

SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS  
A Research Summary for Decision Makers

**Edited by Joan Ogden and Lorraine Anderson**



Institute of Transportation Studies  
University of California, Davis  
One Shields Avenue, Davis, California 95616

© 2011 by The Regents of the University of California, Davis campus  
All rights reserved. Published 2011

Available under a Creative Commons BY-NC-ND 3.0 license  
<http://creativecommons.org/licenses/by-nc-nd/3.0/>.  
For information on commercial licensing, contact [copyright@ucdavis.edu](mailto:copyright@ucdavis.edu).

## Acknowledgments: STEPS Program Sponsors

Much of the research presented in this book was drawn from the Sustainable Transportation Energy Pathways (STEPS) program at the Institute of Transportation Studies at the University of California, Davis. STEPS was created in 2007 as a four-year research consortium to explore the prospects for alternative fuels and vehicles. The STEPS program was made possible through the generous support of 23 STEPS consortium sponsors. Our sponsors are global leaders in the areas of alternative fuels and vehicles, bringing diverse perspectives from the automotive and energy industries and the public sector. In addition to providing program funding, STEPS sponsors contributed their ideas, insights and expertise through a series of STEPS workshops and many individual meetings. UC Davis researchers and students benefited greatly from these valuable interactions. We deeply appreciate our sponsors' support and engagement. The work presented in this book would not have been possible without them.

The STEPS program was sponsored by the following 23 organizations:

**BMW**  
**BP**  
**California Air Resources Board**  
**Caltrans**  
**Chevron**  
**Conoco Phillips**  
**Daimler**  
**Ford**  
**GM**  
**Honda**  
**Indian Oil**  
**Natural Resources Canada**  
**Nissan**  
**Pacific Gas & Electric Company**  
**Sempra Energy**  
**Shell**  
**South Coast Air Quality Management District**  
**Total**  
**Toyota**  
**U.S. Department of Energy**  
**U.S. Department of Transportation**  
**U.S. Environmental Protection Agency**  
**Volkswagen**

# Acknowledgments

We would like to thank David Greene (Oak Ridge National Laboratory), Steve Plotkin (Argonne National Laboratory), Anthony Eggert (California Energy Commission), Joshua Cunningham (California Environmental Protection Agency), and Marc Melaina (National Renewable Energy Laboratory) for their insightful expert reviews of sections of this book in draft form. We also thank all the STEPS researchers over the past four years who have contributed to the program's success.

## **Chapter 1: The Biofuels Pathway**

The authors would like to thank Quinn Hart, Peter Tittmann, and Colin Murphy (UC Davis), Richard Nelson (Kansas State University), Ken Skog (USFS), Ed Gray (Antares), and Alex Schroeder (Western Governors' Association) for sharing their expertise through conversations over the years and contributing to the case study presented in the chapter. Additionally, the authors thank Yueyue Fan, Sonia Yeh, and Dan Sperling (UC Davis) for helping develop our understanding in many useful discussions.

## **Chapter 2: The Plug-In Electric Vehicle Pathway**

The authors would like to thank Jamie Davies, Michael Nicholas, and Justin Woodjack for contributing insights from their research to improve this chapter. We would like to acknowledge the STEPS program and the UC Davis PH&EV Research Center for their support of this research. Individual authors would also like to thank the California Energy Commission and the Social Sciences and Humanities Research Council of Canada for funding aspects of this research.

## **Chapter 3: The Hydrogen Fuel Pathway**

The authors would like to thank Daniel Sperling, Mark Delucchi, Sonia Yeh, and Andrew Burke (UC Davis), David Greene, Paul Leiby, and Zhenhong Lin (ORNL), Steve Plotkin and Marianne Mintz (Argonne National Laboratory), Catherine Dunwoody and Bill Elrick (California Fuel Cell Partnership), Anthony Eggert (CEC), Marc Melaina (NREL), Uli Bunger, Christophe Stiller, and Reiner Wurster (LBST), and Alan Lloyd (ICCT) for many useful discussions about hydrogen transitions over the years that have helped inform our thinking. We also acknowledge valuable input from STEPS sponsors, including Phil Baxley, Jim Volk, Duncan Macleod, and Angus Gillespie (Shell), Puneet Verma, Nichole Barber, and Jonathan Weinert (Chevron), Andreas Truckenbrodt (Daimler), Ben Knight, Robert Bienenfeld, and Steve Ellis (Honda), Craig Scott, Tak Yokoo, and Bill Reinert (Toyota), Fred Joseck and Sunita Satypal (USDOE), and Britta Gross and Norm Brinkman (GM).

## **Chapter 4: Comparing Fuel Economies and Costs of Advanced vs. Conventional Vehicles**

The authors would like to thank the UC Davis PH&EV Research Center for partial support, and Lorraine Anderson in particular for her careful edits of this chapter.

