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CALIFORNIA PATH PROGRAM  
INSTITUTE OF TRANSPORTATION STUDIES  
UNIVERSITY OF CALIFORNIA, BERKELEY

## **ITS-Davis - Hydrogen Pathways Program**

**Joshua M. Cunningham**  
*University of California, Davis*

**California PATH Reports to Caltrans 2008-C1**

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

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Final Report for Task Order 6107

July 2008

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**ITS-Davis  
Hydrogen Pathways Program**

***Final Research Report***

Prepared By: Joshua M Cunningham  
Program Manager, STEPS Program

Submitted to:  
**California Department of Transportation**  
**PATH Task Order: #6107**

Submitted On:  
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## **Abstract**

The contractor, through the Institute of Transportation Studies at the University of California, Davis (ITS-Davis), through the study “Clean Hydrogen for Transportation Applications”, conducted a two year research and outreach program that addressed the technical, operational, and logistical issues related to the transition to a hydrogen economy. The projects and its associated studies focused on the demands, capacity, and evolution of the transport and distribution of hydrogen for use in the transportation sector. The research goal was to identify a broad set of transparent facts that will be accepted by all stakeholders in the hydrogen economy and that can be used to establish a common basis regarding hydrogen pathways.

A Special Project is also described in this report. Section 3 summarizes the ITS-Davis Asilomar Conference where the Caltrans special project funds for this contract were utilized and highlights key discussion outcomes from the event. Caltrans representatives were able to participate and contribute to this event.

## Executive Summary

The following project deliverables and supporting information are listed as they appeared in the original contract.

1. *ITS-Davis will issue working papers and reports each year to all Program Sponsors on the progress of the project.*
  - Publications from the recent quarter are listed at the end of this report.
  - The program websites (listed in Section 1.2 above) have a cumulative summary of all the program publications and presentations.
  - A sample of a few project summaries are included in Appendix A, projects that Caltrans may best relate to. This is a selection from the 25+ projects currently active in the STEPS program.
2. *A high-level, invitation-only annual conference will be conducted to provide a review of the research outputs from the program.*
  - The STEPS Research Symposium took place on May 21-22, 2007. After logging into the STEPS program website, an events web page will direct you to the event materials.
  - The event agenda and sponsor feedback notes are included in Appendix B.
3. *At least one research workshop will be held each year on critical technical issues and topics, such as station siting, transportation hydrogen demand scenarios, and energy stations.*
  - The Hydrogen Pathways final workshop was held September 26-27, 2007. Event material can be found from the Hydrogen Pathways website.
  - The event agenda is included in Appendix C.
4. *Each year at least one special public process event will be held. These may include tutorial workshops for public agency leaders and staff, policy issue forums, and information gathering sessions requested by public agencies.*
  - A Federal Government outreach event was held on January 23, 2007 in Washington DC. The event focused on the basics of hydrogen and other alternative fuels in meeting our national energy goals.
  - The event agenda is included in Appendix D.
5. *Caltrans will be provided with the opportunity to participate in near-term pilot projects facilitated by or led by ITS-Davis.*
  - A near-term pilot project is not currently being planned.
6. *The Hydrogen Pathways Program will make available to Caltrans research-based knowledge, experience, and recommendations relative to hydrogen fueling stations.*
  - No current station is being reviewed.

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# 1 Project Background

As a sponsor of this research, you should have received a log-in ID and password for our program websites. Please let us know if you don't have this information. The reference web pages below provide more detailed information about our research efforts.

- Hydrogen Pathways (H2P) main website: <http://hydrogen.its.ucdavis.edu>
- H2P publications list (through 2006): <http://hydrogen.its.ucdavis.edu/publications>
- Sustainable Transportation Energy Pathways: <http://steps.its.ucdavis.edu>
- STEPS publications (2007 to present): <http://steps.its.ucdavis.edu/publications>

# 2 Project Status Summary

## 2.1 Timeline

The PATH Task Order #6107 was a two year contract with a performance period from July 1, 2005 to June 30, 2007. A no-cost extension (through September 30, 2007) was requested and obtained to allow for Caltrans to support the ITS-Davis Asilomar Conference from this task order (Special Project described herein). There is no need for a further extension, and with this Final Report, the Task Order #6107 will come to a close.

