

Addressing Transportation Energy and Environmental Impacts: Technical and Policy Research Directions

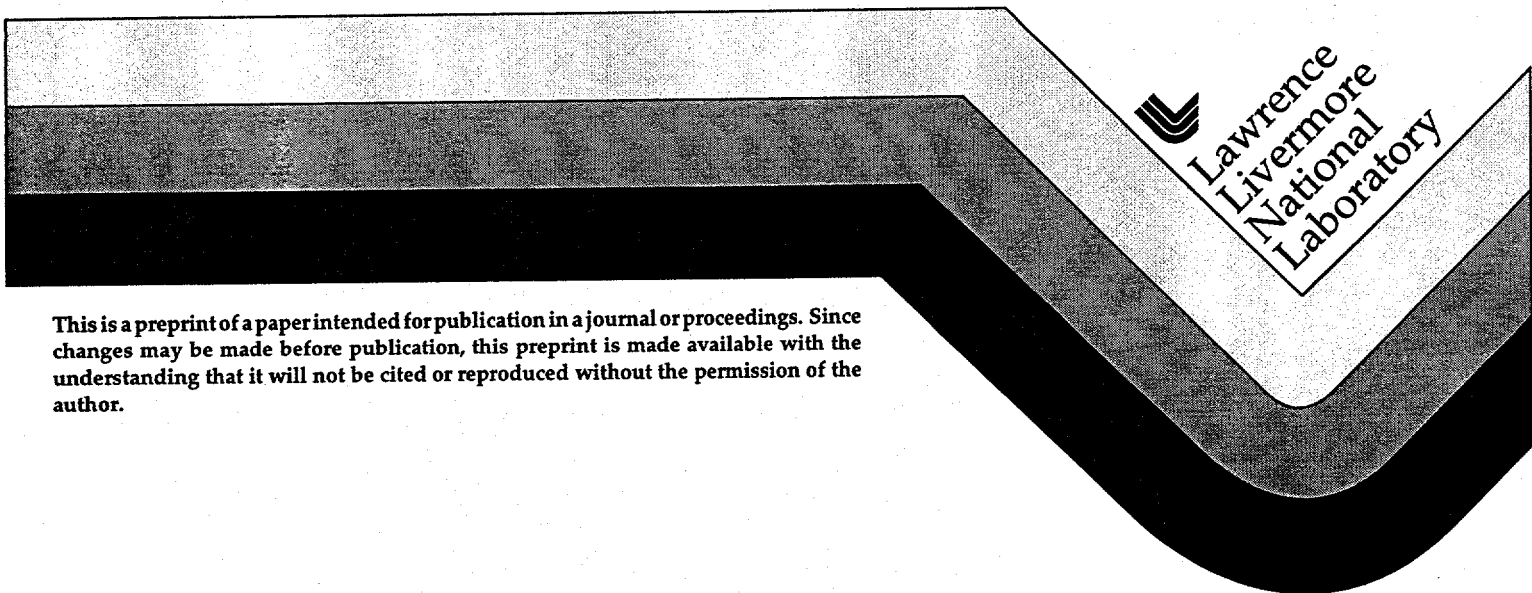
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A report on a workshop sponsored by the Lawrence
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August 10, 1995



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Summary*

The Lawrence Livermore National Laboratory (LLNL) is establishing a local chapter of the University of California Energy Institute (UCEI). In order to most effectively contribute to the Institute, LLNL sponsored a workshop on energy and environmental issues in transportation. This workshop took place in Livermore on August 10 and brought together researchers from throughout the UC systems in order to establish a joint LLNL-UC research program in transportation, with a focus on energy and environmental impacts.

This multi-disciplinary workshop was an occasion to learn about each other's research work and resources, and to identify research priorities and promising partnerships. We attempted to identify projects that will uniquely benefit from joint LLNL-UC efforts.

Following is an outline of the workshop goals, organization and topics. Following this outline are sections that report on the results of each breakout session. A list of attendees is contained in appendix B.

