Global Climate Change and Energy Systems
Workshop for the Riverside Unified School District

Agenda:

Thursday, October 15

6:15pm  Kawai Tam, Department of Chemical & Environmental Engineering:  Sustainability
6:45pm  Mirvat Ebrik, Sustainable Energy Systems Group at CE-CERT:  Cellulosic Biomass to Ethanol
7:15pm  Matthew Barth, Department of Electrical Engineering:  Solar Energy Systems
7:45pm  Tour of CE-CERT Labs

Thursday, October 22

6:15pm  Matthew Barth, Transportation Systems Research Group at CE-CERT:  Transportation
6:45pm  David Cocker, Department of Chemical & Environmental Engineering:  Atmospheric Particles
7:15pm  Akua Asa-Awuku, Department of Chemical & Environmental Engineering:  Climate
7:45pm  Tour of CE-CERT Labs
“Green” Transportation Systems

Matthew Barth
Professor and Director
College of Engineering-Center for Environmental Research and Technology
University of California-Riverside
CE-CERT’s Laboratories:

**Emissions and Fuels Research**  
Wayne Miller, Tom Durbin, David Cocker, Heejung Jung

**Transportation Systems Research**  
Matt Barth, Kanok Boriboonsomsin, Yushan Yan

**Atmospheric Processes Research**  
Bill Carter, Dennis Fitz, David Cocker, Kwangsam Na

**Environmental Modeling**  
Gail Tonnesen, Zion Wang, Mohammad Omari, Chao-Jung Chien

**Sustainable Energy Research**  
Joe Norbeck, Charles Wyman, Chan Seung Park, Bin Yang

www.cert.ucr.edu
Air Quality

Air quality in Southern California

Number of Exceedances


1980's

1990's
key factor: emission certification standards
Transportation: Energy and Emissions

- Increasing concern to stabilize greenhouse gases (GHG) to below levels emitted today (while still meeting energy needs)
- Transportation accounts for 33% of U.S. CO₂ emissions
- 80% of transportation CO₂ comes from cars and trucks
- Major emphasis is on cleaner, more efficient vehicles:
  - making vehicles lighter (and smaller) while maintaining safety
  - improving powertrain efficiency
  - developing alternative technologies (e.g., hybrids, fuel-cell vehicles)
- Focus has also been placed on alternative fuels:
  - biofuels (cellulosic ethanol)
  - synthetic fuels
- Programs that reduce vehicle miles traveled (VMT)
- Programs that increase transportation efficiency (ITS)
California has approved funding for over $5 billion in transportation related funds for research, development, demonstration and deployment of technologies for improving energy efficiency and air quality.

- **Assembly Bill 32**: stabilize GHG emissions to 1990 levels
- **Proposition 1B**: allocates $3 billion for infrastructure and air quality
- **Assembly Bill 118**: provides $1.4 billion for energy efficiency and air quality issues
- **Los Angeles-Long Beach Port Complex**: initiated a $1.2 billion program to clean up air pollution related to port activities; South Coast Air Quality Management District will add another $1 billion
New Vehicle Technology

- **fuel cell vehicles** (example: Honda Clarity)
- **battery electric vehicles** (example: Mitsubishi)
- **hybrid vehicles** (example: Ford Escape)
- **plug-in hybrid vehicles** (example: Chevy Volt)
Alternative Fuels: Ethanol

- **corn-based ethanol:** various studies show that this is not energy efficient and not truly sustainable

- **cellulosic ethanol:**
  - ethanol obtained from any type of cellulosic biomass
  - requires a more elaborate pre-treatment step
Synthetic Fuels

Solid To Liquid: Coal to Liquid (CTL)
Biomass to Liquid (BTL)

Coal, Biomass or Waste → Gasification → CO / H₂ → Fischer Tropsch → FT Products → Hydro-Cracking

Steam → Gas Recycle

H₂O

JP8 or Diesel Fuel

CTL, BTL and WTL utilize same basic process
Personal Mobility:

• personal mobility is an important part of a progressive society
• the automobile has become essential element of life
• our mobility is often restricted due to limitations in transportation infrastructure
• resource management problem:
  • if resources (transportation infrastructure) are limited and demand is high, congestion occurs
Roadway Congestion: impacts on energy and emissions

“slow speeds caused by heavy traffic and/or narrow roadways due to construction, incidents, or too few lanes for the demand”