## 2.2 Budget

The total budget for Task Order #6107 was \$110,000 over two years, \$50,000 per year for primary project funding, and \$10,000 for a special project. Caltrans elected to use the \$10,000 special project funding for their contribution to the Asilomar Conference, August 21-24, 2007. With the submission of this Final Report, the project account balance should be \$0.

A detailed financial quarterly invoice has been submitted to PATH in parallel to this Final Report. Please contact Christina Adamson, the ITS-Davis Financial Coordinator ([cadamson@ucdavis.edu](mailto:cadamson@ucdavis.edu)), for additional copies of this information. All contract invoices are submitted through the university's Sponsored Programs Office (SPO).



### 3 Special Project Summary

For this Task Order, the Caltrans Special Project funds were used to support the ITS-Davis Asilomar Transportation Energy Conference. This event is held every other year and focuses on a critical topic of the time in transportation energy usage. The Caltrans contribution was used for general conference support and was instrumental in making the program a success. This year's event focused on climate change. Event information can be found at: [www.its.ucdavis.edu/events/outreachevents/asilomar2007/index.php](http://www.its.ucdavis.edu/events/outreachevents/asilomar2007/index.php)

#### 3.1 Discussion

The 11th Biennial Conference on Transportation and Energy Policy investigated three broad strategies for reducing greenhouse gas emissions from transportation: reducing motorized travel, shifting to less energy intensive modes, and changing fuels and propulsion technologies. This invitation-only gathering drew its largest attendance yet, 283 attendees, with representatives from industry, academia, international governments and NGOs, and was held August 21-24, 2007 at the Asilomar Conference Center in Pacific Grove, Calif. Following are some highlights of the thorny questions posed at the conference, and some of the many thoughtful perspectives on the issues, as discussed in the closing roundtable discussion.

##### *Can CO2 really be reduced by 60-80% by 2050?*

- We'll need a combination of policies and actions – reduced vehicle miles traveled (VMT), improved vehicle fuel economy, and reduced carbon content in fuel – to successfully reduce GHG in the transportation sector. If you can't do all three and don't get policies lined up to move all three, we could easily see a repeat of the last 20 years, where technology has marched along but rated fuel economy has been flat. --George Eads, CRA International
- It's not a question of what we can do. We have to shift the discussion to 'how do we do what we must do.' Politicians are starting to come around. Consumer behavior is central. It will require creativity but it can be done. Historically, society has shifted and the country has tackled big problems, as soon as politicians have stepped up to the plate. -- John DeCicco, Environmental Defense
- It cannot be done by rationing energy. It needs to be done with a net economic benefit. Everybody has to be involved, and everyone has to want to use less than they can afford. Additionally, cars have to weigh less; we can't do it without that element. -- Bob Epstein, E2

##### *Is VMT reduction a realistic goal and how?*

- Absolute VMT reduction on the global scale is probably not a realistic goal. But cutting growth in half by 2055, is a "slam dunk" and absolute flat VMT is not out of the question, thanks to population aging trends, demand reduction strategies, and increased investment in transit, pedestrian and bicycling projects globally. Ten years from now I'll bet that the 3-year VMT trend is a flat line or downward trend.  
--David Burwell, BBG Group

##### *Is there a paradigm shift in consumer behavior?*

- We've made such a limited effort to change consumer behavior. For example, in California, we've reduced consumer energy consumption by 10% with a modest investment. A similar modest investment in the transportation sector would be far greater than we're doing today. We're understating the potential, with investment in public education. --Tim Carmichael, Coalition for Clean Air
- Anyone counting on it will be sorely disappointed, primarily due to a single factor: rising standard of living. People want to enjoy the fruits of their labor and telling them they can't spend money on things they want is pointless. --John German, Honda

***What is the role of economy-wide policies in transport?***

- We see a perfect storm building. Climate change is one – with an interesting time factor. The second piece is peak oil – we'll be on our knees if it happens. The third piece is mega cities – with severe air pollution. We simply have to get away from oil. We don't have any options. These mega cities with massive numbers of vehicles and stagnant air patterns – even if we're efficient, and we reduce VMT, it still all adds up. The answer is to electrify the vehicle. -- Chris Sloane, General Motors
- We need a portfolio approach and to support a range of technologies, some of which have uncertainties. And given that it takes time to ramp up any of these solutions, it says we can't pick winners. We also need to be willing to stay in there for the long term. --Joan Ogden, ITS-Davis