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

Workshop Outline

Location: LLNL, Livermore CA

Time: One day, Thursday August 10, 1995

Goals:

1. Establish a joint LLNL-UC research program in transportation, with a focus on energy and environmental impacts. Candidate issues include both technical and policy dimensions, with an expectation of representation by all relevant disciplines (science, engineering, economics, planning, public policy).
2. Identify:
 - critical problems and research topics
 - campus and LLNL expertise, resources, interests, and on-going programs
 - opportunities for partnerships
 - funding sources
3. Develop research priorities.
4. Establish mechanisms for continued interactions, e.g., a seminar series, future workshops.
5. Document the results of the workshop.

Workshop Organization

For one day, the staffs of LLNL and UC campuses will meet together to address the above goals. The meeting will be organized into four major topic areas, each coordinated by a representative of LLNL, and each involving contributions from all organizations. The four topic areas and their coordinators are:

1. **Alternative fuels** (Henrik Wallman)
2. **Advanced vehicle technologies** (Ray Smith)
3. **Policy** (Alan Pasternak)
4. **Intelligent Transportation Systems: Energy & Environmental Impacts** (Stein Weissenberger)

Workshop Agenda:

- | | |
|----------|---|
| 10:00 AM | Welcome and overview of program goals and processes |
| 10:30 | Four parallel technical sessions with presentations from campuses and LLNL on each of the four topics |
| 12:15 | Working lunches |
| 1:15 | (Parallel sessions cont.) |
| | Preparation of four program outlines and definition of follow-on processes |
| 5:00 | Formal adjournment and optional social hour/dinner |

Workshop content:

1. Alternate Fuels

- Individual fuel studies (e.g., H₂, CNG, Methanol, DME, reformulated gasoline)
- Cross-cutting studies (supply, emissions, infrastructure, deployment/transition scenarios and strategies, public policies for implementation)

2. Advanced vehicle technologies

- Hybrids
- Components (flywheels, ultra-capacitors, batteries, fuel cells)
- Advanced Vehicles
- Combustion
- Materials
- Catalysis
- Engine Controls

3. Policy

- Environmental and energy impact trends and forecasts: the combined effects of technology, demography, land use, and economics
- Estimating transportation costs and benefits
- Market vs regulatory approaches for producing desired system effects
- Pricing (emissions, road, parking)
- Taxes, subsidies and incentives
- Regulatory options: vehicles, fuels, emissions
- Research planning and policies
- Setting strategic policy goals
- Tools and data for policy analysis
- Policy comparisons
- Travel alternatives (e.g., telecommunications)

4. Intelligent transportation systems

- Emissions monitoring (on-vehicle and remote) and management
- Traffic control and traveler information
- Transportation system management
- Pricing
- Tools and data for estimating the emissions and energy impact of transportation/traffic management operations and policies

A Summary Report on the UC/LLNL Workshop on Alternative Fuels and Fuel Cells

Henrik Wallman

A workshop was held at Lawrence Livermore National Laboratory between researchers from the UC Campuses and LLNL on August 10. The purpose was to promote research collaboration in the area of transportation. This is a report on the sessions held on alternative fuels and fuel cells.

Fuel Cells

Prepared remarks were given by Sol Penner (UC San Diego), Tayhas Palmore (UC Davis), Glenn Rambach (LLNL), Joe Farmer (LLNL) and John Cooper (LLNL).

The potential for a "Center of Excellence" for Fuel Cells at LLNL was discussed at some length. Currently there is no such center in the US, and the opinion of some participants was that LLNL could aspire to such a position. However, some of the participants felt that such a center must have a broad range of FC activities encompassing all important FC types, i.e. proton exchange membranes, solid oxide, molten carbonate and phosphoric acid FCs (the latter two limited to stationary applications). To meet this requirement LLNL would need to establish new activities, or seek collaboration with other organizations so as to cover a broad enough range. Also the applications of the various FCs must be supported by appropriate research activities. However, no obvious funding source was identified for any new LLNL initiatives...

