laboratory, 1986
Technical Achievement Award, Martin Marietta Energy Systems, 1985
Pyke Johnson Award, Transportation Research Board, 1984

PROFESSIONAL ACTIVITIES

- Editorial Advisory Board, *Transportation Research Part D*, 1996–2006
- Editorial Board Member, *Energy Policy*, 2001–present
- Editorial Board Member, *Journal of Transportation and Statistics*, 2001–2006
- Editorial Board Member, *Transportation Quarterly*, 1999–2005
- Editor-in-Chief, *Journal of Transportation and Statistics*, 1997–2000
- Editorial Board Member, Macmillan Encyclopedia of Energy, 1998–2001
- Editorial Advisory Board, *Transportation Research A*, 1986–1997
- National Research Council
    - Transportation Research Board Standing Committees:
        - Committee on Transportation and Sustainability, Member, 2006–present
        - Committee on Energy, A1F01, Chairman 1983–1986, 1986–1990; Member, 1993–1998; Member Emeritus, 1999–present
        - Subcommittee on Forecasting Transportation Energy Demand, A1F01(2), Chairman, 1982–1983
        - Section F, Energy and Environmental Concerns, Chairman, 1990–1992
        - Committee on Alternative Fuels, A1F05, Member, 1993–present, Member Emeritus, 2006–present
        - Task Force on Freight Transportation Data, A1B51, Secretary, 1989–1996
        - Committee on Transportation Information Systems and Data Requirements, Member, 1983–1986, 1986–1989
    - Ad Hoc Committees:
        - Special Task Force on Energy and Climate Change, 2008–2011
        - Committee on Fuel Economy of Light-Duty Vehicles, 2007–2008
        - Planning Group for Workshop on Issues Related to Peaking of Global Oil Production, 2005
        - Committee on State Practices in Setting Mobile Source Emissions Standards, 2004–2006
        - Chair, Committee for the Symposium on Introducing Sustainability into Surface Transportation Planning, 2003–2004
        - Panel on Combating Global Warming through Sustainable Surface Transportation Policy,
          TCRP Project Panel H-21A, 2002–2005
        - Committee on Effectiveness and Impacts of Corporate Average Fuel Economy (CAFE) Standards, 2001
        - Committee for the Study of the Impacts of Highway Capacity Improvements on Air Quality and Energy Consumption, 1993–1994
        - Committee on Fuel Economy of Automobiles and Light Trucks, Energy Engineering Board, Commission on Engineering and Technical Systems, 1991–1992

Committee for the Study of High-Speed Surface Transportation in the United States, 1990
Planning Group on Strategic Issues in Domestic Freight Transportation, 1990
Steering Committee for Conference on Transportation, Urban Form, and the Environment, 1990
National Cooperative Highway Research Program, Panel on "Evaluating Alternative Methods of Highway Finance," 1991–1992

- Intergovernmental Panel on Climate Change
  Lead Author, Working Group III, Fourth Assessment Report, 2007
  Lead Author, Working Group III, Third Assessment, 2001
  Lead Author, Working Group III, Aviation and the Global Atmosphere, 1999
  Principal Lead Author, Working Group II, Second Assessment Report, 1995
- Association of American Geographers
  Board of Directors, Transportation Specialty Group, 1989–1991
  Secretary-Treasurer, Transportation Geography Specialty Group, 1980–1982
  Editor, *Transportation Geography Newsletter*, 1980–1982
- Society of Automotive Engineers, member, 1985–present
- International Association for Energy Economics, member
- Consulting
  International Transport Forum, 2007
  Addx Corporation, 2007
  United Nations Framework Convention on Climate Change, 2007
  Securing America's Future Energy, 2007
  Center for Clean Air Policy, 2007
  Pollution Probe Canada, 2006-2007
  The Energy Foundation China Project, 2005—present
  The Pew Center on Global Climate Change, 2004—present
  Eno Transportation Foundation, 1991–1996
  Transportation Research Board, 1996–1997

BOOKS

and D.W. Jones and Mark Delucchi, eds., *The Full Costs and Benefits of Transportation*, Springer-Verlag, Heidelberg, 1997.

Transportation and Energy, Eno Foundation for Transportation, Lansdowne, Virginia, 1996.

and D. J. Santini, eds., *Transportation and Global Climate Change*, American Council for an Energy Efficient Economy, Washington, DC, 1993.

ARTICLES IN PROFESSIONAL JOURNALS

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J.J. Erickson, D.L. Greene and A.J. Sabadell, "An Analysis of Transportation Energy Conservation Projects in Developing Countries," *Transportation*, vol. 15, no. 3, pp. 163–189, 1988.

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“A Note on Implicit Consumer Discounting of Automobile Fuel Economy: Reviewing the Available Evidence,” *Transportation Research*, vol. 17B, no. 6, pp. 491–499, 1983.

and C.K. Chen, “A Time Series Analysis of State Gasoline Demand, 1975–1980,” *The Professional Geographer*, vol. 35, no. 1, pp 40–51, February 1983.

G.F. Roberts and D.L. Greene, “A Method for Assessing the Market Potential of New Energy-Saving Technologies,” *Transactions on Systems, Man, and Cybernetics*, Institute of Electrical and Electronics Engineers, vol. SMC-13, no. 1, pp. 3–7, January/February 1983.

Eric Hirst et al., “Effects of Improved Energy Efficiency on U.S. Energy Use: 1973–1980,” *Energy*, vol. 7, no. 11, pp. 897–907, 1982.

and G. Kulp, “An Analysis of the 1979–1980 Decline in gasoline Consumption in the United States,” *Energy*, vol. 7, no. 4, pp. 367–375, 1982.

and G. Walton, “Data and Methodological Problems in Establishing State Gasoline Conservation Targets,” *Transportation Research Record*, no. 815, pp. 24–30, 1981.

and E. Chen, “Scrappage and Survival Rates of Passenger Cars and Trucks in the U.S., 1966–77,” *Transportation Research*, vol. 15A, no. 5, pp. 383–389, 1981.

“City Size Distribution and Income Distribution in Space: A Comment,” *Regional Development Dialogue*, vol. II, no. 1, pp. 124–126, Spring 1981.

“A State Level Stock System Model of Gasoline Demand,” *Transportation Research Record*, no. 801, pp. 44–50, 1981.

“Estimated Speed/Fuel Consumption Relationships for a Large Sample of Cars,” *Energy*, vol. 6, pp. 441–446, 1981.

“The Spatial Dimension of Gasoline Demand,” *Geographical Survey*, vol. 9, no. 2, pp. 19–28, April 1980.

“Regional Demand for Gasoline: Comment,” *Journal of Regional Science*, vol. 20, no. 1, pp. 103–109, 1980.

“Urban Subcenters: Recent Trends in Urban Spatial Structure,” *Growth and Change*, vol. 11, no. 1, pp. 103–109, January 1980.

R. Dubin, D.L. Greene and C. Begovich, “Multivariate Classification of Automobiles Using an Automobile’s Characteristics’ Data Base,” *Transportation Research Record*, no. 726, pp. 29–27, 1979.

“State Differences in the Demand for Gasoline: An Econometric Analysis,” *Energy Systems and Policy*, vol. 3, no. 2, pp. 191–212, 1978.

and Joern Barnbrock, “A Note on Problems in Estimating Urban Density Models,” *Journal of Urban Economics*, vol. 5, April 1978.

and Rolf R. Schmitt, “An Alternative Derivation of the Intervening Opportunities Model,” *Geographical Analysis*, vol. 10, no. 1, January 1978.

Joern Barnbrock and D.L. Greene, “A Comment on Population Density and Trend Surface Analysis,” *Land Economics*, vol. 53, no. 2, May 1977.

CONTRIBUTIONS TO NATIONAL RESEARCH COUNCIL REPORTS

J. Zucchetto, *Trends in Oil Supply and Demand, Potential for Peaking of Conventional Oil Production, and Possible Mitigation Options*, a summary report of the Modeling the Oil Transition workshop, Member, Planning Group and Keynote Speaker, Washington, DC, April 2006.

“State and Federal Standards for Mobile Source Emissions,” Report of the Committee on State Practices in Setting Mobile Source Emissions Standards, National Research Council, National Academies Press, Washington, DC, March 2006.

“Integrating Sustainability into the Transportation Planning Process,” *Conference Proceedings 37*, Transportation Research Board of the National Academies, Washington, DC, 2005.

"Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," Report of the Committee, National Research Council, National Academy Press, Washington, 2002.

"Ecological, Environmental and Energy-Related Issues, in *The Future Highway Transportation System and Society*, Transportation Research Board, National Research Council, National Academy Press, Washington, DC, 1997.

Expanding Metropolitan Highways: Implications for Air Quality and Energy Use, Special Report 245, Transportation Research Board, National Research Council, Washington, DC, July 1995.

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CONGRESSIONAL TESTIMONY

"Is Cap-and-Trade a Sufficient Carbon Policy for Transportation?" Testimony to the U.S. Senate Committee on Environment and Public Works, November 13, 2007, Washington, DC.

"Energy Challenges for Transportation in the 21st Century," Testimony to the National Surface Transportation Policy and Revenue Study Commission, March 19, 2007, Washington, DC.

"Corporate Average Fuel Economy (CAFE) Standards," Testimony to the U.S. Senate Commerce Committee, March 6, 2007, Washington, DC.

"Policies to Increase Passenger Car and Light Truck Fuel Economy," Testimony to the U.S. Senate Committee on Energy and Natural Resources, January 30, 2007, Washington, DC .

"Observations on the H-Prize Act of 2006 (H.R. 5143)," Testimony to the U.S. House of Representatives Committee on Science, April 27, 2006, Washington, DC.

"Improving the Nation's Energy Security: Can Cars and Trucks be Made More Fuel Efficient?" Testimony to the U.S. House of Representatives Committee on Science, February 9, 2005, Serial No. 109-3, U.S.G.P.O, Washington, DC.

"The Outlook for Surface Transportation Growth," Testimony to the Subcommittee on Surface Transportation of the Committee on Transportation Infrastructure of the United States House of Representatives, March 28, 1996.

CONTRIBUTIONS TO BOOKS

Ribeiro, S.K., S. Kobayashi, D.L. Greene et al., "Transport and its Infrastructure," Chapter 5 in

Climate Change 2007: Mitigation of Climate Change, Working Group III contribution to the Fourth

Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge Press, Cambridge, United Kingdom.