**3.2 Conclusions**

The ITS-Davis Asilomar Conference has become an important venue for true stakeholder dialogue on the important transportation issues, in this year's case climate change. The majority of attendees recognize that the level of expertise and the caliber of dialogue are very high at this event. Involving Caltrans in such a dialogue is critical given how influential the agency continues to be in California's transportation system. One important outcome of this event is the recognition from each attendee of how other stakeholders view the challenge. This interdisciplinary awareness is very important as climate change issues will force Caltrans and other organizations to work together in solving the problem.

At the conclusion of the event, David Greene of Oak Ridge National Laboratory posed a final declaration for all attendees – an assumed common understanding:

- Climate change is real, transportation's emissions are a major part of the problem, and they must be reduced.
- National policy has so far failed to adequately address transportation's role in climate change; this can and must be remedied.
- All stakeholders want to work cooperatively to reduce transportation's GHG emissions, for the public good.
- There are innovative solutions to the problem of GHG emissions from transportation that will contribute to a better transportation system for current and future generations.

**3.3 Recommendations**

It is recommended that Caltrans continue to take part in these and other similar events. Opportunities such as this will be available through future ITS-Davis Asilomar conferences (every other year), and through Caltrans' participation in the new ITS-Davis Sustainable Transportation Energy Pathways (STEPS) Program. A new Task Order 6121 has already been

approved for sponsorship of the STEPS Program and ITS-Davis looks forward to working with Caltrans in this new program.

## 4 Recent Publications

- Farrell, Alexander E. and Daniel Sperling (2007) A Low-Carbon Fuel Standard for California, Part 1: Technical Analysis. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-07-07
- Farrell, Alexander E. and Daniel Sperling (2007) A Low-Carbon Fuel Standard for California, Part 2: Policy Analysis. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-07-08
- Heffner, Reid R., Kenneth S. Kurani, Thomas S. Turrentine (2007) Symbolism In Early Markets For Hybrid Electric Vehicles. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-07-01
- Hughes, J.E., C.R. Knittel and D. Sperling, "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand," *Energy Journal*, 29(1), January 2008.
- Hughes, J.E., C.R. Knittel and S.P. Holland, "Greenhouse Gas Reductions under Low Carbon Fuel Standards?," *In submission*.
- Lin, Z., C.W. Chen, J.M. Ogden and Y. Fan. "Optimized Pathways for Regional H<sub>2</sub> Infrastructure Transitions: A Case Study for Southern California," Presented at the 2nd World Congress of Young Scientists on Hydrogen energy systems, accepted for publication in *International Journal of Hydrogen Energy*, 2007.
- McCarthy RW, Ogden JM, and D Sperling (2007) "Assessing reliability in energy supply systems," *Energy Policy*, 35(4):2151:2162.
- Nicholas, M.A. and J.M. Ogden (2007) "Detailed Analysis of Urban Station Siting for California Hydrogen Highway Network." *Transportation Research Record 2006* (1983), 129 - 139.
- Parker, Nathan C. (2007) Optimizing the Design of Biomass Hydrogen Supply Chains Using Real-World Spatial Distributions: A Case Study Using California Rice Straw. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-07-04
- Sperling, D., review of *Beyond Oil and Gas: The Methanol Economy*, by George A. Olah, Alain Goeppert, G.K. Surya Prakash (Wiley-VCH, 2005), in *Energy Journal*, 28(1) 2007:178-179.
- Sperling, D., "Asilomar Declaration on Climate Policy," *Access* (University of California Transportation Center), Fall 2006, pp.11-21
- Turrentine, Thomas S. and Kenneth S. Kurani (2007) Car buyers and fuel economy?. *Energy Policy* 35 (2007), 1213 – 1223
- Wang, G., J.M. Ogden, M.A. Nicholas, "Lifecycle impacts of natural gas to hydrogen pathways on urban air quality," *International Journal of Hydrogen Energy*, Article in Press, Corrected Proof
- Weinert, J.X., Shaojun, L., J.M. Ogden, and Jianxin, M., "Hydrogen Refueling Station Costs in Shanghai," accepted for publication in the *International Journal of Hydrogen Energy*, 2007.
- Williams, Brett D. and Kenneth S. Kurani (2007) Commercializing light-duty plug-in/plug-out hydrogen-fuel-cell vehicles: "Mobile Electricity" technologies and opportunities. *Journal of Power Sources* 166 (2), 549 – 566
- Yang, C., and J.M. Ogden (2007). "Determining the lowest-cost hydrogen delivery mode." *International Journal of Hydrogen Energy*, 32(2), 268-286.