Alternative Fuels

Prepared remarks were given by David Rocke (UC Davis), Ken Kurani (UC Davis), Robert Dibble (UC Berkeley), Gene Berry (LLNL), John Reynolds (LLNL) and Henrik Wallman (LLNL).

Reformulated gasoline and its effects on emissions from on-highway vehicles was the subject of extensive discussions. The participants found the vehicle-to-vehicle variations particularly interesting and agreed that statistical analysis of on-highway performance is essential (Dynamometer testing alone does not provide the full picture). Future field measurements should include engine out emissions and not only tail pipe emissions so as to decouple catalytic converter effects from engine/fuel effects.

Reformulated diesel fuel was discussed briefly followed by a more extensive discussion of dimethyl ether (DME) as a new clean-burning diesel fuel. With respect to DME an opportunity of collaboration between UC Berkeley (Professor Dibble) and LLNL (Henrik Wallman) was identified. UCB's interest is centered on the engine performance with DME as a fuel whereas LLNL's interest is on the production of DME particularly from renewable sources such municipal and agricultural waste. LLNL has submitted a draft proposal to DOE and the California Energy Commission for a DME study.

Summary of Observations

The workshop was useful for making the participants aware of each other's activities. An example of this was the on-going DME work at UCB just as a LLNL researcher was preparing a DME proposal in a related field (Note that this was not competition for the same work but rather a complementary activity).

Increased collaboration between UC and LLNL has a very significant potential benefit to LLNL in the form of UC graduate students who conduct at least part of their research at LLNL. LLNL ought to promote the idea of graduate student research assistants or "GSRAs" working on site.

A Summary Report on the UC/LLNL Workshop on Addressing Transportation Energy and Environmental Impacts: Technical and Policy Research Directions

Stein Weissenberger

Intelligent Transportation Systems (ITS) Breakout Session

The ITS Breakout Session hear prepared presentations from the following:

Matt Barth (UCI): modal emissions assessment; modeling the emissions of an automated highway system (AHS); and a study using on-vehicle sensing for correlating driver/vehicle behavior with emissions.

Don Davis (LLNL): use of on-board sensors (required under OBD II) together with vehicle-to-roadside-communication (VRC) systems for monitoring the status of vehicle emissions control systems.

Mark Miller (UCB/PATH): studies of the environmental impacts of AHS.

Susan Shaheen (UCD): studies of the possible/likely impacts of ITS and related technologies over the next 20 years.

Alex Skabardonis (UCB): enhancements to signalized controls to achieve fuel and environmental benefits; integration of planning and simulation models for determining speed/acceleration profiles; research on car driving behavior.

Rao Vemuri (UCD): development of "personalized user interfaces," where the system learns patterns and applications of user, e.g., as an "information filter" for screening E-mail.

In addition, Bob Sawyer (UCB) stimulated a discussion of the status of engine/vehicle/emissions data. Lots of data exists, and it is not always either well-know or easily accessible. We should try to put what does exist to better use. Where the data isn't adequate (and there are numerous deficiencies), we should get good and appropriate data from direct measurements, minimizing our use of models until they are adequately calibrated and validated. Troy Young (UCD) cited his use of a GM "scanner" package that is convenient for recording vehicle states.

Possible topics for collaboration

Several topics were identified and discussed as promising for future UC/LLNL collaborations.

1. Use LLNL VRC technology for integrated programs in data collection for studies of emissions, correlation of emissions with driving behavior and traffic, and trip choice. Potentially interested parties: Davis, Barth, Troy Young (UCD), Skabardonis, Bob Sawyer (UCB). Use for calibrating models and evaluating policies.
2. Make use of LLNL models of advanced technologies in various modeling and analysis studies going on in the various campuses. E.g., test Davis' concept for emissions system status and monitoring in Susan Shaheem's analysis of the impact of ITS on emissions. Applies broadly (outside of ITS) to virtually all technologies being studied at LLNL. The campuses contain many disciplines necessary for a full analysis of the impact of transportation technologies (e.g., including market and demand modeling), while LLNL is developing the technologies; collaborations should be mutually beneficial in, on the one hand, informing the campus modeling work with accurate technical descriptions, and on the other hand, providing LLNL with broad and well-informed analyses of the relevant impacts of these technologies.