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FORTHCOMING PUBLICATIONS

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and J. German and M. A. Delucchi, "Fuel Economy: The Case for Market Failure," forthcoming, *Proceedings of the Asilomar Conference on Sustainable Transportation*, University of California, Davis.

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"Measuring Energy Security: Can the United States Achieve Oil Independence?", forthcoming, *Energy Policy*.

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Short Biography – October 2008

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David Bunch is Professor of Management, Graduate School of Management at UC Davis. Professor Bunch is known for his work in identification and estimation of discrete choice models, stated choice experiments, and combining stated and revealed preference data for modeling and forecasting consumer market behavior. Application areas for his research and teaching include marketing research, e-commerce and Internet marketing, product management, and transportation systems (through his affiliation with the UC Davis Institute of Transportation Studies since its inception). Professor Bunch was a principle in conceiving and directing a large multi-year program to develop comprehensive forecasting models and systems for vehicle purchase and usage behavior in California, designed to include future alternative-fuel vehicles (e.g., electric cars). More recently, Professor Bunch developed the CARBITS model for use by the California Air Resources Board in its work to establish regulations on greenhouse gas emissions in California.

Education Ph. D., Rice University, 1985 (Mathematical Sciences); Master in Applied Mathematical Sciences, Rice University, 1981; M. S., Northwestern University, 1979 (Chemistry); B. A. (cum laude), Rice University, 1978 (Chemistry)

Selected Publications

"Behavioral Frontiers in Choice Modeling," (with W. Adamowicz, T. A. Cameron, B. G. B. C. Dellaert, M. Hanneman, M. Keane, J. Louviere, R. Meyer, T. Steenburgh and J. Swait), Marketing Letters, In Press (2008).

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"Hybrid Choice Models: Progress and Challenges," (with Moshe Ben-Akiva, Daniel McFadden, Kenneth Train, Joan Walker, Chandra Bhat, Michel Bierlaire, Denis Bolduc, Axel Borsch-Supan, David Brownstone, Andrew Daly, Andre de Palma, Dinesh Gopinath, Anders Karlstrom, Marcela A. Munizaga), Marketing Letters, 13(3): pp. 163-175 (August 2002).

"Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-fuel Vehicles" (with David Brownstone and Kenneth Train). Transportation Research B, Volume 34, Issue 5 (June 2000), pp. 315-449.

"Combining Sources of Preference Data for Modeling Complex Decision Processes" (with Jordan J. Louviere, Robert J. Meyer, Richard Carson, Benedict Delleart, W. Michael Hanemann, David Hensher, and Julie Irwin). Marketing Letters, Volume 10, Issue 3 (August 1999), pp. 205-217.

"Determinants of Alternative Fuel Vehicle Choice in the Continental United States" (with Melanie Tompkins, Danilo Santini, Mark Bradley, Anant Vyas, and David Poyer), Transportation Research Record, Number 1641, Energy and Environment: Energy Air Quality, and Fuels 1998, Transportation Research Board, National Research Council.

"Commercial Fleet Demand for Alternative-fuel Vehicles," (with Thomas F. Golob, Jane Torous, David Brownstone, Soheila Crane, and Mark Bradley), Transportation Research A Vol. 31A (1997): 219-233.

"A Vehicle Usage Forecasting Model Based on Revealed and Stated Vehicle Type Choice and Utilization Data," (with Thomas F. Golob and David Brownstone), Journal of Transport Economics and Policy Vol. 31 (1997): 69-92.

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"Predicting the Market Penetration of Electric and Clean-fuel Vehicles" (with Thomas F. Golob, Ryuichi Kitamura, and Mark Bradley), The Science of the Total Environment, 134 (1993) pp. 371-381.

"Estimability in the Multinomial Probit Model," Transportation Research B, 1991, Vol 25B(1), pp. 1-12.

"Heterogeneity and State Dependence in Household Car Ownership: A Panel Analysis Using Ordered-Response Probit Models with Error Components," 11th International Symposium on Transportation and Traffic Theory, Elsevier, July 1990 (with Ryuichi Kitamura).

Curriculum Vitae

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RESEARCH INTERESTS:

Applied mathematics and computation focusing on transportation and energy systems modeling and optimization: large-scale network optimization and real-time adaptive network routing, stochastic transportation and energy infrastructure system optimization, and risk management of transportation networks subject to seismic or other natural hazards.

EDUCATION:

May 2003 Doctor of Philosophy in Civil and Environmental Engineering, University of Southern California.

EMPLOYMENT:

July 2003 - present Assistant Professor, Department of Civil and Environmental Engineering, University of California, Davis

JOURNAL PUBLICATIONS:

[Dynamic Programming Applied to Linear, Quadratic, and Optimal Control Problems]

1. Y. Fan and R. Kalaba, Dynamic Programming and Pseudo-inverses, *Applied Mathematics and Computation*, Volume 139, Pages 323-342, 2003.
2. Y. Fan and R. Kalaba, A General Linear Quadratic Problem, *Journal of Optimization Theory and Applications*, Volume 127, Page 485-496, 2005.
3. Y. Fan, H. Bhargava, H. Natsuyama, Dynamic Pricing via Dynamic Programming, *Journal of Optimization Theory and Applications*, Volume 127, Page 565-577, 2005.

[Adaptive Network Routing]

4. Y. Fan, R. Kalaba, and J. Moore, Optimal Routing through Networks with Correlated Link Travel Times, *Computers and Mathematics with Applications*, Volume 49, Pages 1549-1564, 2005.
5. Y. Fan, R. Kalaba, and J. Moore, Arriving on Time, *Journal of Optimization Theory and Applications*, Volume 127, Page 497-513, 2005.
6. Y. Nie, and Y. Fan, The Arriving-On-Time Problem: A Discrete Algorithm that Ensures Convergence, *Transportation Research Record*, No. 1964, pp. 193-200, 2006.
7. Y. Fan and Y. Nie, Optimal Routing for Maximizing the Travel Time Reliability, *Journal of Networks and Spatial Economics*, Vol. 6, pp. 333-344, 2006.

[Transportation and Energy Infrastructure System Planning]

8. A. Kiremidjian, J. Moore, Y. Fan, O. Yazlali, N. Basoz, M. Williams, Seismic Risk Assessment of Transportation Network Systems, *Journal of Earthquake Engineering*, Volume 11, Issue 3, pages 371 – 382, 2007.

9. Y.X. Huang, Y. Fan, and R.L. Cheu, Optimal Allocation of Multiple Emergency Service Resources for Critical Transportation Infrastructure Protection, *Transportation Research Record*, No. 2022, pp1-8, 2007.

10. R.P. Naga and Y. Fan, Quick Estimation of Network Performance Measures Using Associative Memory Techniques, to appear in *Transportation Research Record* (Network Modeling Committee).

11. C.Z. Liu, Y. Fan, and F. Ordonez, A two-stage stochastic programming model for transportation network protection, to appear in *Computers and Operations Research*.

12. Y. Fan and C.Z. Liu, Solving Stochastic Transportation Network Protection Problem using the Progressive Hedging-Based Method, to appear in *Networks and Spatial Economics*.

13. Z. Lin, J. Ogden, Y. Fan, C.W. Chen, The Fuel-Travel-Back Approach to Hydrogen Station Siting, to appear in *Journal of Hydrogen Energy*.

14. Z. Lin, C.W. Chen, J. Ogden, Y. Fan, The Least-cost Hydrogen for Southern California, to appear in *Journal of Hydrogen Energy*.

15. N. Parker, J. Ogden, Y. Fan, The role of biomass in California's hydrogen economy, to appear in *Journal of Energy Policy*.

[Dynamic Mechanical Systems]

16. Y. Fan, R. Kalaba, H. Natsuyama, and F. Udwadia, Reflections on the Gauss's Principle of Least Constraint, *Journal of Optimization Theory and Applications*, Vol. 127, pp. 475-484, 2005.

17. F. Udwadia, R. Kalaba, and Y. Fan, Is Analytical Dynamics a Theoretical or An Experimental Science? *Journal of Nonlinear Analysis,* Vol. 63, pp. 692-698, 2005.

SELECTED CONFERENCE PRESENTATIONS AND SEMINARS

"Adaptive network routing for maximum reliability of on-time-arrival", UC Berkeley ITS Seminar, Berkeley, CA, 2004.

"Finding the best routing strategies for on-time arrival in stochastic networks", 2nd International Symposium on Transportation Network Reliability, Christchurch, New Zealand, 2004.

"Solving the constrained motion problem using the GI method", the 10th International Symposium on Artificial Life and Robotics, Oita, Japan, 2005.

"Revisiting arriving on time problem", INFORMS Annual Meeting, San Francisco, CA, 2005.

"Optimal allocation of emergency service resources for critical transportation Infrastructure protection", Transportation Research Broad Annual Meeting, Washington D.C., 2006.

"Stochastic network retrofit with recourse", INFORMS Annual Meeting, Pittsburgh, PA, 2006.

"Optimal network routing under emergency", Workshop on Network Analysis Applications to Homeland Security, Naval Postgraduate School, Monterey, CA, 2006.

"A two-stage stochastic programming model for transportation network protection", UC Berkeley ITS Seminar, Berkeley, CA, 2007.

"Reinforcement learning in post-disaster management and response", INFORMS Annual Meeting, Seattle, WA, 2007.

"Converting HOV to HOT: Efficiency, Profit, and Equity", INFORMS Annual Meeting, Seattle, WA, 2007.

"From Waste to Hydrogen: An Optimal Design of Energy Production and Distribution Network", National Urban Freight Conference, Long Beach, CA, 2007.

“Highway network retrofit under seismic hazard”, 10th International Conference on Application of Advanced Technologies in Transportation, Athens, Greece, 2008.

RESEARCH GRANTS

Transportation Network Design under Earthquake Hazards, supported by Pacific Earthquake Engineering Research Center, $214,800, 2004-2007 (single PI).

An Integrated Multi-pathway Biofuel System Design under Uncertainties, supported by Chevron Technology Ventures, LLC, $299,082, 2007-2009, (PI: Yueyue Fan; Co-PI: Joan Ogden).

Optimal Design for A Self-sustainable HOT Network, supported by Sustainable Transportation Center at UC Davis, $ 59912.33, 2007-2008 (single PI).

National Biorefinery Siting Model, supported by Department of Energy Office of Biomass Program, $145,000, 2008-2009 (PI: Bryan Jenkins; Co-PI: Yueyue Fan and Joan Ogden).