## **Chapter 5: Comparing Infrastructure Requirements**

The authors would like to thank Nils Johnson, Peter Tittman, Bryan Jenkins, Mike Nicholas, Steven Chen, and Eric Huang (UC Davis) for their insights on infrastructure designs that helped inform our thinking.

## **Chapter 6: Comparing Greenhouse Gas Emissions**

The authors would like to thank Andy Lentz and Anthony Kwong for compiling information useful for the preparation of this chapter. We would also like to thank Michael Wang, Joan Ogden, Stefan Unnasch, and Robert Williams for many years of useful and productive discussions and information sharing on the topic of the emissions from motor vehicle fuel cycles. We thank the UC Davis PH&EV Research Center for partial support, and Lorraine Anderson in particular for her careful edits of this chapter.

## **Chapter 7: Comparing Land, Water, and Materials Impacts**

The authors would like to thank the contributing authors of the journal articles on which this chapter is largely based, including Sarah Jordaan, Adam M. Brandt, Merritt R. Turetsky, and Sabrina Spatari, as well as David W. Keith for the fossil fuel land-use analysis. The authors would also like to thank the STEPS program for partial funding support, Joan Ogden for useful discussion and inputs, and Lorraine Anderson for helpful edits.

## **Chapter 8: Scenarios for Deep Reductions in Greenhouse Gas Emissions**

The authors would like to acknowledge Ryan McCarthy and Joan Ogden for contributions to the 80in50 modeling and analysis. In addition, we would like to thank the STEPS program for providing support for this research, participants at the Asilomar conference for inspiring this line of research, and Daniel Sperling, Joshua Cunningham, and Nic Lutsey for providing comments and guidance. Finally, we would like to acknowledge Lorraine Anderson for her help in editing this chapter.

## **Chapter 9: Transitioning the U.S. Light-Duty Sector**

The authors thank Daniel Sperling (UC Davis), Anthony Eggert (CEC), Joshua Cunningham (CARB), Wayne Leighty (Shell), and David Greene (ORNL) for useful discussions about light-duty vehicle transitions. Joan Ogden acknowledges the committee members of the NRC transition studies on hydrogen (2008) and plug-in hybrid vehicles (2009), especially Michael Ramage, Ed Rubin, Jim Katzer, Bob Shaw, Gene Nemanich, and Alan Crane, for many useful conversations while she served on these committees. Also, the authors would like to acknowledge Marc Melaina (NREL) for his role in helping develop the hydrogen transition model used in this study while he was a postdoctoral researcher at UC Davis.

## **Chapter 10: Optimizing the Transportation Climate Mitigation Wedge**

This chapter is largely based on work contributed by Alex Farrell, Richard Plevin, Alan Sanstad, and John Weyant for the U.S. analysis. The discussion of future work—some of which is already ongoing, especially the California model—benefited greatly from discussion and collaboration with Joan Ogden, Chris Yang, Daniel Sperling, and others in the STEPS program. We also thank Lorraine Anderson for her careful edits and useful suggestions that improved the accessibility of the chapter.

## **Chapter 11: Toward a Universal Low-Carbon Fuel Standard**

This chapter is a summary of the work on the California LCFS in the past three years and lays out the foundation for the ongoing work on the national LCFS led by the UC Davis Institute of Transportation Studies. The authors would like to honor their colleague Professor Alex Farrell for his leadership and intellectual contributions in developing the initial design of California's LCFS. Along with Daniel Sperling, he co-directed the initial study design of the LCFS in California and helped conceptualize this chapter before his untimely death in April 2008. We also acknowledge other UC colleagues who have contributed to the California LCFS work, including S. M. Arons, A. R. Brandt, M. A. Delucchi, A. Eggert, 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, and C. Yang; and colleagues who have collaborated with us on the national LCFS implementation and design, including Michael Griffin, Paulina Jaramillo, Haixiao Huang, Madhu Khana, Paul Leiby, Hayri Onal, Joan Ogden, Nathan Parker, Jonathan Rubin, Julie Witcover, and Christopher Yang.

## **Chapter 12: Key Measurement Uncertainties for Biofuel Policy**

The authors would like to thank the contributing authors of the journal articles on which this chapter is largely based, including Brenda Chang and Ben Sharpe for the time accounting analysis; as well as useful feedback by colleagues including Richard Plevin and Michael O'Hare (time accounting). We acknowledge the funding support of the California Air Resources Board, the Energy Foundation, the Packard Foundation, and the STEPS program.

## **Chapter 13: Beyond Life-Cycle Analysis: Developing a Better Tool for Simulating Policy Impacts**

The author would like to thank Richard Plevin of UC Berkeley for inspiring him to write this chapter and for helping develop some of the ideas (although the author takes full responsibility for the material). The author thanks the UC Davis/Chevron Research Program for partial support, and Lorraine Anderson for her excellent editorial suggestions.