3. (Off-line discussions) Explore collaborations between LLNL decision analysts and UC PATH researchers in the following areas: a. research program planning and management, and b. ITS implementation planning. Joy Dahlgren (UCB/PATH) has invited Alan Sicherman (LLNL) to give a seminar at PATH to kick off the explorations.

Conclusions

In addition to the three specific points listed above, the discussion highlighted the simulative value of bringing together different viewpoints and disciplines. Further meetings around specific topics (e.g., the three cited above) could continue to provide the stimulation for new and productive ideas.

There was general agreement throughout the workshop that a better and more intensive use of graduate student researchers would be in everyone's interest.

Advanced Vehicle Technology Breakout Session

Ray Smith

The Advanced Vehicle Technology Working Group covered a number of potential collaborations between LLNL UC Faculty. The session was chaired by Ray Smith of LLNL who started the discussion by describing the LDRD supported Hybrid Vehicle Evaluation Code and its application to system studies on hybrid automobiles. Lively discussion ensued on the choice and sizing of the various components for such vehicles.

Don Bender, LLNL, described the current flywheel storage system (Electromechanical Battery or EMB) with emphasis on the research being done on magnetic bearings and containment. The CRADA's with both Westinghouse (stationary applications) and General Motors were discussed. It was also pointed out that Trinity Flywheel was building the rotors for LLNL's research program per our design criteria. Although the present containment structure weighs about 180 kgs, the 60,000 rpm, 0.75 kwh storage device is projected to ultimately weigh only about 50 kgs.

Tony Oppenheim who is already working with Allen Kuhl of LLNL on modeling combustion processes pointed out that people generally regard piston engines as the worst thing in the world! Tony, Professor Emeritus at UC Berkeley, maintains that modern microprocessor control of combustion, can reverse this thinking trend. He proposes the use of turbulent jets directed radially into the combustion chamber of piston engines could improve part load efficiency. Claims of in cylinder NOx reduction by a factor of 100 were made for such a system. Tony is seeking support of Allen Kuhl to do computational combustion modeling to support his proposition. They propose to target PNGV as a funding source.

Andy Frank, Professor of Mechanical Engineering at UC Davis, had an extensive handout on advanced electric and hybrid vehicles, ultralight super safe electric vehicles and a vehicle mass transportation system. Professor Frank suggested the following specific projects that could be cooperative between UC Davis and LLNL: (1) design and demonstration of hybrid powertrain alternatives;(2) design and demonstration of manufacturable vehicle structures which are safer, cheaper, stronger and lighter than steel and aluminum ;(3)

Advanced Vehicle Technology Breakout Session

Attendees/Outline of Discussion

Andy Frank -- Hybrid Vehicle

Jay Farrel, CECERT; Hydrogen trucks

UC Riverside, IVAS, GPS, navigation, power management

Drive by wire to reduce power transients and minimize emissions

Frank Tokarz, LLNL

John Cooper, LLNL -- Zinc Air Refuelable Battery

Allen Kuhl, LLNL -- A Division, turbulent mixing in exothermic systems; large Reynolds numbers; improved performance and Tony Oppenheim, 45 yr, writers

Jim Bobrow -- Control system design, UC Irvine, robotics, works with Derek Dunn-Rankin On-board

Jeff Wolfenstein, UC Irvine -- Chemistry and Material Sciences, now energy interest

Li battery with JPL, for spacecraft

L_{ion}

Salvador Aceves -- Hybrid simulations, accessory load efficiency improvement

Derek Dunn-Rankin -- Combustion in engines; how do universities contribute?

Action Item: how can labs help?

Ray Smith, LLNL -- System analysis for series hybrid vehicles

Don Bender, LLNL -- Passive magnetic barriers, currently mechanical bearings.