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CURRENT APPOINTMENTS:

2006-present, Associate Professor of Economics, University of California, Davis

2008-present, Chancellor's Fellow, University of California, Davis

2007-present, Research Associate, National Bureau of Economic Research. Groups: Environmental Economics and Energy, Industrial Organization, and Productivity

2003-present, Visiting Research Fellow, University of California Energy Institute

2005-present, Faculty Affiliate, Institute of Transportation Studies, UC Davis

2006-present, Strategy and Policy Thread Leader for STEPS

2006-present, Associate Editor, *The Journal of Industrial Economics*

2007-present, Associate Editor, *American Economic Journal – Economic Policy*

2007-present, Associate Editor, *The Journal of Energy Markets*

PREVIOUS APPOINTMENTS:

2002-2006, Assistant Professor of Economics, University of California, Davis

2004-2007, Faculty Research Fellow, National Bureau of Economic Research. Groups: Environmental Economics and Energy, Industrial Organization, and Productivity

1999-2002, Assistant Professor of Finance and Economics, School of Management, Boston University

1996-1999, Research Assistant, University of California Energy Institute

1994-1996, Teaching Assistant, University of California, Davis

EDUCATION:

Ph.D., University of California, Berkeley, 1999 (Economics)

M.A., University of California, Davis, 1996 (Economics)

B.A., California State University, Stanislaus, *summa cum laude*, 1994 (Economics and Political Science)

PUBLICATIONS:

- Holland, Stephen P., Jonathan E. Hughes and Christopher R. Knittel. "Greenhouse Gas Reductions under Low Carbon Fuel Standards?," forthcoming in ***The American Economic Journal – Economic Policy***.
- Knittel, Christopher R. and Victor Stango. "How Does Incompatibility Affect Prices?: Evidence from ATMs," forthcoming in ***The Journal of Industrial Economics***.
- Borenstein, Severin, James Bushnell, Christopher R. Knittel and Catherine Wolfram. "Trading Inefficiencies in California's Electricity Markets," ***The Journal of Industrial Economics***, LVI(2), June 2008, pp. 347-378.
- Feenstra, Robert and Christopher R. Knittel. "Re-Assessing the Quality Adjustment to Computer Prices: Do U.S. Procedures Overstate the Gains?," forthcoming ***Price Index Concepts and Measurement***, NBER and the Chicago Press.
- Knittel, Christopher R. and Konstantinos Metaxoglou. "Diagnosing Unilateral Market Power in Electricity Reserves Market," ***The Journal of Energy Markets***, 1(1), Spring 2008.
- Knittel, Christopher R. and Victor Stango. "Incompatibility, Product Attributes and Consumer Welfare: Evidence from ATMs," ***The BE Journal of Economic Analysis & Policy, Advances***, 8(1), January 2008. Available at: http://www.bepress.com/bejeap/vol8/iss1/art1.
- Hughes, Jonathan E., Christopher R. Knittel and Daniel Sperling. "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline." ***The Energy Journal***, 29(1), January 2008.
- Heisler, Jeffrey, Christopher R. Knittel, John J. Neumann and Scott Stewart. "Why Do Institutional Plan Sponsors Hire and Fire their Investment Managers?" Best Paper Award for the 31st NBEA Conference. ***The Journal of Business and Economics Studies***, 13(1), Spring 2007, pp. 88-116.
- Kim, Dae-Wook and Christopher R. Knittel "Biases in Static Oligopoly Models? Evidence from the California Electricity Market," ***The Journal of Industrial Economics***, LIV(4), December 2006, pp. 451-470.
- Knittel, Christopher R. "The Adoption of State Electricity Regulation: The Role of Interest Groups," ***The Journal of Industrial Economics***, LIV(2), June 2006.
- Knittel, Christopher R. and Michael R. Roberts. "Financial Models of Deregulated Electricity Prices: An Application to the California Market," ***Energy Economics***, 27(5), September 2005, pp. 791-817.
- Knittel, Christopher R. "Regulatory Restructuring and Incumbent Price Dynamics: The Case of Local Telephone Markets," ***Review of Economics and Statistics,*** 86(2), May 2004, pp. 614-625.
- Knittel, Christopher R. and Victor Stango. "Price Ceilings as Focal Points for Tacit Collusion: Evidence from the Credit Card Market," ***The American Economic Review***, 93(5), December 2003, pp. 1703-1729.
- Knittel, Christopher R. "Market Structure and the Pricing of Electricity and Natural Gas," ***The Journal of Industrial Economics***, LI(2), June 2003, pp. 167-191.
- Knittel, Christopher R. "Alternative Regulatory Methods and Firm Efficiency: Stochastic Frontier Evidence the US Electricity Industry," ***Review of Economics and Statistics***, 84(3), August 2002, pp. 530-540.

- Borenstein, Severin, James Bushnell, and Christopher R. Knittel. "Market Power in Electricity Markets: Beyond Concentration Measures," ***The Energy Journal***, 20(4), October 1999, pp. 65-88.
- Knittel, Christopher R. "Long Distance Rates: Search Costs, Switching Costs, and Market Power," ***Review of Industrial Organization***, 12(4), August 1997, pp. 519-536.

WORKING PAPERS:

- Knittel, Christopher R. and Jason J. Lepore. "Tacit Collusion in the Presence of Cyclical Demand and Endogenous Capacity Levels." Revised and resubmitted to ***The International Journal of Industrial Organization***.
- Knittel, Christopher R. and Victor Stango. "Strategic Incompatibility in ATMs." Revisions requested from ***The International Journal of Industrial Organization***.
- Knittel, Christopher R. and Konstantinos Metaxoglou. "Estimation of Random Coefficient Demand Models: Challenges, Difficulties and Warnings"
- Fowlie, Meredith, Christopher R. Knittel and Catherine Wolfram. "Sacred Cars: Optimal Regulation of Stationary and Non-stationary Pollution Sources."
- Knittel, Christopher R. and Victor Stango. "The Productivity Benefits of IT Outsourcing"
- Heisler, Jeffrey, Christopher R. Knittel, John J. Neumann and Scott Stewart. "An Analysis of Re-Allocation Decision by Institutional Plan Sponsors" mimeo, UC Davis. Distinguished Paper for the 2006 Academy of Finance.

WORK IN PROGRESS:

- Consumer Expectations, Gasoline Prices and Vehicle Choice (with Meghan Busse and Florian Zettelmeyer)
- IT Outsourcing, Mergers and Industry Exit (with Victor Stango)
- Pharmaceuticals, Patents and Health Outcomes (with Peter Huckfeldt)
- Traffic and Infant Health (with Douglas Miller and Nick Sanders)
- Price Ceilings in Electricity Markets (with Victor Stango)
- Industry Dynamics in ATM Network Markets (with Victor Stango)
- Electricity Regulatory Restructuring: Efficiency Gains and Executive Pay (with Dae-Wook Kim)
- Durables and Changes in Software: Implications for Price Indexes and Software Firm Incentives (with Robert Feenstra)

AWARDS, HONORS, AND GRANTS:

- Barry D. McNutt Award for Excellence in Automotive Policy Analysis (with Jonathan Hughes and Dan Sperling), 2008
- National Science Foundation Grant (with Victor Stango), 2008-2010, $240,000
- Chevron Bio-Fuel Research Grant, 2007-2008, $127,000
- Chevron Bio-Fuel Research Grant, 2007-2008, $77,000
- Chevron Bio-Fuel Research Grant (Co-PI), 2007-2009, $370,000
- Woods Institute for the Environment Leadership Scholar Training, 2007
- Distinguished Paper, 2006 Academy of Finance
- University of California Energy Institute Research Grant, 2005-2006, $50,000

- Best Paper Award for the 31st NBEA Conference
- ASUCD Excellence in Teaching Award, 2004
- University of California Energy Institute Research Grant, 2003
- Faculty Research Grant, UC Davis, 2002, 2003, 20004, 2005, 2006
- Institute of Governmental Affairs Junior Faculty Grant, 2002, 2003, 2004, 2005
- Junior Faculty Research Grant, Boston University, 2001
- Graduate Fellowship, University of California, Berkeley, 1997–1999
- Graduate Fellowship, University of California, Davis, 1994–1996
- Institute of Transportation Fellow, University of California, Davis, 1995–1996
- Student Commencement Speaker, California State University, Stanislaus, 1994

REFEREE SERVICES:

Agricultural Economics, American Economic Review, Bulletin of Economic Research, Census Bureau, *Econometrica, Economic Inquiry, The Economic Journal, Economics Letters, Energy Economics, The Energy Journal, Energy Studies Review, European Economic Review, International Journal of Industrial Organization, International Journal of Power and Energy Systems, Journal of Banking and Finance, The Journal of Business, Journal of Business and Economic Statistics, Journal of Economic Behavior and Organization, Journal of Economic Education, Journal of Economics and Management Strategy, Journal of Futures Markets, Journal of Industrial Economics, Journal Institutional and Theoretical Economics, Journal of Law and Economics, Politics and Economics, Quarterly Journal of Economics, Rand Journal of Economics, Resource and Energy Economics, Review of Economic Studies, Review of Economics and Statistics, Review of Industrial Organization, Review of Network Economics, Southern Economic Journal, Socio-Economic Planning Sciences, Utilities Policy,* University of California Energy Institute Grant Program, NSF Grant Program

INVITED PRESENTATIONS:

"Climate Change and Economics"

- University Retirement Community, February 2008

"Carbon Taxes versus Cap and Trade"

- New American Foundation, February 2008
- Tainjin Chinese Delegation at UC Davis

"Carbon Policies for Transport"

- UCEI Policy Conference, December 2007

"Greenhouse Gas Reductions under Low Carbon Fuel Standards?"

- University of California Energy Institute, July 2007

"Sacred Cars: Optimal Regulation of Stationary and Non-stationary Pollution Sources."

- University of California at Davis, Institute of Transportation Studies, October 2007
- NBER Environmental Economics and Energy Summer Institute, July 2007
- 9th Occasional Workshop on Environmental and Resource Economics, Santa Barbara, November 2006

"Estimation of Random Coefficient Demand Models: Challenges, Difficulties and Warnings""

- University of California at Berkeley, Department of Economics, November 2007
- University of Alberta and Calgary University Industrial Organization Conference, October 2007

"Strategic Incompatibility in ATM Markets"

- Federal Trade Commission, November 2006
- University of California at Los Angeles, Department of Economics, October 2006

"Evidence of a Shift in the Short-Run Price Elasticity of Gasoline."

