

PROGRAM SUMMARY

Sustainable Transportation Energy Pathways Program

Institute of Transportation Studies
 University of California, Davis
 January 2009

The UC Davis Institute of Transportation Studies (ITS-Davis) launched the *Sustainable Transportation Energy Pathways (STEPS) Program*, a four-year, multi-disciplinary research effort, in 2007. The overarching objectives of the STEPS program are (1) to develop the theory, tools and methods that allow for *self-consistent* and *transparent* comparisons of promising alternative energy and vehicle pathways; and (2) to apply these tools and methods in comparative assessments of four general transportation energy pathways—*hydrogen, biofuels, electricity and fossil fuels*.

The goals of the STEPS program are to inform the public debate and to assist our public and private sponsors by providing tools and knowledge concerning sustainable transportation alternatives. The program carefully analyzes potential transitions in the transportation sector by addressing markets and consumer behavior, engineering and economics of vehicles and fuel infrastructure systems, societal and lifecycle environmental impacts (climate change, air quality, energy security) and public policy. Our intent is to generate a strong understanding and solid foundation of knowledge for companies and government agencies analyzing technology, investment and policy options.

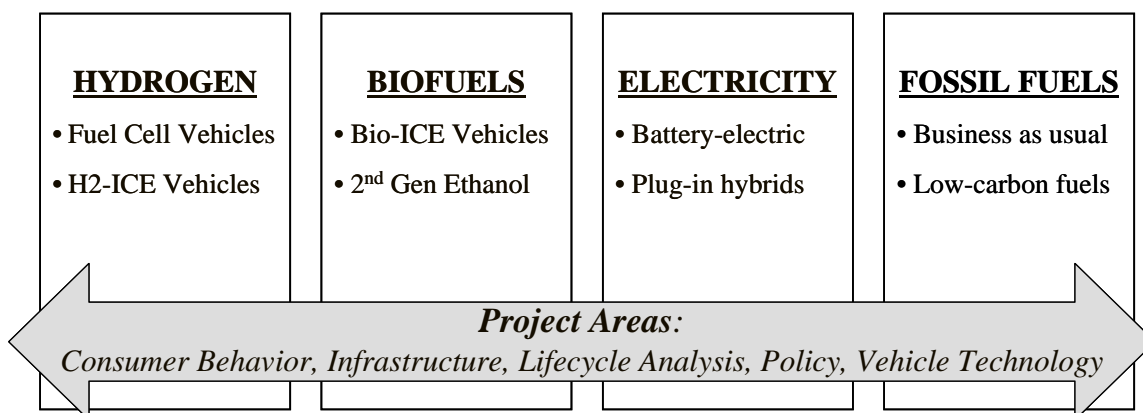


Figure 1: STEPS Research Scope and Project Areas—
 Program organized into energy tracks with comparative analysis in project areas

STEPS Builds on ITS-Davis Research

Over the past 12 years, ITS-Davis has developed an international reputation for its consortium-based transportation research. The STEPS Program extends two previous ITS-Davis research programs: the *Fuel Cell Vehicle Modeling Program*, which focused on fuel cell vehicles, and the

Hydrogen Pathways Program, which focused on hydrogen fuel.¹ The research scope of the STEPS Program allows comparisons across a greater number of alternative fuel and vehicle combinations, with the goal of enabling government agencies and industry to evaluate a broader range of future transportation options. An expanded description of current projects and program sponsors can be found on our program website (www.steps.its.ucdavis.edu).