Spring '94 CRADA's

Trinity - Westinghouse

GM - prototype

Trinity - generic energy storage

Questions on containment: How do you handle the momentum transfer?

Answer: 25 kg. does not include containment; 1st containment structure weighs, 400 lbs.; 60,000 rpm, .75 kwh, total wt ~ 100 lbs.

Tony Oppenheim -- "Piston Engines are the Worst Things in the World" - is what people think.

Best known exothermi systems use combustion

Second Law should help us reduce irreversibilities

Microprocessor control of combustion within the cylinder

Turbulent jets directed radically into the cylinder to improve part load efficiency.

In cylinder No_x reduction could be reduced by factor of 100.

Need support for research to do computational combustion (with Kuhl).

Andy Frank -- handout; likes 2,200 lbs. empty wt.

Otto - Atkinson engine by over comparison

1) Advance hybrid electric vehicles

2) Ultralight super safe electric vehicles

3) Mass transport of vehicles (and people)

Rick Pekala -- Carbon aerogel ultracapacitors

0.8 g/cm³ → 25 farads/cm³

Bipolar stacks, university thermal & structural analysis

Students could do engineering analysis.

Andy Burke would like to look at doing that problem.

John Cooper, LLNL -- Zinc Air Battery refuelable and uses existing electrical infrastructure (electrical grid) to recover the zinc fuel (i.e., it's recycled).

Andy Burke -- Hybrid Vehicles - aftershock - Ford Taurus (Proposal rejected, submitted in 12/95)

Fuel Cells - PEMs with Ballard, steady state and transient ops.; modeling

Batteries - ZnBr with power cell;

Ultracapacitors - testing latest UC's by PRI; 2-3 kwh is beyond UC capabilities

[David Swan to Aerovironment]

Derek Dunn-Rankin -- Combustion control

Burner control - optimum performance with emissions

Search algorithms, *need for stability sensor NOx controlling fuel flow, swirl, also Sang Scheme.

*Find HP contact for vehicle software

Engine Controls of with optimizations

Students -- Getting involved will help. They can do some of the engineering less expensively

Mike Lederer -- UCB

Technology demonstration

Transportation concepts and scenarios

possibility of some kind of interactive group

Finally: New technologies for vehicles may open up totally new concepts for transportation.

Policy Breakout Session

Alan Pasternak

1. David Brownstone, Associate Professor of Economics at UC Irvine does micro-simulation modeling of demand for alternative fuel vehicles. He said he needs some help with alternative technologies and costs and developing defensible scenarios. I think he would really like to work with LLNL.
2. Bob Johnston, of the Division of Environmental Studies at UC Davis does regional economic and environmental modeling. His models link economic and GIS (Geographic Information Systems) models for regional transportation planning. The models are very large, and I think he would like some help with algorithms to simplify his models.
3. During another presentation by UCD (I believe it was Marshal Miller's) their work on hydrogen infrastructure was mentioned. Gene Berry, a summer student, has done some good work for us in this area. Perhaps there is an opportunity for some collaborative work here, although I would be surprised if Gene is not aware of what's going on at UCD in hydrogen.

APPENDIX A

Combustion in Engines

by

A.L. Kuhl and A.K. Oppenheim

Whereas combustion is the oldest technology of mankind, paradoxically enough, in primemovers such as the internal combustion engine, it has been taken so much for granted that today it is at a remarkably primitive stage--an unfortunate consequence of the belief that once the fuel is ignited, the rest is in the hands of God. This misconception is particularly striking if one takes into account the fact that, with the advent of micro-electronics, the execution of the process of combustion in an engine is appreciably longer than the time response of a micro-processor event. To make matters worse, public opinion about the drawbacks of combustion prime-movers, with their relatively low efficiency and harmful environmental impact, is based on the notably poor performance due to the archaic state of their technology.