- CSEM Gasoline Conference, December 2006
- 9th Occasional Workshop on Environmental and Resource Economics, Santa Barbara, November 2006
- University of California Energy Institute, October 2006

"Incompatibility and Consumer Demand: Evidence from ATMs"

- Washington University, Olin School of Business, November 2007
- The Net Institute Conference, New York University, April 2005.
- University of California at Santa Cruz, Department of Economics, December 2004
- University of California at San Diego, Department of Economics, November 2004
- Penn State, Department of Economics, October 2004.
- NBER Summer Institute, Productivity/IO Meetings, July 2004.
- University of California, Berkeley, Haas School of Management, January 2004.
- American Economic Association Meetings, January 2004.

"Compatibility and Pricing with Indirect Network Effects: Evidence from ATMs,"

- NBER Summer Institute, Productivity/CRIW Meetings, July 2004.

"Re-Assessing the Quality Adjustment to Computer Prices: Do U.S. Procedures Overstate the Gains?"

- NBER/CRIW Conference, Vancouver, June 2004

"Biases in Static Oligopoly Models?"

- University of California Energy Institute, November 2003.

"Price Ceilings as Focal Points for Tacit Collusion: Evidence from the Credit Card Market"

- Boston University, Department of Finance and Economics, April 2002.
- University of California, Irvine, Department of Economics, January 2002.
- University of California, Davis, Department of Economics, January 2002.
- University Arizona, Department of Economics, January 2002.
- Northwestern University, Kellogg School of Management, November 2001.
- University of Maryland, Department of Economics, November 2001.
- NBER Summer Institute, Industrial Organization Meetings, August 2001.

"Trading Inefficiencies in California's Electricity Markets"

- NBER Summer Institute, Industrial Organization Meetings, July 2003.
- University of California, Davis, Department of Economics, October 2002.
- Boston University, Finance Seminar Series, November 2000.
- Harvard University, Industrial Organization Seminar Series, November 2000.
- POWER 5th Annual Electricity Conference, UC Berkeley, March 2000.

"Regulatory Restructuring and Incumbent Price Dynamics: The Case of Local Telephone Restructuring"

- NBER Summer Institute, Industrial Organization Meetings, August 2000.
- NBER Productivity Lunch, October 1999.
- INSEAD, Economics Seminar Series, May 1999.
- Boston University, Finance and Economics Seminar Series, May 1999.
- University of Western Ontario, Microeconomics Seminar Series, May 1999.
- University of California, Berkeley, Industrial Organization Seminar Series, August 1999.
- Georgetown University, Strategy Seminar Series, April 1999.
- University of California, Davis, Applied Microeconomics Seminar Series, April 1999.
- SMU, Applied Microeconomics Seminar Series, April 1999.
- Federal Reserve Board of Governors, Economics Seminar Series, April 1999.

"Does Incentive Regulation Provide the Correct Incentives?: Stochastic Frontier Evidence the US Electricity Industry"

- University of California, Berkeley, October 1998, Econometrics Seminar Series.
- INFORMS – Seattle, September 1999, Summer Conference.

"The Origins of State Electricity Regulation: Revisiting an Unsettled Topic"

- University of California Energy Institute, December 1997, UCEI Seminar Series.

Discussant, 2005 TPUG/ASSA Meetings, Philadelphia
Discussant, 2004 UCEI Annual Energy Conference, Berkeley
Discussant, 2003 UCEI Annual Energy Conference, Berkeley
Discussant, 2003 TPUG/ASSA Meetings, Washington D.C.
Discussant, 2000 Stanford University Strategy Meetings.
Discussant, 2000 NBER Winter IO Meetings, Stanford University

REGULATORY FILINGS:

- Arons, S.M., A.R. Brandt, M.A. Delucchi, A. Eggert, A.E. Farrell, B.K. Haya, J. Hughes, B.M. Jenkins, A.D. Jones, D.M. Kammen, S.R. Kaffka, C.R. Knittel, D.M. Lemoine, E.W. Martin, M.W. Melaina, J.M. Ogden, R.J. Plevin, D. Sperling, B.T. Turner, R.B. Williams, C. Yang, 2007. "A Low-Carbon Fuel Standard for California, Part 1: Technical Analysis." Available Online: http://www.lcfs.ucdavis.edu.

- Brandt, A.R., A.E. Farrell, B.K. Haya, J. Hughes, B.M. Jenkins, A.D. Jones, D.M. Kammen, C.R. Knittel, M.W. Melaina, M. O'Hare, R.J. Plevin, D. Sperling, 2007. "A

Low-Carbon Fuel Standard for California, Part 2: Policy Analysis." Available Online: http://www.lcfs.ucdavis.edu.

- Peer Review Comments on AB 1493, California Environmental Protection Agency Air Resource Board, September 2004.

- "Comments on the Use of Computer Models for Merger Analysis in the Electricity Industry," (Joint with Severin Borenstein and James Bushnell), Federal Energy Regulatory Commission. Docket No. PL98-6-000, June 1998.

- "A Cournot-Nash Equilibrium Analysis of the New Jersey Electricity Market," December 1997. (Joint with Severin Borenstein and James Bushnell). Filed with the New Jersey Public Utility Commission as testimony on the potential for market power in a deregulated Pennsylvania-Jersey-Maryland Power Pool.

CONSULTING:

Customers First! Coalition, Energy Information Agency, Korean Electric Power Company, California Air Resource Board, City of West Sacramento

PH.D. COMMITTEES (FIRST JOB):

UC Davis:
Jonathan Hughes (chair, on-going)
Peter Huckfeldt (on-going)
Nick Sanders (on-going)
Adib Bagh (University of Kentucky, Math and Economics)
Seungjoon Lee (Korean Insurance Research Institute)
Jason Lepore (chair, Cal Poly)
Wei-Min Hu (Peking University)
Byeongil Ahn (Gyeongsang University)
Konstantinos Metaxoglou (chair, Bates and White LLC.)
Lan Li (University of Melbourne)
Neil Norman (Cornerstone Research)
Dae-Wook Kim (chair, Korean Institute for Industrial Economics and Trade)

Boston University:
Gustavo Genoni (2002, Finance, IAE, School of Business, Universidad Austral)
John Neumann (2003, Finance, St. John's University)

TEACHING:

- UC Davis
  - Graduate Empirical Industrial Organization (5 times)
    - Ratings: Mean 4.9 (out of 5)
  - Transportation Economics (3 times)
    - Ratings: Mean 4.6
  - Intermediate Microeconomics (1 time),
    - Ratings: Mean 4.8

  - Undergraduate Industrial Organization (9 times)
    - Ratings: Mean 4.8
- Boston University
  - Modeling Business Decision Making,
    - Spring 2000, Spring 2001 and Spring 2002
    - Ratings: 4.53 (out of 5), 4.77, 4.70
  - Modeling Business Decision Making (honors),
    - Spring 2001 and Spring 2002
    - Ratings: 4.88, 4.70

UNIVERSITY SERVICE:

UC Davis:
2007-2008, Co-writer (with Jean Vandergehst) of a proposal for a Graduate Program in "Energy Science and Technology" and "Energy Policy and Management"
2006-Present, Member, Energy Institute Steering Committee
2008, Founding Faculty Member, UC Davis Energy Institute
2005-2006, Hiring Committee and Interviewing Committee
2004-2005, Hiring Committee and Interviewing Committee
2002-2003, Hiring Committee and Interviewing Committee
2002-2007, Graduate Advisor
Oral committees: Dae-Wook Kim, Konstantinos Metaxoglou, Neil Norman (chair), Seungjoon Lee, Wei-Min Hu, Lan Li, Sunhwa Lee, Byeongil Ahn, Michele Amaral, David Ong, Adib Bagh, Jason Lepore, Bei Li, Chenguang Li, Tina Saitone, Carlo Russo, Sandhya Patlolla, Peter Huckfeldt. Kyungwon Rho

Boston University:
2000-2001, Finance Hiring Committee and Interviewing Committee
1999-2000, Finance Hiring Committee

RECENT MEDIA CITATIONS:

Print: Alameda Times-Star, Arizona Daily Star, Argus, ATMmarketplace.com, Austin-American Statesman, Boston Globe, Buffalo News, California Aggie, Contra Costa Times, PE.com, bankrate.com, marketwatch.com, Crain's Business Report (New York), Credit Card Magazine, Kiosk Marketplace News, LA Observed, LA Times, International Herald Tribune, Northwestern Herald, Oakland Tribune, Oregonian, Philadelphia Inquirer, Providence Journal, New York Times, Sacramento Bee, St. Petersburg Times, Salon.com, San Diego Union Tribune, Salt Lake Tribune, San Diego Union Tribune, SF Chronicle, San Mateo County Times, Santa Rosa Press Democrat, Sarasota Herald-Tribune, Scripps News (DC), Tuscaloosa News Sun Herald, Quad City News (Iowa), Winston-Salem Journal, Worcester Telegram
Radio: KQED's "Forum", KXJZ, KFBK, KUOP, KCBS, KNX, WHYY with Marty Moss-Coane, WPR with Kathleen Dunn, Bloomberg Radio, Lambasted by Rush Limbaugh
Television: KCRA-3, CBS-13 Sacramento, NBC Nightly News, ABC World News, CBS Evening News, ABC Good Morning America

TIMOTHY E. LIPMAN, PHD
Co-Director
Transportation Sustainability Research Center
Institute of Transportation Studies
2614 Dwight Way, 2nd Floor, MC 1728
University of California, Berkeley, CA 94720-3830
Phone: 510-642-4501 Email: telipman@tsrc.berkeley.edu
http://www.its.berkeley.edu/sustainabilitycenter/

PROFESSIONAL PREPARATION
Stanford University Anthropology B.A., 1990
University of California – Davis Transp. Technology and Policy M.S., 1998
University of California – Davis Ecology (Envt'l Policy Analysis AOE) Ph.D., 1999
University of California – Davis Inst. of Transportation Studies Postdoc, 2000
University of California – Berkeley Energy and Resources Group Postdoc, 2000-2003

APPOINTMENTS
- May 2008 – present: **Co-Director**, Transp. Sustainability Research Center, UC Berkeley
- July 2006 – April 2008: **Research Director**, Transp. Sustainability Research Center, UC Berkeley
- February 2004 – present: **Assistant Research Engineer**, Inst. of Transportation Studies, UC Berk.
- 2005 – present: **Member**, Transportation Research Board Committee on Transportation Energy
- ADC70
- November 2003 – June 2004: **Assistant Research Scientist**, Energy and Resources Group, UC Berk.
- June 2003 – October 2003: **Staff Research Associate**, Energy and Resources Group, UC Berkeley
- January 2003 – May 2003: **Post-Doctoral Researcher**, Inst. of Transportation Studies, UC Davis
- September 2000 – August 2002: **Post-Doctoral Researcher**, Energy and Resources Group, UC Berk.
- January 2000 – August 2000: **Post-Doctoral Researcher**, Inst. of Transportation Studies, UC Davis

SELECTED PEER-REVIEWED JOURNAL PUBLICATIONS
Lipman, Timothy E. and Mark A. Delucchi (2006), "An Analysis of the Retail and Lifecycle Costs of Hybrid Electric Vehicles," *Transportation Research – D* **11**(2): 115-132.