## 5 Appendix A: Select Project Summaries

**Project Title:** LA Case Study of Hydrogen Infrastructure Transition Model  
**Project Leader:** Zhenhong Lin (David)  
**Related Thread or Track and advisor:** Hydrogen+Infrastructure, J.Ogden, Y. Fan)

### *Project Objectives*

The project is to apply the HIT model to the Los Angeles area. The HIT model, developed as part of the Hydrogen Pathway Program, identifies the regional least-cost hydrogen by considering regional details, technology improvement, competition and coexistence, carbon policy and demand growth. Understanding the regional least-cost hydrogen is important not only to improving knowledge of hydrogen as a new fuel, but also to ensuring proper fuel comparison.

### *Project Milestones*

- Two papers were accepted for presentation at the Hysydays 2007 conference and publication on the International Journal of Hydrogen Energy. One of them won the Best Paper award.
- One paper is accepted for presentation at the incoming EVS-23 conference.

### *Project Description*

My current on-going project, called HIT-LA, is applying the Hydrogen Infrastructure Transition (HIT) model to the Greater Los Angeles area. The HIT model, developed as part of the Hydrogen Pathway Program, looks at the optimal regional transition to a hydrogen fuel system under user-specified scenarios.

The HIT-LA project fits within the scope of the STEPS Program. Firstly, it tries to explore the least-cost transition to a hydrogen fuel system. Understanding the best that can be done is important not only to improving knowledge of hydrogen as a new fuel, but also to ensuring proper fuel comparison. Secondly, the HIT-LA project will also consider the transition from the current gasoline system to a hydrogen system. It will explore the optimal market penetration process of hydrogen (and fuel cell vehicles) under the perspective of maximizing the social welfare in meeting transportation demand (not hydrogen demand) over time.

The main modeling technique is dynamic programming, which optimizes the infrastructure buildup decisions over time to minimize the cost. The model is basically finished and ready for specific region application. For the LA case study, data collection and analysis have been completed for some scenarios. We will look at more scenarios.

### *Collaboration Goals and/or Interests*

Dr. Joan Ogden and Dr. Yueyue Fan are the two main guiding advisors of this project. Steven Chen has also helped with the project.

**Project Title:** Station Network Analysis  
**Project Leader:** Marc Melaina and Joel Bremson  
**Related Thread or Track and advisor:** Infrastructure, Melaina

### ***Project Objectives***

Complete analysis of station clustering and document results. Extract appropriate data for publication in a journal-quality article. Target journal: Energy Policy.

### ***Project Milestones***

1. Completed tasks of previous 3 months:
  - a. Draft paper completed for station density thresholds (station availability analysis)
2. Goals for next 12 months:
  - a. Complete final version of station density threshold paper and submit to Energy Policy.
  - b. Prepare second paper on clustering and station sizes. This paper will outline the results related to a regular distribution of relative station sizes within and across urban areas.
3. Long-term goals through project completion and graduation.
  - a. At least one additional paper will be based upon this analysis. It will compare the clustering results to similar studies completed and presented in the context of Zipf's law for regular distributions of size across multiple phenomena.

### ***Project Description***

The goal of this project is to improve simulation models representing the near-term development of hydrogen refueling station networks, with an emphasis on station numbers, sizes, locations and rollout dynamics. The model under development includes two levels of resolution: 1) urban areas, and 2) interstates and rural areas. The analysis of station networks in urban areas compliments other H2 Pathways research projects, including the idealized city model and station siting analysis. The policy question to be addressed is the role of competition and stakeholder coordination in the early stages of infrastructure rollout.