It is, indeed, for this reason that the pursuit of perfecting the execution of the exothermic process of combustion in engines has been abandoned much too early--without any attempt to get out of this blind circle. As documented in numerous studies, on the other hand (vid. REFERENCES), the process of engine combustion can be significantly improved if one resorts to *internal treatment* instead of *external treatment* (e.g., chemical plants in the exhaust system, such as catalytic converters, particulate traps etc.), that have been adopted throughout the world for no other reason than people's disenchantment with the status quo of combustion technology. This is especially noteworthy if one takes into account the fact that the latter involves an intrinsic trade-off between fuel economy and pollutant emissions, while the former provides a remarkable synergy between these two constraints. A particular system whereby such a goal can be achieved is a micro-electronically controlled, direct-injection, stratified-charge combustion engine, based on the use of solenoid activated generators of pulsed-jet plumes described in Ref. 77. The CCE (Controlled Combustion Engine) featuring this system operates on a lean air-fuel charge (the air excess coefficient, $\lambda \geq 2$, including an appreciable dilution by recirculated residual gas). It offers potential for a remarkable operating flexibility with fuel economy below 0.5 kg/kWhr at all loads and pollutant emissions meeting the stringiest rules envisaged today for hydrocarbon energy resources.

All this is notable reflected in that portion of the PNGV program concerned with power plant technology--where primary attention has been given to substituting the contemporary internal combustion engine either in part by hybrid systems, or in full by fuel cells. The former are rendered unnecessary by the flexibility of the CCE system, whereas the latter furnishes, in effect, a limit to the intrinsically low-temperature oxidation of a hydrocarbon fuel it features. Thus CCE appears to provide either a superior substitute or a stepping stone to the most ambitious concepts pursued by the PNGV program. Above all, it is based fully on the existing infrastructure for fuel supply as well as maintenance, let alone its adaptability to much wider fuel independence that afforded by contemporary internal combustion engines.

Of course, as with any scientific claim (according to Karl Popper's "Conjectures and Refutations"), the above statements are refutable. A rational examination of their validity should be, therefore, considered as eminently deserving a program study under the auspices of PNGV for the sake of its own viability, let alone the potential benefits which may be thereby achieved.

APPENDIX B

Attendance List UCEI Workshop at LLNL August 10, 1995

<u>Name</u>	<u>Subject of Interest</u>	<u>Breakout Session</u>	<u>Affiliation</u>
Aceves, Salvador M.		Alternate Fuels or Advanced Vehicle Technologies	LLNL
Barth, Matthew J.			Center for Environmental Research & Tech UC Riverside
Bender, Don			LLNL
Bergemann, Richard J.		Advanced Vehicle Technologies	Institute for Defense Analyses
Bobrow, James	Engine Control at UCI (Only if you need me to)	Advanced Vehicle Technologies	Dept. of Mechanical & Aerospace Engineering, UC Irvine
Brownstore, David	Micro Simulation Modeling of Alternative Fuel and Vehicle Demand	Policy	Dept. of Economics, UC Irvine
Burke, Andrew	Ultra-Capacitors and Hybrid Vehicles	Advanced Vehicle Technologies	Institute of Transportation Studies, UC Davis
Chargin, Tony			LLNL (EMATT)
Clark, Woody			LLNL (EMATT)
Dahlgren, Joy		Policy	Institute of Transportation Studies/PATH UC Berkeley
Davis, Don			LLNL (EMATT)
Dibble, Robert W.		Alternate Fuels	Combustion Lab, UC Berkeley
Dunn-Rankin, Derek	Combustion and Control	Advanced Vehicle Technologies	UCI, UC Irvine
Farrell, Jay A.		Advanced Vehicle Technologies	Center for Environmental Research & Tech UC Riverside
Frank, Andrew	1. Hybrid Development; 2. Vehicle Mass Transit (Advanced Transportation System); 3. Ultra Light Safe Electric Vehicles	Advanced Vehicle Technologies	Mechanical Engineering, UC Davis
Johnston, Bob	Regional Economic/ Environmental Modeling	Policy	Division of Environmental Studies, UC Davis
Kuhl, Dr. Allen L.	Dynamics of Exothermic Systems	Advanced Vehicle Technologies	LLNL