Lipman, Timothy E., Jennifer L. Edwards, and Daniel M. Kammen (2004), "Fuel Cell System Economics: Comparing the Costs of Generating Power with Stationary and Motor Vehicle PEM Fuel Cell Systems," *Energy Policy* **32**(1): 101-125.

Lipman, Timothy E. and Mark A. Delucchi (2002), "Emissions of Nitrous Oxide and Methane from Conventional and Alternative Motor Vehicles," *Climatic Change* **53**: 477-516.

Brodrick, Christine-Joy, Timothy E. Lipman, Mohammed Farschi, Nicholas Lutsey, Harry A. Dwyer, Daniel Sperling, S. William Gouse, D. Bruce Harris, and Foy G. King (2002), "Evaluation of Fuel Cell Auxiliary Power Units for Heavy-Duty Diesel Trucks," *Transportation Research – D* **7**(4): 303-315.

Herzog, Antonia V., Timothy E. Lipman, Jennifer L. Edwards, and Daniel M. Kammen (2001), "Renewable Energy: A Viable Choice," *Environment* **43** (10): 8-20.

Delucchi, Mark A. and Timothy E. Lipman (2001), "An Analysis of the Retail and Lifecycle Cost of Battery-Powered Electric Vehicles," *Transportation Research – D* **6**: 371-404.

Lipman, Timothy E. and Daniel Sperling (1997), "Forecasting the Cost Path of an Electric Vehicle Drive System: A Monte Carlo Experience Curve Simulation," *Transportation Research Record* **1587**: 19-26.

ADDITIONAL SELECTED PUBLICATIONS

Lipman, Timothy E. (2004), “Integration of Motor Vehicle and Distributed Energy Systems,” *Encyclopedia* of *Energy*, Academic Press/Elsevier Inc., ISBN 0-12-176480, March.

Lipman, Timothy E. and Daniel Sperling (2003), “Fuel Cell Commercialization Perspectives: Market concepts, competing technologies and cost challenges for automotive and stationary applications,” *Handbook of Fuel Cells – Fundamentals, Technology, and Applications, Vol. 4: Fuel Cell Technology and Applications Part 2*, Edited by W. Vielstich, H. Gasteiger, and A. Lamm, John Wiley and Sons, Ltd., Chichester, pp. 1318-1329.

Shaheen, Susan, Timothy Lipman, and Elliot Martin (2006), “F-Cell” Fuel Cell Vehicle Fleet Driver Response Study,” Prepared for DaimlerChrysler Research and Technology North America, December.

Weinert, Jonathan X. and Timothy E. Lipman (2006), *An Assessment of the Near-Term Costs of Hydrogen Refueling Stations and Station Components*, Inst. of Transportation Studies, Davis, UCD-ITSRR-06-03, January.

Delucchi, Mark A. and Timothy E. Lipman (2003), *A Lifecycle Emissions Model (LEM): Lifecycle Emissions from Transportation Fuels, Motor Vehicles, Transportation Modes, Electricity Use, Heating and Cooking Fuels, and Materials, APPENDIX A: Energy Use and Emissions from the Lifecycle of Diesel-Like Fuels Derived From Biomass*, Inst. of Transportation Studies, Davis, UCD-ITS-RR-03-17A, December 1.

Lipman, Timothy E. and Mark A. Delucchi (2003*), Retail and Lifecycle Cost Analysis of Hybrid Electric Vehicle Designs*, Inst. of Transportation Studies, Davis, UCD-ITS-RR-03-01, April.

Lipman, Timothy E., Jennifer L. Edwards, and Daniel M. Kammen (2002), “Economic Analysis of Hydrogen Energy Station Concepts: Are “H2E-Stations” a Key Link to a Hydrogen Fuel Cell Vehicle Infrastructure?” *Energy Development and Technology Working Paper Series*, EDT-003, University of California Energy Institute (UCEI), November.

SYNERGISTIC ACTIVITIES

- 2007-present: Co-Principle Investigator “California Clean Mobility Partnership” funded by AB 1811to test and investigate plug-in hybrid electric and fuel cell powered vehicles
- 2005-present: Co-Director of Pacific Region Combined Heat and Power Application Center
- 2005-present: Co-Principal Investigator for National Science Foundation MUSES Project: Automotive Material Flows and Greenhouse Gas Emissions Policies
- 2001-2006: Research Track Director for UC Davis Hydrogen Pathways Program
- 2001-present: Ongoing development and use of the MATLAB/Simulink Clean Energy Technologies Economics and Emissions Model (CETEEM)

Daniel M. Kammen

Research Focus: renewable energy science, technology and policy. Energy and climate change. Risk analysis.

a. **Professional Preparation**

Cornell University Physics (Cum Laude) B.A. 1984
Harvard University Physics M.A.1986
Harvard University Physics Ph.D. 1988

b. Appointments

Faculty Positions: Class of 1935 Distinguished Chair in Energy (2004 -); Professor, Goldman School of Public Policy, University of California, Berkeley (2001-present); Professor, Energy and Resources Group, University of California, Berkeley (2001-present); Professor, Department of Nuclear Engineering, University of California, Berkeley (2001-present); Associate Professor, Energy and Resources Group (1998-2001); Assistant Professor of Public and International Affairs, Woodrow Wilson School of Public and International Affairs, Princeton University (1993-98).

Administration and Research: Co-Director, Berkeley Institute of the Environment (2005-present); Founding Director, Renewable and Appropriate Energy Laboratory, University of California, Berkeley (1998-present); Director, Transportation Sustainability Research Center (2008-present); Postdoctoral Fellow, Department of Physics and Kennedy School of Government, Harvard University, (1991 – 1993); Weizmann Postdoctoral Fellow, Division of Engineering, and Division of Biology, California Institute of Technology (1998 – 1991). Permanent Fellow, African Academy of Sciences (2000 – present). Fellow, American Physical Society (1999 – present); Chair, Science, Technology and Environmental Policy Program, Princeton University (1994 – 1998).

National Advisory Board, Union of Concerned Scientists (2004 – present); Board of Directors, The Utility Reform Network (2002 – present), Associate Editor, *Annual Review of Environment and Resources* (2002-2006). Editor-in-Chief, *Environmental Research Letters* (2006 -)

c. Publications (182 journal articles; 5 books; 20+ research reports; 11 US House and Senate Committee Testimonies)

(i) Selected Publications:

Farrell A. E., Plevin, R. J. Turner, B. T., Jones, A. D. O'Hare, M. and Kammen, D. M. (2006) "Ethanol can contribute to energy and environmental goals", *Science*, **311**, 506 – 508.

Bailis, R., Ezzati, M. and Kammen, D. M. (2005) "Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa", **308**, *Science*, 98 – 103.

Jacobson, A. and Kammen, D. M. (2005) " Science and engineering research that values the planet", *The Bridge: Journal of the National Academy of Engineering,* **Winter,** 11 – 17.

Herzog, A. V., Lipman, T., Edwards, J. and Kammen, D. M. (2001) "Renewable Energy: A Viable Choice", *Environment*, **43 (10)**, 8 – 20.

Ezzati, M. and Kammen, D. (2001) "Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: An Exposure-response study", *The Lancet*, **358**, 619 – 624.

(ii) 5 other selected publications:

Kammen, D., M. and Pacca, S. (2004) "Assessing the costs of electricity", *Annual Review of Environment and Resources*, **29**, 1 – 44.

Bailis, R., Ezzati, M., and Kammen, D. M. (2003) "Greenhouse Gas Emissions from Cooking Technologies in Kenya", *Environmental Science & Technology*, **37 (10)**, 2051 - 2059.

Margolis, R. and Kammen, D. M. (1999) "Underinvestment: The energy technology and R&D policy challenge", *Science,* **285**, 690 - 692.

Duke, R. D., and Kammen, D. M. (1999) "The economics of energy market transformation initiatives", *The Energy Journal*, **20 (4)**, 15 – 64.

Kammen, D. M. and Hassenzahl, D. M. *Should We Risk It? Exploring Environmental, Health and Technological Problem Solving*, in press, Princeton University Press. ISBN 0-169-00426-9, 406 pages, 77 tables, 82 illustrations.. Book Club Selection: *Library of Science*. Reviewed in *Science, Risk Analysis, Scientific American, WholeEarth.*

d. **Synergistic Activities**.

(i) Research and Project Management

Member, Science and Technology Review Committee for the Global Environment Facility (GEF) for which he has reviewed, and participated in project and budget evaluation and oversight for over $1.4 billion in international energy and environmental projects, ranging in size from $5 - $400 million.

(ii) Curriculum and Program Development

Professor Kammen was the Chair of the Science, Technology and Environmental Policy Program at Princeton University, and played a significant role in developing the program. At Berkeley he is the founding director of the Renewable and Appropriate Energy Laboratory. Kammen has been a visiting lecturer in the Department of Physics, the University of Nairobi.

(iii) Public and Professional Lectures

Professor Kammen lectures internationally on a regular basis. Within the last six months he has been invited and spoke at the Erice Summer School in Physics, Sicily, Italy; Harvard, Princeton, Yale, Stanford, and Duke Universities. He has testified in front of both U. S. House and Senate committees on a range of energy, environment, and technology issues, as well in front of State of California energy and environmental committees. He has appeared on *'60 Minutes'*, *CNN*, , the ABC nightly news, NPR (and is a regular guest on *Science Friday)*, and local news on a regular basis.

(iv) Consultancies

Professor Kammen provides technical and policy input, reviews, and consultancies for, the U.S. Department of Energy, and the U.S. Environmental Protection Agency, the World Bank, the World Health Organization, the President's Council on Science and Technology, the Government of Sweden, and the United Nations Development Program.