### ***Collaboration Goals and/or Interests***

This project will provide a generic representation of gasoline station size distributions within cities, and will prove useful for a variety of existing and future infrastructure studies. For example, it may inform improvements to the hydrogen Steady State Model (C. Yang), or various ongoing and proposed infrastructure transition models (J. Ogden or Y. Fan projects).

## 6 Appendix B: STEPS Research Symposium

### 6.1 Agenda

#### 2007 Research Symposium Agenda

University Club  
University of California, Davis

*Monday, May 21, 2007*

**7:30 am**      **Continental Breakfast**

**8:00 am**      **Welcome and Event Overview**

*Joshua Cunningham, Program Manager, STEPS Program*

**8:15 am**      **The Dynamic Context for Sustainable Transportation Energy Research**

*Joan Ogden, Professor and Director, STEPS Program*

Professor Ogden will describe the current context and prospects for alternative fuels in the United States and around the world, highlighting recent trends in technology advancement and policy. This will set the context for the role of an academic research program, the Sustainable Transportation Energy Pathways (STEPS) Program.

**8:45 am**      **The Low Carbon Fuel Standard in California**

*Marc Melaina, Project Scientist, ITS-Davis*

The low carbon fuel standard (LCFS) in California is an innovative policy measure with the goal of cutting carbon intensity of fuels by 10% by 2020. Dr. Marc Melaina is on the UC Davis team evaluating options for meeting the LCFS. This talk describes the policy process and scenarios for this initiative.

**9:00 am**      **STEPS Research Program Overview**

*Joshua Cunningham, Program Manager, STEPS Program*

This talk will outline the goals and research plans for the STEPS Program, describing how our research will contribute to understanding future options for reducing emissions of greenhouse gases and criteria pollutants and diversifying fuel supply

**9:15 am**      **Break**

**9:30 am**      **STEPS Research Highlights**

*STEPS Program Research Leaders*

The STEPS Program and research team encompasses a broad suite of expertise. Research “track” and “thread” summaries will be presented by STEPS research leaders, highlighting important research questions in each area and specific projects already launched. The goal is to present our proposed research plan, and to solicit feedback from our sponsors and invited experts.



- 9:30 am *Consumer Demand and Behavior Thread – Ken Kurani*
- 9:50 am *Policy & Business Strategies Thread – Chris Knittel*
- 10:10 am *Vehicle Technical Evaluation Thread – Andy Burke*
- 10:30 am *Integrative Scenarios Thread – Marc Melaina*
- 10:50 am *Infrastructure System Analysis Thread – Chris Yang*
- 11:10 am *Discussion – possible research topics pertaining to Research Threads*
- 11:30 pm Lunch**
- 1:00 pm Program Sponsorship Overview**  
*Joe Krovoza, Director of Development, ITS-Davis*
- 1:10 pm STEPS Research Highlights, continued**
- 1:10 pm *Biofuels Track – Bryan Jenkins*
- 1:25 pm *Electricity Track – Tom Turrentine*
- 1:40 pm *Fossil Fuels Track – Cynthia Lin*
- 1:55 pm *Hydrogen Track – Joan Ogden*
- 2:10 pm *Environment, Energy, & Cost Analysis Thread – Mark Delucchi*
- 2:30 pm *Discussion and questions*
- 2:45 pm Break**
- 3:00 pm Stakeholder Perspectives on Sustainable Energy for Transportation**  
*Moderator: Marc Melaina, Project Scientist, ITS-Davis*
- Through a series of presentations, this session will highlight key technology, business and policy issues of the various stakeholders involved; including industry, government, and the environmental community. Each speaker will identify key challenges and questions about alternative fuels and vehicles that can be addressed in an academic program such as STEPS.
- 3:00 pm *Automobile Industry Perspective – Andreas Truckenbrodt, DaimlerChrysler*
- 3:20 pm *Electric and Gas Utility Perspective – Jill Egbert, Pacific Gas & Electric*
- 3:40 pm *NGO / Environmental Group Perspective – Roland Hwang, NRDC*
- 4:00 pm *Biofuels Industry Perspective – Luca Zullo, Cargill*
- 4:20 pm *Energy Company Perspective – Dave Austgen, Shell Hydrogen*
- 4:40 pm *Discussion – Possible research directions for STEPS*
- 5:30 pm Adjourn**  
**Cocktails & Dinner Reception at Bistro 33**  
*226 F Street, Davis (corner of F and 3<sup>rd</sup>)*

*Tuesday, May 22, 2007*

**7:30 am**      **Continental Breakfast**

**8:00 am**      **Welcome, Overview of Second Day**  
*Joshua Cunningham, Program Manager, STEPS Program*

**8:15 am**      **Insights from Modeling Alternative Fuel Transitions**  
*Paul Leiby, Oak Ridge National Laboratory*

Dr. Leiby will discuss lessons learned from his studies of transitions in the transportation sector, considering consumer decisions, infrastructure buildup and technology evolution.