STEPS research is leveraged by UC Davis's growing commitment to alternative fuels, renewable energy and transportation energy research. In 2007 the campus selected energy as one of five key research thrusts for the university. Through the UC Davis Energy Initiative, the university has already brought in new faculty with expertise in lifecycle analysis, biofuels and fuel cells and is committed to hiring a total of 15 new faculty in the energy area. Other UC Davis energy-related initiatives include the Energy Efficiency Center, the California Biomass Collaborative, the Plug-in Hybrid Electric Vehicle (PHEV) Research Center and other programs at ITS-Davis.²

Program Overview

The STEPS Program draws upon research methods from a broad range of academic fields, including vehicle engineering and design, systems analysis and operations research, chemical and mechanical engineering, lifecycle cost and emissions analysis, market research, sociology and anthropology, economics and business strategy, and policy and political analysis. Our research team includes 15 Ph.D.-level faculty and research scientists and 25 graduate students, drawn from a variety of departments. The focus is on understanding transitions toward a more sustainable transportation system, one that will rely on more than one solution to meet energy supply and greenhouse gas objectives. We consider both near-term and long-term technologies to analyze possible paths forward. A key issue is to understand how one technology path can enable another, and how multiple technologies can be either synergistic or competitive.

Scope of STEPS Projects

Figure 1 above summarizes the four transportation energy tracks and indicates the types of projects for comparative analysis. They include:

- **Hydrogen.** Continuing research conducted under the Hydrogen Pathways Program, we are exploring new areas such as hydrogen/electricity systems, regional transition case studies, well-to-tank energy and emissions modeling and enhancing key hydrogen pathways models for infrastructure development strategies.
- **Biofuels.** This track builds upon UC Davis's current work within the California Biomass Collaborative and the considerable agricultural and biological expertise of the university. The biofuels track includes analysis of various biorefinery production systems, infrastructure strategies, environmental and land-use impacts and vehicle analysis.

¹ From 1998 through 2002, the Fuel Cell Vehicle Modeling Program (FCVMP) developed advanced fuel cell vehicle simulation models of a variety of fuel and powertrain combinations, providing a comparison tool for sponsors to use for their in-house evaluations. Over the course of five years, the program supported nine graduate students and several faculty, resulting in 60 publications and presentations. The program was supported by 20 corporate sponsors and two government agencies (<http://www.its.ucdavis.edu/research/vehicletechnologies/fcvmp.html>).

ITS-Davis conducted its next research consortium from 2003 through 2006—the Hydrogen Pathways Program (<http://hydrogen.its.ucdavis.edu/>). This program focused on understanding the potential transition to a hydrogen-based transportation system. The Hydrogen Pathways Program produced over 100 research publications, received several national awards for its contributions, educated over 20 graduate students and informed hydrogen policy at the state and national level. The program was supported by 16 corporate sponsors and 5 government agencies.

² Additional information on these other programs can be found on the ITS-Davis program website (www.its.ucdavis.edu).

- **Electricity.** Electricity production methods, total grid capacity and time-of-day charging impacts on the utility sector are studied for both plug-in vehicles and hydrogen production. Additionally, research is conducted on consumer behavior and preferences for electric drive attributes, including all-electric range and charging time. This work is leveraged by the UC Davis PHEV Research Center.
- **Fossil Fuels.** This track includes both the business-as-usual reference case, where conventional petroleum fuels continue to dominate transportation energy, and the evolution of fuels produced from other fossil fuel resources, including tar sands, oil shale and coal with carbon capture and sequestration.

STEPS Comparative Research Methods

To conduct robust comparative analyses among different energy and vehicle pathways, the STEPS Program's research is organized into cross-cutting comparative project areas (as indicated in Figure 1). A few of these are highlighted below.

- **Infrastructure Analysis.** Using geographic information system (GIS) analysis, mathematical optimization methods and resource assessment tools to study total supply chain costs for biofuels, hydrogen and electricity; comparing design, costs and GHG impacts for different fuel supply pathways for the production and delivery of liquid fuels and hydrogen.
- **Energy, Environmental and Cost Analysis.** Using lifecycle analysis tools, such as the UC Davis LEM & AVCEM models, to study and compare well-to-wheels energy use and emissions for fuel production and use in vehicles; studying broader sustainability impacts such as water resources and land-use changes.
- **Vehicle Technology Evaluation.** Using Matlab/Simulink vehicle system engineering modeling tools to evaluate PHEV battery and system design tradeoffs; comparing performance of PHEVs to fuel cell vehicles and battery electric vehicles.
- **Integrative Scenarios.** Integration of multiple alternatives into economy-wide models with the ability to simulate various policy options into the future, incorporating regional differences, resource availability, market dynamics and complete system interactions.