(v) Service to the Scientific Community

Professor Kammen is a regular reviewer for *Science, Nature, Environmental Science & Technology, Energy Policy,* and *The Energy Journal.* He has served on US EPA and US DoE review committees, as well as on committees of the National Academy of Science. Kammen has been on the review committee for the Link Energy Fellowships, and a consultant for the e7 Energy Fellowships (for students from developing nations).

(vi) Student Mentoring

Professor Kammen currently supervises 13 doctoral and six masters students, teaches courses on career development in energy science and policy, teaches the gateway course at UC Berkeley on 'energy and society', and has mentored undergraduates at UC Berkeley, Princeton University, and Harvard University, as well as through minority science and engineering programs. His doctoral advisees are now on the faculty at: Harvard (School of Public Health), Yale (School of Forestry), U. of Wisconsin (Environmental Sciences), Georgetown (School of Foreign Service),

(vii) Research Support

US Dept. of Energy, The Energy Foundation, the California Energy Commission, ITRI (current annual total ~ $1,500,000/year).

e. **Collaborators & Other Affiliations**

(i) Collaborators: Dr. Evans Kituyi (University of Nairobi); Professor Majid Ezzati (School of Public Health, Harvard University); Professor John Holdren (Harvard University); Professor José Goldemberg (University of Sao Paulo, Brazil).

(ii) Graduate and Postdoctoral Advisors

Post-doctoral Advisor: Harvard: Professor Richard Wilson (Physics)
Post-doctoral Advisor: Caltech: Professor Christof Koch, Division of Biology and Computational Neural Systems Program
Ph.D. Advisor: Professor Robert Westervelt, Harvard University (Solid State Physics)

(iii) Graduate Students and Post-graduate Scholars Sponsored (past 5 years)

Post-doctoral advisees at the University of California, Berkeley (6): Dr. Tim Lipman, Dr. Magda Moner e Girona; Dr. Antonia Herzog; Dr. Lloyd Connelly, Dr. Frank Ling
Post-doctoral advisees at Princeton University (2): Dr. Daniel Klooster, Dr. Lisa Naughton
Doctoral advisees at the University of California, Berkeley (7 completed, 9 current)
Doctoral advisees at the Princeton University (5)

SUSAN A. SHAHEEN, PH.D.
CO-DIRECTOR & RESEARCH SCIENTIST

Transportation Sustainability Research Center (TSRC), University of California (UC), Berkeley;
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Susan Shaheen holds a joint research appointment at the Transportation Sustainability Research Center (TSRC) and at the Institute of Transportation Studies-Davis. She is codirector of the transportation track of the Energy Efficiency Center at UC Davis and was honored as the first Honda Distinguished Scholar in Transportation in 2000. In October 2007, Susan became a Research Director at TSRC. She served as the Policy & Behavioral Research Program Leader at California Partners for Advanced Transit and Highways from 2003 to 2007, and as a special assistant to the Director's Office of the California Department of Transportation from 2001 to 2004. She has a Ph.D. in ecology, focusing on technology management and the environmental aspects of transportation, from the University of California, Davis (1999) and a MS in public policy analysis from the University of Rochester (1990). She completed her post-doctoral studies on advanced public transportation systems at UC Berkeley in July 2001. She has earned a variety of honors, including two national research awards for her contributions to a carsharing pilot program (2001) and a smart parking field test (2005). In May 2007, she received the Berkeley Staff Assembly's "Excellence in Management" award in recognition of her leadership and mentorship. She has co-edited one book and authored 31 journal articles and over 45 reports and proceedings articles. She is the chair of the Emerging and Innovative Public Transport and Technologies (AP020) Committee of the Transportation Research Board and served as the founding chair of the Carsharing/Station Car TRB Subcommittee from 1999 to 2004.

EDUCATION

Ph.D., University of California, Davis, Ecology with major emphasis on Technology Management and Environmental Aspects of Transportation (3.8 GPA), September 1999.
Dissertation: *Dynamics in Behavioral Adaptation to a Transportation Innovation: A Case Study of CarLink—A Smart Carsharing System.*
Thesis Committee: Daniel Sperling (chair), Ryuichi Kitamura, and Richard Walters.

MS, University of Rochester, Public Policy Analysis, 1990

BA, Nazareth College, Political Science and English, 1988 (Magna Cum Laude)

SELECTED BOOKS, PAPERS, AND REPORTS

Shaheen, Susan, Elliot Martin, and Timothy Lipman (2008). "Dynamics in Behavioral Response to A Fuel Cell Vehicle Fleet and Hydrogen Fueling Infrastructure," *Transportation Research Record*, Publication Forthcoming.

Shaheen, Susan and Timothy Lipman (2007). "Reducing Greenhouse Gas Emissions and Fuel Consumption: Sustainable Approaches for Surface Transportation," *Journal of International Association of Traffic and Safety Sciences (IATSS) Research.* Vol. 31, No. 1, pp. 6-20.

Lipman, Timothy and Susan Shaheen (2005). *Integrated Hydrogen and Intelligent Transportation Systems Evaluation for the California Department of Transportation*. UCB-ITS-PRR-2005-34. Berkeley, California. November, 63 pp.

Shaheen, Susan, Andrew Schwartz, and Kamill Wipyewski (2004). "Policy Considerations for Carsharing and Station Cars: Monitoring Growth, Trends, and Overall Impacts," *Transportation Research Record* No. 1887, pp. 128-136.

Shaheen, Susan and Rachel Finson (2004). "Intelligent Transportation Systems." *Energy Encyclopedia, Volume 3,* pp. 487-496.

Shaheen, Susan, Caroline Rodier, and Rachel Finson (2003). *Smart Mobility Model: A Case Study of the University of California & Davis Region.* UCB-ITS-PRR-2003-28. Berkeley, California. September, 184 pp.

Rodier, Caroline and Susan Shaheen (2003). "Carsharing and Carfree Housing: Predicted Travel, Emission, and Economic Benefits. A Case Study of the Sacramento, California Region," *Transportation Research Board 83rd Annual Meeting*, Washington, D.C.

Shaheen, Susan A. (2002). Introduction. *Cool Careers for Girls as Environmentalists*. By Ceel Pasternak. Manassas Park, VA: Impact Publications. 129 pp.

Shaheen, Susan (1999). *Dynamics in Behavioral Adaptation to a Transportation Innovation: A Case Study of CarLink—A Smart Carsharing System*. UCD-ITS-RR-99-16. Davis, California. October, 232 pp.

Sperling, Daniel and Susan A. Shaheen, editors. (1995). *Energy Strategies for a Sustainable Transportation System*. Washington, D.C.: American Council for an Energy Efficient Economy. 305 pp.

Shaheen, Susan A., Randall Guensler, and Francisca Mar. (1995). "Concurrent Air Quality Analysis Under the National Environmental Policy Act and Transportation/Air Quality Conformity," *Transportation Quarterly*, Fall, pp. 55-72.

CAROLINE J. RODIER, Ph.D.

CURRENT POSITION

Senior Researcher, Transportation Sustainability Research Center, Institute of Transportation Studies, University of California, Berkeley

EDUCATION

Ph.D., University of California, Davis, Ecology with major emphasis on Environmental Policy Analysis and Transportation Planning, 2000
Dissertation: Uncertainty in Travel and Emissions Models: A Case Study in the Sacramento Region. Dissertation Committee: Robert Johnston, Patricia Mokhtarian, James Cramer & David Layton

M.S., University of California, Davis, Community Development, 1994

B. A., Barnard College, Columbia University, U.S. History, 1989

EVALUATION RESEARCH

- *Apply research evaluation methods (observational, focus groups, and surveys) and conduct analyses to evaluate the travel, economic, and environmental effects of transportation and environmental policies (e.g., transit access technologies, social marketing, automated speed enforcement, and changeable message signs).*
- Conduct analysis of institutional barriers and steps to overcome those barriers (including literature reviews and expert and stakeholder interviews) related to implementation and enforcement of transportation and air quality regulations.
- Investigate the transportation needs and preferences of diverse population groups, such as elderly, immigrants, and Native Americans, and explore innovative transportation programs to address those needs.

URBAN MODELING RESEARCH

- Research support to the California Air Resources Board in their development of the scoping plan for Assembly Bill 32, the *Global Warming Solutions Act*, including an international review of the modeling evidence on the effectiveness of transit, land use, and auto pricing strategies.
- Modeled and evaluated the travel, economic, and air quality effects of intelligent transportation systems technologies, high occupancy vehicle lanes, transit improvements, and road pricing and land use control measures using the Sacramento land use, travel, and emissions models.
- Apply methods of uncertainty analysis to assess errors in land use, travel, and emissions models due to model structure, population projections, and induced travel in the Sacramento region.

SELECTED EXPERT SERVICE/PROFESSIONAL ACTIVITIES

- Research Associate, the Mineta Transportation Institute
- Transportation Research Board, Integrated Transportation and Land-Use Modeling Subcommittee, Member, 2001 to present
- Transportation Research Board, New Public Transportation Technologies Committee, Friend, 2004 to present

SELECTED PUBLICATIONS

Rodier, C. (2008). An International Review of the Modeling Evidence on the Effectiveness of Transit, Land Use, and Auto Pricing Strategies. Submitted to the Transportation Research Record. August 1.

Rodier, C., Benjamin-Chung, J. and S. Shaheen. (2008). Comprehension and Effectiveness of Safety Campaign Messages on Changeable Message Signs. Submitted to the Transportation Research Record. August 1.

Rodier, C., Benjamin-Chung, J. and Shaheen, S. (2008). Changeable Message Signs: Understanding Public Preferences for Message Types. Submitted to the Transportation Research Record. August 1.

Rodier, C. J. (2007). Verifying the Accuracy of Land Use Models Used in Transportation and Air Quality Planning: A Case Study in the Sacramento, California Region. WCTR Annual Meeting, June.

Shaheen, S.A. and C.J. Rodier. (2007) Video Transit Training for Older Travelers: A Case Study of the Rossmoor Senior Adult Community, California. *Transportation Research Record* No. 2034, pp. 11-1889-194.

Rodier, C. J., S. A., Shaheen, and A. Eaken. (2005). Transit-based smart parking in the San Francisco Bay Area: an assessment of user demand and behavioral effects. Transportation Research Record (in press).

Rodier, C. J. (2004). Verifying the Accuracy of Regional Models Used in Transportation and Air Quality Planning. Transportation Research Record, 1898, 45-51.

Rodier, C. J., R. A. Johnston, and D. R. Shabazian. (2003). Evaluation of advanced transit alternatives using consumer welfare. In Transportation and Information Systems. Cheltenham, England: Edward Elgar Publishing, 139-153.