**8:45 am**      **The U.S. DOE Multi-Pathway Research Program**  
*Margaret Singh, Argonne National Laboratory*

The U.S. Department of Energy has launched an analysis program comparing the merits of multiple alternative fuel and vehicle pathway combinations. Highlights of this program will be presented.

**9:15 am**      **Break-Out Discussion Groups**  
*Moderator: Joshua Cunningham, Program Manager, STEPS Program*

A key advantage for sponsors of the STEPS Program is the ability to provide feedback and suggest new research directions. In this session, several breakout groups will be organized around a series of STEPS research topics (for example: “biofuels” or “infrastructure development”). A discussion will be led by STEPS principal researchers, with assistance from graduate students. The goal is to brainstorm about the proposed STEPS research program and gather valuable feedback from sponsors and invited experts.

**10:30 am**      **Break**

**10:45 am**      **Summary and Highlights from Break-Out Group Discussions**  
*Moderator: Aaron Singer-Englar, Assistant Program Mgr, STEPS Program*

**11:45 am**      **Concluding Remarks, Next Steps**  
*Joan Ogden, Professor and Director, STEPS Program*

**12:00 pm**      **Adjourn**

## 6.2 Sponsor Feedback Notes

During the second day of the STEPS Research Symposium, the sponsor members and UC Davis researchers split into teams to discuss pre-selected topics. The goal of the discussion period was to identify the key challenges and opportunities for the various alternative fuel and vehicle options considered for the transportation energy challenge. This section outlines the compilation of comments from the discussion groups.

### ***Stakeholder General Perspectives***

- Automobile Industry
  - The customer will decide
  - Realistic technology progress, product development timeline
  - Realistic Policy expectations are important
- Electric and Gas Utility
  - Integrate vehicles into utility demand. Better utilize grid with PHEVs (little new infrastructure change to get started)
  - This is the best Use of Feedstock
  - Capturing Externalities in Market Decisions; LCA
- NGO/Environmental Group
  - Stresses efficiency. Environmental impacts of unconventional oil, coal, biofuels? Need to consider all of this
- Biofuels
  - Diversity of paths with differing impacts
- Energy Company
  - Future energy sources must address 3 E's

### ***Understanding Alternative Fuel Transitions***

- Transition barriers are very important
- Simulations almost always see only one fuel/technology in the future
- Need some initial push for alternative fuel vehicles, coupled w/policies
- Niche markets won't necessarily address retail availability, and may not move fast enough
- Hydrogen and fuel cells may be the toughest transition to model
  - Policy required to cross to competitiveness, sustainable transition is possible
  - Costs to reach sustainable transition may not be unthinkably high (\$10sB)
- Do we need 1 silver bullet or 2? (more than one problem)
- Important questions (STEPS topics?):
  - How can we best represent technological change?
  - Interactions with other energy markets? Supply curves?
  - How do consumers value fuel availability? (outside home region?)

### ***Understanding Multiple Alternative Fuel Pathways***

DOE Multi-Path study outlined

- Phase 1: Developed 10 scenarios with different mixes of Light duty vehicles. Employed scenarios models (VISION)

- Phase 2: Will include more pathways, characterize scenarios more fully. Far more focus on costs. Consider criteria pollutants, oil security, risk analysis, interactions with rest of economy (NEMS EERE). Add consideration of consumer choice. Add feedback on fuel prices.
- STEPS will interact with multi-path study going forward. An ITS-Davis intern is now resident in Washington DC working on this project.

### **Group 1: Electric vehicles**

#### WHAT SHOULD STEPS ADDRESS?

- Consumer behavior, expectations
  - How do we quantify value of the vehicle features?
  - How much are they willing to pay?
  - Who are they?
- Policy solutions to incentivize consumers?
- Niche markets?