- Texas Transportation Institute Annual Mobility Study:
  - [http://mobility.tamu.edu/ums](http://mobility.tamu.edu/ums)
  - congestion has grown everywhere in areas of all sizes
  - congestion occurs during longer portions of the day and delays more travelers and goods than ever before
  - billions of gallons of fuel are wasted every year, more emissions
General Solutions to Reducing Congestion

- **Manage Supply:**
  - build more lanes to increase roadway capacity
  - build more infrastructure for alternative modes (bike, rail, transit) *shown to be more cost effective (Lipman, 2006)*
  - improve system operations (e.g., respond quickly to incidents)
  - implement *intelligent transportation system* techniques

- **Manage Demand:**
  - implement pricing mechanisms to limit use of resources
  - provide greater range of alternative modes
  - allow for alternative work locations and schedules
  - have employers provide travel support programs

- **Manage Land Use:**
  - implement better urban design
  - provide for mixed use development of land
  - increase housing and industrial density
  - allow for innovative planning and zoning
  - implement some type of growth management
Intelligent Transportation Systems

application of advanced and emerging technologies from the fields of electronics, communications, control, and information processing to improve surface transportation

Targeted Benefits:

- **Improving Safety**
  - reducing accidents (42,000 fatalities per year)
  - making accidents more survivable

- **Improving Transportation Efficiency:**
  - increasing throughput
  - reducing congestion
  - maximizing economics

- **Energy/Environment:**
  - in-direct benefits
  - directed benefits
Improving Efficiency: Intelligent Transportation Systems

Key ITS Research Areas with Energy/Emissions Impacts:

**Advanced Vehicle Control and Safety Systems:**
- Longitudinal Collision Avoidance
- Lateral Collision Avoidance
- Intersection Collision Avoidance
- Automated Highway Systems → vehicle platooning

**Advanced Transportation Management Systems:**
- Traffic Monitoring and Management → Traffic PeMS
- Corridor Management → Corridor speed management
- Incident Management
- Demand Management and Operations → congestion pricing

**Advanced Transportation Information Systems:**
- Route Guidance → ECO-Route Guidance
- En-Route Driver Information → Dynamic ECO-Driving
- Traveler Service Information → Safe Trip-21
- Electronic Payment Services
Vehicle Activity Data Collection in Southern California
Vehicle Activity:
Real-Time Traffic Data

- real-time traffic density, speed, and flow is becoming more readily available
- Example: California Traffic Performance Measurement System (PeMS)
- Real-Time data can be used to measure congestion
CO₂ Emissions as a Function of Average Traffic Speed

Methodology:

Vehicle Activity Database containing sample vehicle velocity trajectories

Vehicle/technology category selection

CMEM (microscopic fuel consumption/emissions model)

\[ \ln(y) = b_0 + b_1 \cdot x + b_2 \cdot x^2 + b_3 \cdot x^3 + b_4 \cdot x^4 \]

Real-world activity

Steady-state activity

Average Speed (mph)
Different ITS strategies to reduce on-road emissions

- Ramp metering, signal synchronization, incident management, etc.
- Better enforcement, speed limiters, active accelerator pedal, etc.

Graph showing the relationship between Average Speed (mph) and CO₂ emissions (g/mi) for Real-world activity and Steady-state activity. Strategies include:

- Congestion Mitigation Strategies
- Speed Management Techniques
- Traffic flow smoothing techniques
- Variable speed limit, Intelligent speed adaptation, etc.
Example ITS Programs aimed at Environmental/Energy Concerns:

Advanced Vehicle Control and Safety Systems:
- Automated Highway Systems: platooning of vehicles

Advanced Transportation Management Systems:
- Dynamic Eco-Driving
- Corridor Speed Management

Advanced Transportation Information Systems:
- Environmentally Friendly Route Guidance
Initial Energy and Emissions Analysis of Automated Highway Systems:

- sponsored by NAHSC/PATH
- CO₂ and fuel are linearly related
- used energy/emissions model with typical driving activity

reference:
“Dynamic Eco-Driving”

Eco-Driving Advice with Dynamic Feedback

• **Static advice, for example:**
  • Shift up as soon as possible
  • Maintain a steady speed
  • Anticipate traffic flow
  • Accelerate smoothly
  • Decelerate softly
  • Check the tire pressure frequently