Rodier, C. J. and R. A. Johnston. (2002). Uncertain socioeconomic projections used in travel and emissions models: could plausible errors result in air quality nonconformity? Transportation Research A, 36:613-631.

Hunt, J. D., R. A. Johnston, J. E. Abraham, C. J. Rodier, G. Garry, S. H. Putnam, and T. de la Barra. (2001). Comparisons from the Sacramento Model Testbed. Transportation Research Record, 1780, 53-63.

Walter McManus, PhD

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Summary

Dr. Walter McManus is the Director of the Automotive Analysis division of the University of Michigan Transportation Research Institute. He earned a BA in economics from Louisiana State University in 1977 and a PhD in economics from UCLA (where he was a Stern Fellow) in 1983.

He is an economist with 20 years of automotive industry experience. His research applies tools of econometrics, competitive analysis, consumer demand theory, and forecasting to understand trends in the automotive industry. His research currently focuses on the interaction of the industry, society, and the environment.

His business career included nine years at General Motors (1989-1998) where he held various positions in market analysis and product development; and spent a year in a components factory as a production supervisor. He became executive director of forecasting and analytics for J.D. Power and Associates in 1999. In addition to leading the firm's global forecasting activities, he conducted research on the market diffusion of new technologies including powertrain (electric, hybrid, clean diesel, fuel cell, alternative fuels), safety, and telematics.

He recently received the National Association for Business Economics' Abramson Award for an article (the link between gasoline prices and vehicle sales: economic theory trumps conventional Detroit wisdom, Business Economics 1.42(2007): pp. 54-60) that criticized automotive industry economists for failing to recognize and warn the industry of the growing value of fuel economy to consumers since 2001. The result was that Detroit's false conventional wisdom was not overturned before billions of dollars of losses accumulated and thousands of American jobs were lost.

Areas of Expertise

- Applied economics
- Statistics and forecasting
- Applied demographic analysis
- Development of tools that enable better decision-making
- Visualizing information
- Leadership in multi-disciplinary project teams
- Knowledge of markets for light-duty vehicles
- Knowledge of technology diffusion in light-duty vehicles

Education

- PhD in Economics, UCLA, 1983
    - Sidney Stern Fellow
    - Fields: Labor, Industrial Organization, and Econometrics
    - Dissertation: "Effects of Language Characteristics on Earnings"
    - Dissertation Advisor: Finis Welch
    - U.S. DOL Dissertation Fellowship in Employment and Training
- BA in Economics, Louisiana State University, 1977

Selected Publications

The Link Between Gasoline Prices and Vehicle Sales, Business Economics, p. 53, January 2007.

Economic Analysis of Feebates to Reduce Greenhouse Gas Emissions from Light Vehicles for California, Automotive Analysis Division (AAD), University of Michigan Transportation Research Institute (UMTRI), May 2007.

Can Proactive Fuel Economy Strategies Help Automakers Mitigate Fuel-Price Risks? Automotive Analysis Division, (AAD), University of Michigan Transportation Research Institute (UMTRI), September 2006.

In The Tank – How Oil Prices Threaten Automakers' Profits and Jobs (with Alan Baum, Roland Hwang and Daniel D. Luria) Office for the Study of Automotive Transportation, July 2005.

The Effects of Higher Gasoline Prices on U.S. Light Vehicle Sales, Prices, and Variable Profit by Segment and Manufacturer Group, 2001 and 2004. Office for the Study of Automotive Transportation (OSAT), University of Michigan Transportation Research Institute (UMTRI), June 2005.

Future Potential of Hybrid and Diesel Powertrains in the US Light-Duty Vehicle Market, (with David L. Greene and K.G. Duleep), Report to Department of Energy, July 2004.
Consumer Acceptance of Alternative Powertrains, OE Industry Review. Troy, MI: Original Equipment Suppliers Association, 2004.

Analysis of Tax Credits to Stimulate Consumer Demand for Advanced-Technology Fuel-Efficient Vehicles: Final Report to Energy Future Coalition Transportation Working Group. Westlake Village, CA: J.D. Power and Associates, 2003.

RESUME
NAME: K.G. Duleep

EDUCATION:

1989 M.B.A.
Wharton School
University of Pennsylvania
Philadelphia, Pennsylvania

1976 Doctoral Candidate (Aerospace Engineering)
University of Michigan
Ann Arbor, Michigan

1975 MS (Aerospace Engineering/Computer Information and Control Engineering)
University of Michigan
Ann Arbor, Michigan

1972 Bachelor of Technology (Aerospace Engineering)
Indian Institute of Technology
Madras, India

EXPERIENCE:

1988 - Present **Energy and Environmental Analysis, Inc.**
Managing Director

Responsible for directing all studies in the area of mobile source emission control, alternative fuels and fuel economy. Major projects under his direction include:

- Analysis of new technologies to improve vehicle fuel economy
- Development of techno-economic models to forecast vehicle attributes in the future
- Analysis of new polices and regulations to improve light vehicle fuel economy
- Support to auto manufacturers on compliance issues relating to fuel economy and emissions

1979 - 1988 **Energy and Environmental Analysis, Inc.**
Senior Professional

Lead engineering analyst on all mobile source emissions and fuel economy issues. Projects included:

- Development of emission factors for EPA's MOBILE3/4 Models.
- Estimates of 1990/95 fuel economy potential for domestic auto-manufacturers.

- Analysis of post-1990 heavy duty truck emission standards, and implications for Canada.
- Analysis of alternative fuel vehicle technology development.
- Review of inspection/maintenance data from several states to estimate program quality**.**

1976 - 1978 **Bendix**
Electronics and Engine Control Systems Group
Senior Engineer

Involved in a variety of design and development projects. Participated in the development of digital microprocessor control of engine parameters and contributed to control law analysis. Helped design a closed loop fuel control for 3-way catalyst systems, focusing on oxygen sensor operation.

Studied the design and development of a low-cost throttle body injection (TBI) system and marketed TBI systems to Chrysler, Ford and Fiat. Also helped design dynamometer testing and vehicle calibration to meet the statutory emission standards of 0.4 HC/3.4 CO/0.4 NO_x g/mile.

1973 - 1976 **University of Michigan**
Department of Aerospace Engineering
Research Assistant

Involved in gas dynamics/combustion/control projects: NO_x formation during methane combustion (AGA Project), control theory application to anticoagulant therapy, and light aircraft engine emissions baseline.

1972 - 1973 **Aeronautical Development Establishment**
Junior Scientific Officer

Scientific officer in the aerodynamics division responsible for aerodynamic design of target drones, wind-tunnel testing of MIG-21, and development of dynamic behavior model for transonic missile.

PUBLICATIONS:

Duleep, K.G., "Optimization Applications in Anti-Coagulant Therapy," AIAA Paper 76-204, presented at the AIAA/AAS Astrodynamic Conference, 1976.

Duleep, K.G., "Jet Flow Field During 'Screech,'" Applied Sciences (32), August 1976.

Duleep, K.G., "Survey and Analysis of Collection Methods for Automobile Particulate Emissions," APCA Paper 79-47, June 1979.

Difiglio, C., Dulla, R., and Duleep, K.G., "Cost-Effectiveness of 1985 Automobile Fuel Economy Standards," prepared for the Society of Automobile Engineers, October 1979.

Duleep, K.G., "Analysis of Automotive Particulate Sampling Techniques," SAE Paper No. 800184, February 1980.

Duleep, K.G., Kuhn, D.P., and Crawford, R.W., "1985 Light-Duty Truck Fuel Economy," SAE Paper No. 801387, October 1980.

Duleep, K.G. "Forecasting Fuel Economy - Review of Critical Issues," oral presentation at the SAE June 1982 meeting.

Lax, D.L., and Duleep, K.G., "Recent Trends in Factors Influencing Automotive Fuel Demand," SAE Paper No. 83054, 1983.

Duleep, K.G., "Future Automotive Emission Control Technology and Strategy," SAE Paper No. 841244, October 1984.

Duleep, K.G., Wang, D., and Crawford, R.W., "I/M Short Tests and Cutpoints for 1981 and Newer Emission Control Technology," SAE Paper No. 851185, May 1985.

Duleep, K.G., "Heavy-Duty Vehicle Fuel Economy Potential to 2001" presented at 71st Annual Meeting of the Transportation Research Board, January 1992.

Greene, David, and Duleep, K.G., "Costs and Benefits of Automotive Fuel Improvement: A Partial Analysis" presented at 71st Annual Meeting of the Transportation Research Board, January 1992.

Duleep, K.G., and Holmes, J.G., " Role of Oxygenates in Meeting U.S. Reformulated Gasoline Requirements" IX International Symposium on Alcohol Fuels, November 1991.

Duleep, K.G., "Post-2000 Fuel Economy Opportunities" SAE Government/Industry Meeting, May 1991.

Duleep, K.G., "Fuel Economy Technology Potential to 2010" OECD Conference on the Low Emissions/Low Consumption Automobile, Berlin, March 1991.

Duleep, K.G., "Technology Improvements to Increase Fuel Economy" OECD Conference on Low Emissions/Low Consumption Automobile, Rome, February 1990.

HONORS:

Directors List (First Rank), Wharton School

Merit Scholarship, University of Michigan.

First Prize Winner, University Science Fair, India.

PROFESSIONAL MEMBERSHIPS:

Tau Beta Pi (Engineering Honor Society).

Society of Automotive Engineers.

IV. Related research

Dr. David L. Greene

Dr. Greene has been conducting research on transportation energy and related policy issues for the U.S. Departments of Energy and Transportation and the Environmental Protection Agency for the past 30 years. Some of his recent research relevant to this proposal is listed below.

Systems Analysis of the Transition to Hydrogen Vehicles. Design and implementation of a market simulation model representing the transition to hydrogen-powered light-duty vehicle in the U.S. Model development and analysis sponsored by the U.S. Dept. of Energy over a period of 4 years. Total budget approximately $2.5 million. Ongoing.

Analysis of the Rebound Effect for Light-Duty Vehicles. A re-examination and re-estimation of the relationship between motor vehicle fuel economy and use. Sponsored by the U.S. Environmental Protection Agency, $100,000. Ongoing.

Analysis of the Potential for Voluntary Fuel Economy Standards in the U.S. and of Alternative Formulations of Standards Including Tradable Credits. Sponsored by the U.S. Department of Energy, approximately $100,000. Completed.