#### SPECIFIC PROJECTS

- Consumer behavior studies
- Identify large niche markets? (postal service, etc.)
- Business proposition for batteries? (secondary markets, recycling, mitigate risk)
- New comparative metrics for EVs and liquid fuels?
- Strategic and supply constraints (materials for PHEVs)

### **Group 2: LCA Energy, Environmental and Cost Analysis**

- Discussion centered on lifetime cost analysis (ITS-Davis AVCEM model)
- WHAT ARE THE BIG QUESTIONS?
  - What costs should be included?
  - Treatment of fixed costs in producing automobiles
  - How to pick system boundaries for the analysis (national, global?)
- SPECIFIC STEPS PROJECTS
  - Use AVCEM as input to policy analysis
  - Better understand relationship between production volume and manufacturing costs (how many suppliers?)
  - What is the role of conventional combustion engines as new vehicles/fuels are being introduced?
  - How much can we trade-off performance vs. cost for alt fueled vehicles?

### **Group 3: Business and policy strategy**

#### Biggest hurdles in next 25 years?

- Regional best options should be maximized
- Variable time horizon (product cycles, policy, elections, long term plans)
- Lack of info, confusion among consumers and policymakers
- Many variables in business decisions. complicated
- Data availability, realism

#### Projects/areas for STEPS to address

- Information creation
  - Technologies, scenarios

- Information dissemination
- Design of policies
- Resource pricing

**Group 4: Challenges in infrastructure systems development**

- Hydrogen
  - Home refueling
  - Hydrogen distribution to homes for heating, etc.,
  - Synergies between hydrogen and wind
  - What policies could get us to hydrogen?
- Biofuels
  - Some biofuels are relatively easy to use in existing infrastructure, ethanol is not compatible
  - Technology lock-in with ethanol? Spatial lock-in if we build much larger corn ethanol system?
  - Better biofuels than ethanol?

**Group 5: Biofuels**

Biggest hurdles in next 25 years?

- Social Impacts of biomass production and use including
- Ethanol combustion issues
- Competition for feedstock when biofuels are developed at scale (among biofuels pathways as well as biomass for electricity/heat)
- Cost of biofuels (related to all of the above)

Projects/areas for STEPS to address

- Look at biofuels other than ethanol and fatty acid methyl-ester (FAME) biodiesel
- Need to model cross sector impacts from large biomass/biofuels development
- Need strong agricultural community and ag. econ. Involvement
- Public Education and Outreach regarding biofuels and biomass

## 7 Appendix C: Hydrogen Pathways Final Workshop

### ***Hydrogen Pathways Workshop Agenda*** **“What Have We Learned from The Hydrogen Pathways Program?”**

*Tuesday, September 26, 2006*

#### ***Registration and Continental Breakfast at 8:00 AM***

##### **Session I: Welcome and Workshop Overview**

*Dan Sperling and Joan Ogden, UC Davis Institute of Transportation Studies*

The Hydrogen Pathways program is an interdisciplinary exploration of a contentious piece of the energy puzzle: use of hydrogen in transportation. In this workshop our goal is to synthesize what we have learned by considering a set of crucial issues. The introductory talk sets the context and poses the key questions.

##### **Session II: Why Hydrogen and When?**

*Joan Ogden, UC Davis Institute of Transportation Studies*

We focus on transportation energy context and the motivations for considering hydrogen as a future transportation fuel.

##### **Session III: Who Will Buy a Hydrogen Car?**

*Ken Kurani, UC Davis Institute of Transportation Studies*

Understanding potential demand for hydrogen is difficult because both the technology and the policy landscape are rapidly evolving. While recognizing that future demand cannot be predicted with certainty, we seek to understand the factors that might drive demand for hydrogen. Will attributes such as mobile electricity, plug-in capability or zero emissions make hydrogen vehicles attractive to consumers?

##### **Session IV: Graduate Researchers present posters**

*David McCollum, UC Davis Institute of Transportation Studies*

This session will start with a brief introduction of each Graduate Student in the Hydrogen Pathways Program and topics for their posters. We then break up and participants are free to walk around and discuss the posters with the researchers.