A Sampling of STEPS Projects and Early Results

In 2007 and 2008, STEPS researchers produced over 75 research publications and reports. A full list of our publications can be found on the program website (www.steps.its.ucdavis.edu). Included here are three examples of recent STEPS research projects.

Our scenario studies have shown the importance of a portfolio approach in reducing carbon emissions and gasoline use in transportation over the next few decades. In a recent study, STEPS researchers developed possible scenarios for meeting California's ambitious goal of reaching an 80% reduction in GHG emissions below 1990 levels by 2050. While no single mitigation option can meet the target alone, the goal can be met by utilizing a combination of technological and behavioral options.

(Yang, C., D. McCollum, R. McCarthy, and W. Leighty. 2008. 80-in-50 scenarios for deep reductions in GHG emissions from California transportation. Publication pending.)

The future role of PHEVs in meeting near-term or long-term energy and emissions goals depends not only on their technology (vehicle design and performance), but also on drivers' travel and refueling/recharging behaviors. In a recent survey-based analysis, STEPS researchers found that at least half of the survey respondents have modern electrical systems that would allow at-home vehicle recharging without costly retrofits. Although respondents showed interest in a range of possible PHEV benefits, the appeal of increased fuel economy ranked higher than a large all-electric

range or speed. These results may help inform decision-makers as PHEV battery specifications and goals are being evaluated.

(Axsen, J. and K. Kurani. 2008. The early U.S. market for PHEVs: Anticipating consumer awareness, recharging potential, design priorities and energy impacts. ITS-Davis Research Report UCD-ITS-RR-08-22.)

A STEPS analysis of gasoline use reveals that behavioral and structural factors over the past several decades have changed the responsiveness of U.S. consumers to gasoline price fluctuations (short-run elasticities are *reduced*). One implication of these findings is that gasoline taxes would need to be significantly larger today in order to achieve an equivalent reduction in gasoline consumption. This suggests that policies and technologies designed to improve fuel economy are likely becoming relatively more attractive as a means to reduce fuel consumption.

(Knittel, C., J. Hughes, and D. Sperling. 2008. Evidence of a shift in the short-run price elasticity of gasoline demand. *Energy Journal* 29(1): 113–134.)

Program Participation

The STEPS program has four funding cycles corresponding to calendar years 2007 through 2010. Program Sponsors provided \$50,000 per year to participate for the first two years and will contribute \$60,000 per year thereafter. Program Sponsors joining after the first two years must provide 40% back pay for each year while not a member. This policy recognizes the cumulative nature of the research and the past commitments of existing sponsors. For each calendar year during the program, ITS-Davis will invite sponsors to renew their participation; an up-front pledge for four years is not required.

Sponsorship Activities and Benefits

Program Sponsors are encouraged to participate in all program activities listed below. The level of participation will be decided independently by each sponsor.

- ***STEPS Advisory Committee.*** The committee meets at least once per year to advise the program's leadership on the coming year's research and program activities.
- ***Technical Workshops.*** Each year, at least one high-level, invitation-only research workshop will be held on critical technical issues and topics.
- ***Research Reports.*** Researchers will issue reports and working papers over the course of the program. These reports are provided immediately to Program Sponsors, often prior to publication.
- ***Research Bulletins.*** A quarterly newsletter for Program Sponsors and researchers highlights recent program news including research results, new projects and events.
- ***Website.*** The STEPS Program hosts a password-protected website. Program Sponsors have instant access to STEPS research and program information.
- ***Public Process Activities.*** In addition to events for our sponsors, special public process events are conducted. These include tutorial workshops for policymakers at the state and national levels and policy issue forums.
- ***Program Sponsor Advisors and Internships.*** Where there is interest, Program Sponsors and STEPS researchers interact closely on specific projects, arrange for student internships at Program Sponsor locations and host extended visits from Program Sponsors at ITS-Davis.

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