Assessment of the Market Potential for Hybrid and Diesel Vehicles in the United States. Sponsored by the U.S. Department of Energy, approximately $75,000. Completed.

Transitional Alternative Fuel Vehicles Model. An integrated market simulation model for analysis of potential transitions to alternative fuel vehicles in the U.S. Sponsored by the U.S. Department of Energy, approximately $600,000. Completed.

Analysis of Feebates, Rebates and Gas-Guzzler Taxes. Sponsored by the U.S. Department of Energy, approximately $60,000. Completed.

An Integrated Multi-pathway Biofuel System Design under Uncertainties, supported by Chevron Technology Ventures, LLC, $299,082, 2007-2009, (PI: Yueyue Fan; Co-PI: Joan Ogden): In this research, we are developing optimization for strategic bioenergy infrastructure system planning incorporating spatial and temporal dynamics and biomass feedstock supply uncertainties.

Optimal Design for A Self-sustainable HOT Network, supported by Sustainable Transportation Center at UC Davis, $ 59,912.33, 2007-2008 (PI: Yueyue Fan): In this research, we developed a mathematical programming model that determines, for multiple performance measures, the best toll pricing strategies with simultaneously considering carpooling behaviors of drivers from various income groups reacting to different tolls. The model developed in this project is simpler than the proposed project in terms of scale and complexity, but shares a similar structure as the one proposed for manufacturer's decision model, i.e., a nonlinear optimization model subject to logit user behavior constraints.

Several previous studies of the manufacturing and lifecycle costs of advanced technology vehicles, various sponsors, 1996-2008 (Lipman)

Assessment of Material Flows in the US Auto Industry in Response to Greenhouse Gas Emission Policies, National Science Foundation MUSES,2006-2011 (Lipman, McManus, and others)

Feebate Policy Assessment Studies, Energy Foundation and Union of Concerned Scientists, 2005-2008 (McManus)

Stakeholder Assessment of Potential AB 32 Policies, Air Resources Board, 2007-2008 (Shaheen and Rodier)

Plug-in hybrid vehicle commercialization assessments, 2006-2008, Energy Foundation and NREL (Kammen)

V. Publications list

1. Bunch, D.S., "Behavioral Frontiers in Choice Modeling," (with W. Adamowicz, T. A. Cameron, B. G. B. C. Dellaert, M. Hanneman, M. Keane, J. Louviere, R. Meyer, T. Steenburgh and J. Swait), Marketing Letters, In Press (2008).
2. Bunch, D.S., California Air Resources Board –Institute of Transportation Studies (CARBITS) Vehicle Market Microsimulation Model for California, June 8, 2004. Prepared for California Air Resources Board under contract 02-310.
3. Bunch, D.S., "Automobile Demand and Type Choice," (with B. Chen), Handbook of Transport Modeling, Second Edition, David A. Hensher and Kenneth J. Button, editors, Pergamon (2008), pp. 541-556.
4. Bunch, D.S., "Hybrid Choice Models: Progress and Challenges," (with Moshe Ben-Akiva, Daniel McFadden, Kenneth Train, Joan Walker, Chandra Bhat, Michel Bierlaire, Denis Bolduc, Axel Borsch-Supan, David Brownstone, Andrew Daly, Andre de Palma, Dinesh Gopinath, Anders Karlstrom, Marcela A. Munizaga), Marketing Letters, 13(3): pp. 163-175 (August 2002).
5. Bunch, D.S., "Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-fuel Vehicles" (with David Brownstone and Kenneth Train). Transportation Research B, Volume 34, Issue 5 (June 2000), pp. 315-449.
6. Bunch, D.S., "Combining Sources of Preference Data for Modeling Complex Decision Processes" (with Jordan J. Louviere, Robert J. Meyer, Richard Carson, Benedict Delleart, W. Michael Hanemann, David Hensher, and Julie Irwin). Marketing Letters, Volume 10, Issue 3 (August 1999), pp. 205-217.
7. Bunch, D.S., "Determinants of Alternative Fuel Vehicle Choice in the Continental United States" (with Melanie Tompkins, Danilo Santini, Mark Bradley, Anant Vyas, and David Poyer), Transportation Research Record, Number 1641, Energy and Environment: Energy Air Quality, and Fuels 1998, Transportation Research Board, National Research Council.
8. Bunch, D.S., "Commercial Fleet Demand for Alternative-fuel Vehicles," (with Thomas F. Golob, Jane Torous, David Brownstone, Soheila Crane, and Mark Bradley), Transportation Research A Vol. 31A (1997): 219-233.
9. Bunch, D.S., "A Vehicle Usage Forecasting Model Based on Revealed and Stated Vehicle Type Choice and Utilization Data," (with Thomas F. Golob and David Brownstone), Journal of Transport Economics and Policy Vol. 31 (1997): 69-92.
10. Bunch, D.S., "A Dynamic Forecasting System for Vehicle Markets with Clean-Fuel Vehicles," (with David Brownstone and Thomas F. Golob). In D. A. Hensher, J. King, and T. H Oum eds., World Transport Research, Volume 1 (1996): 189-203.
11. Bunch, D.S., "A Vehicle Transactions Choice Model for Use in Forecasting Demand for Alternative-Fuel Vehicles," (with David Brownstone, Thomas F. Golob, and Weiping Ren), Research in Transportation Economics, Vol. 4 (1996): 87-129.
12. Bunch, D.S., "Demand for Clean-Fuel Vehicles in California: A Discrete-Choice Stated Preference Survey" (with Mark Bradley, Thomas F. Golob, Ryuichi Kitamura, Gareth P. Occhiuzzo). Transportation Research A, Vol. 27A, No. 3, pp. 237-253, 1993.

13. Bunch, D.S., "Predicting the Market Penetration of Electric and Clean-fuel Vehicles" (with Thomas F. Golob, Ryuichi Kitamura, and Mark Bradley), The Science of the Total Environment, 134 (1993) pp. 371-381.
14. Bunch, D.S., "Estimability in the Multinomial Probit Model," Transportation Research B, 1991, Vol 25B(1), pp. 1-12.
15. Bunch, D.S., "Heterogeneity and State Dependence in Household Car Ownership: A Panel Analysis Using Ordered-Response Probit Models with Error Components," 11th International Symposium on Transportation and Traffic Theory, Elsevier, July 1990 (with Ryuichi Kitamura).
28. Davis, W.B., M.D. Levine, K. Train and K.G. Duleep, 1995. "Effects of Feebates on Vehicle Fuel Economy, Carbon Dioxide Emissions, and Consumer Surplus", DOE/PO-0031, Office of Policy, U.S. Department of Energy, Washington, D.C.
29. Delucchi, Mark A. and Timothy E. Lipman (2001), "An Analysis of the Retail and Lifecycle Cost of Battery-Powered Electric Vehicles," Transportation Research – D 6: 371-404.
30. Dumas, A., D.L. Greene and A. Bourbeau, 2007. "North America Feebate Analysis Model", chapter 7 in D. Sperling and J.S. Cannon, eds., *Driving Climate Change,* Academic Press, New York.
31. Energy and Environmental Analysis, Inc., 2006. "Technologies to Reduce Greenhouse Gas Emissions from Light-Duty Vehicles", Draft Final Report, prepared for Transport Canada, Ottawa, Ontario, Canada, June, 2006.
32. Energy and Environmental Analysis, Inc., 2005. "Automotive Technology Cost and Benefit Estimates", prepared for Transport Canada, Ottawa, Canada by EEA, Inc., Arlington, Virginia, March.
33. Greene, D.L., J. German and M.A. Delucchi, 2009. "Fuel Economy: the Case for Market Failure", in D. Sperling and J. Cannon eds., *Reducing Climate Impacts in the Transportation Sector*, Springer Science+Business Media.
34. Greene, D.L., 2008. "Feebates, Footprints and Highway Safety", *Transportation Research D*, forthcoming.
35. Greene, D.L., P.D. Patterson, M. Singh, and J. Li, 2005. "Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy", *Energy Policy*, vol. 33, pp. 757-775.
36. Greene, D.L, K.G. Duleep, and W. McManus, 2004. *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market*, ORNL/TM-2004/181, Oak Ridge National Laboratory, Oak Ridge, Tennessee, August.
37. Greene, D.L. and J.L. Hopson, 2003. "Analysis of Alternative Forms of Automotive Fuel Economy Standards for the United States", *Transportation Research Record 1842*, pp. 20-28, Transportation Research Board, National Research Council, Washington, D.C.
38. Greene, D.L. and J. DeCicco, 2000. "Engineering-Economic Analysis of Automotive Fuel Economy Potential in the United States", pp. 477-536 in, *Annual Review of Energy and the Environment,* vol. 25, Annual Reviews, Palo Alto, California.
39. Greene, D.L., 1991. "The Cost of Short-run Pricing Strategies to Increase Corporate Average Fuel Economy," *Economic Inquiry,* vol. XXIX, no. 1, pp. 101-114.
40. Kammen, D. M., Arons, S., Lemoine, D., and Hummel, H. (2008) "Evaluating the cost-effectiveness of greenhouse gas emission reductions from deploying plug-in hybrid electric vehicles," Brooking Institute (Washington, DC).
41. Leiby, P.N., D.L. Greene, D. Bowman and E. Tworek, "Systems Analysis of Hydrogen Transition with HyTrans," *Transportation Research Record*, No. 1983, pp. 129-139, 2007.
42. Lemoine, D., Kammen, D.M., and Farrell, A.E. (2008) "An innovation and policy agenda for commercially competitive plug-in hybrid electric vehicles", Environmental Research Letters, 3, 1 – 8.
43. Lipman, Timothy E. and Mark A. Delucchi (2006), "An Analysis of the Retail and Lifecycle Costs of Hybrid Electric Vehicles," Transportation Research – D 11(2): 115-132.

44. McManus, W.S. *Economic Analysis of Feebates to Reduce Greenhouse Gas Emissions from Light Vehicles for California*. Publication UMTRI-2007-9-12. University of Michigan Transportation Research Institute, Ann Arbor, Michigan. 2007.
45. McManus, W., 2007. "Economic analysis of feebates to reduce greenhouse gas emissions from light vehicles for California", University of Michigan Transportation Research Institute, Ann Arbor, Michigan, May; on line at http://mpra.ub.uni-muenchen.de/3461/ .
46. National Research Council (NRC), 2002. *Effectiveness and Impacts of Corporate Average Fuel Economy (CAFE) Standards*, National Academies Press, Washington, D.C. (D.L. Greene, committee member)