• **Dynamic advice/feedback, for example:**
  • Intelligent speed adaptation (ISA)
  • Instantaneous fuel economy readings
  • Cumulative real-time travel cost display
Dynamic Eco-Driver Field Experiments: Example Results

same travel time results:

<table>
<thead>
<tr>
<th>Energy/Emissions</th>
<th>Non-ISA</th>
<th>ISA</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 (g)</td>
<td>5439</td>
<td>4781</td>
<td>-12%</td>
</tr>
<tr>
<td>CO (g)</td>
<td>97.01</td>
<td>50.47</td>
<td>-48%</td>
</tr>
<tr>
<td>HC (g)</td>
<td>3.20</td>
<td>1.90</td>
<td>-41%</td>
</tr>
<tr>
<td>NOx (g)</td>
<td>6.28</td>
<td>3.97</td>
<td>-37%</td>
</tr>
<tr>
<td>Fuel (g)</td>
<td>1766</td>
<td>1534</td>
<td>-13%</td>
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</tbody>
</table>

reference:
Signalized Corridor Speed Management

- Much fuel is wasted and CO$_2$ is emitted by vehicles waiting at signalized intersections
- Vehicle speed trajectory can be planned based on knowledge of signal timing
- Concept: broadcast signal timing information to vehicle to plan vehicle trajectories
- Potential target demonstration: California VII corridor where DSRC equipment is already in place with signal information
Single Intersection Optimization with Signal Phase and Timing Information

Advanced signal information can help reduce intersection-influenced fuel consumption by 14% for cars and 12% for trucks.

<table>
<thead>
<tr>
<th>LDV24</th>
<th>Fuel</th>
<th>CO₂</th>
<th>CO</th>
<th>HC</th>
<th>NOₓ</th>
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<tbody>
<tr>
<td>Vehicle 1</td>
<td>27.8</td>
<td>87.5</td>
<td>0.378</td>
<td>0.013</td>
<td>0.011</td>
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<tr>
<td>Vehicle 2</td>
<td>70.6</td>
<td>222.4</td>
<td>0.990</td>
<td>0.045</td>
<td>0.063</td>
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<tr>
<td>Vehicle 3</td>
<td>64.5</td>
<td>203.1</td>
<td>0.873</td>
<td>0.034</td>
<td>0.067</td>
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<td>% 3 vs 2</td>
<td>-8.7</td>
<td>-8.7</td>
<td>-11.8</td>
<td>-24.8</td>
<td>+6.4</td>
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<tr>
<td>(2-1)</td>
<td>42.9</td>
<td>134.9</td>
<td>0.612</td>
<td>0.032</td>
<td>0.052</td>
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<tr>
<td>(3-1)</td>
<td>36.7</td>
<td>115.6</td>
<td>0.496</td>
<td>0.021</td>
<td>0.056</td>
</tr>
<tr>
<td>% (3-1) vs (2-1)</td>
<td>-14.3</td>
<td>-14.3</td>
<td>-19.0</td>
<td>-34.7</td>
<td>+7.8</td>
</tr>
</tbody>
</table>

Reference:
Navigation Techniques:

- route finding uses famous *minimum path* algorithms (Dijkstra, etc.)
- shortest distance
- shortest duration (requires traffic info)
- lowest energy, lowest emissions (requires traffic info, road grade, energy & emissions models)
New Navigation Tool: ECO-Routing:

- shortest-distance or shortest-duration path will often be the path that minimizes energy use or emissions
- roadway congestion and other factors (e.g. grade) create scenarios where minimum-energy and minimum-emissions path may be different than shortest duration or distance
Example ECO-Route Scenario
Summary of Energy/Environmental Beneficial ITS Strategies:

**Vehicle Systems:**
- Automation (lateral and longitudinal control, platooning, etc.)
- Closed loop systems: Smart Engines, HEV energy management

**Traffic Operations:**
- *congestion mitigation strategies* that reduce severe congestion such that higher average traffic speeds are achieved (e.g. ramp metering, incident management);
- *speed management techniques* that can bring down excessive speeds to more moderate speeds of approximately 60 mph (e.g. enforcement, ISA);
- *traffic flow smoothing techniques* that can suppress shock waves, and thus, reduce the number of acceleration and deceleration events (e.g. variable speed limits, ISA, Smart Engines)

**Information Systems:**
- Environmental Friendly Navigation
- Dynamic Eco-Driving
- Corridor Speed Management Systems