##### **Session V: Where Will the Hydrogen Come From**

*Anthony Eggert, UC Davis Institute of Transportation Studies*

What are the options for near term and long term supply? Do we have enough resources to make hydrogen for vehicles? How will regional issues and policy impact which resources are used?

##### **Session VI: What Will a Hydrogen Infrastructure Look Like?**

*Christopher Yang, UC Davis Institute of Transportation Studies*

Development of hydrogen infrastructure is an important challenge in implementing hydrogen transportation fuel. UC Davis researchers have developed innovative techniques for analyzing and visualizing how a hydrogen infrastructure might develop over time. Here we present insights about key factors in infrastructure design. How much will hydrogen infrastructure cost? Where will it start? Will it be distributed or centralized? What are the impacts of scale, geographic location, and technological progress?

**Session VII: How Can We Make a Transition to Hydrogen?**

*Joan Ogden, UC Davis Institute of Transportation Studies*

What can we learn from past technological transitions? Are there low cost strategies to build infrastructure over time? Who will build a hydrogen energy system? What is the role of policy?

**Cocktail Hour & Dinner at 5:30 PM**

*Wednesday, September 27, 2006*

**Continental Breakfast at 8:00 AM**

**Session VIII: Hydrogen: what are the social costs and benefits?**

*Mark Delucchi, UC Davis Institute of Transportation Studies*

Through rigorous analysis, we seek to understand the key questions about the societal costs and benefits of hydrogen transportation. What are the potential environmental impacts of using hydrogen as a transportation fuel, with respect to energy use, and emissions of greenhouse gases and criteria pollutants? How might hydrogen impact energy security? This session will demonstrate the LEM and AVCEM models to estimate emissions and societal costs for a range of alternative fuels and vehicles, with a focus on hydrogen.

**Session IX: Business and Policy Strategies**

*Gustavo Collantes, UC Davis Institute of Transportation Studies*

This session will be focusing on 1) policy process surrounding hydrogen; 2) evaluation of policy alternatives and their likely implications for the transition; and 3) the development of business strategies for a hydrogen economy.

**Session X: What Have We Learned and Future Directions**

*Joan Ogden, UC Davis Institute of Transportation Studies*

As a final talk, we will summarize what we learned about the future of hydrogen in transportation from the research conducted under the H2 Pathways program. Are there synergies with other technologies such as hybrid vehicles, and low carbon electric sector technologies? How might hydrogen interact with the rest of the energy system? What are the key questions and recommendations going forward?

**Meeting Adjourns at 12:00 Noon**

**Welcome BBQ with new ITS students**

## 8 Appendix D: STEPS Policymaker Outreach Event

### **Future Transportation Energy Opportunities and Challenges**

Tuesday, January 23, 2007 (2:00 – 4:00 pm)  
Room HC5, Capitol Building (Enter South Side)  
Washington, DC

*Sponsored by Congressman Mike Thompson*

#### **2:00 pm Introduction and Overview**

Anthony Eggert, *Research Director, ITS-Davis*

#### **2:05 pm Future Transportation Energy – What are the promising options and how should we evaluate them?**

Anthony Eggert

#### **2:20pm Biofuels – Current status and future direction**

Dan Sperling, *Professor and Director, ITS-Davis*

#### **2:40pm Hybrids to Plug-ins – Increasing electrification of the automobile**

Tom Turrentine, *Director, Plug-in Hybrid Electric Vehicle Center, ITS-Davis*

#### **3:00 pm Hydrogen and Fuel Cells – Pathways and strategies**

Joan Ogden, *Professor, Environmental Science and Policy; Co-Director, Sustainable Transportation Energy Pathways, ITS-Davis*

#### **3:20 pm Sustainable Transport – Putting it all together**

David Greene, *Senior Researcher, Center for Transportation Analysis, Oak Ridge National Laboratory*

#### **3:40 pm Discussion – All**

#### **4:00 pm Adjourn Panel Discussion (Speakers available until 5:00 pm)**

#### **8:00 pm ITS-Davis, TRB Annual Reception (8:00 – 11:00 pm)**

All invited – John F. Kennedy Presidential Suite, Room 625, Omni Shoreham Hotel, 2500 Calvert Street NW, Washington DC