Overall Energy Impacts Analysis

Includes topics emphasized in later workshop sessions.

Positive Energy Outcomes
- Enabling electrification
- Lightweighting & powertrain/vehicle size optimization
- Higher occupancy
- Less hunting for parking
- Full cycle smoothing
- Efficient routing
- Efficient driving
- Platooning

Negative Energy Outcomes
- More travel
- Travel by underserved
- Faster travel

Implications for advanced powertrains and vehicle design

Overall Energy Impacts Analysis

A few more comments on operations related impacts...

Positive Energy Outcomes
- Enabling electrification
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- Full cycle smoothing
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- Efficient driving
- Platooning
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Negative Energy Outcomes
- More travel
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- Travel by underserved

Intersecting travel behavior/operations impacts

Well Understood Fuel Use Speed Dependence

- Outputs from two different light-duty conventional vehicle models
  - Best efficiency between roughly 25-55 mph

Cruising Speed Fuel Consumption

Analysis Over Many Real-World Profiles
Overall Energy Impacts Analysis

A few more comments on operations related impacts…

Notes from Driver Feedback Fuel Savings Project

Motivation
• “Your mileage will vary”
  o Based on driving conditions & style
• Improve efficiency of existing vehicles

Approach
• Quantify savings from cycle changes
  o Vehicle simulations & cycle analysis
  o On-road experiments over repeated routes
• Identify/understand behavior influences
  o Literature review & expert consultation
  o On-road observations
• Assess feedback methods
  o Survey existing examples
  o Evaluate based on project’s other findings
Driver Feedback Analysis Project: Key findings

- **Driving changes can save fuel**
  - 30%-40% outer bound for “ideal” cycles
  - 20% realistic for aggressive drivers
  - 5%-10% for majority of drivers

- **Existing methods may not change many people’s habits**
  - Other behavior influences dominate
  - Current approaches unlikely to have broad impact

Developed several recommendations to maximize savings...

Overall Energy Impacts Analysis

A few more comments on operations related impacts…

Positive Energy Outcomes

- Enabling electrification
- Lightweighting & powertrain/vehicle size optimization
- Full cycle smoothing
- Optimizing selection and powertrain control optimization over route
- Efficient routing
- Efficient driving
- Platooning
- Higher occupancy
- Less hunting for parking

Negative Energy Outcomes

- More travel
- Faster travel
- Travel by underserved

Fuel Intensity
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

Energy Intensity

Use Intensity

Notes from Collaborative Project on Green Routing and Adaptive Control for the Chevy Volt

- **Candidate Routes**
- **NREL/GM Algorithms**
  - Road Type
  - Real-time Traffic
  - Driver Aggression
  - Drive Cycle Model
  - Cycle Metrics
  - Road Grade
  - Vehicle State
  - Volt PT Model

- **Estimated Energy Use**

- **Computationally heavy to develop**
  - Hundreds of thousands of drive cycles processed, analyzed, and simulated

- **Computationally light to implement in-vehicle**
  - Does not require determination of time/speed trace or real-time simulation of high-fidelity vehicle model

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Green Routing Example

<table>
<thead>
<tr>
<th>Route</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance, mi</td>
<td>81.6</td>
<td>76.2</td>
<td>67.6</td>
</tr>
<tr>
<td>Duration, min</td>
<td>107</td>
<td>107</td>
<td>113</td>
</tr>
<tr>
<td>Avg Elec Rate, Wh/mi*</td>
<td>0.83</td>
<td>0.89</td>
<td>1.0</td>
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<tr>
<td>Avg MPG*</td>
<td>0.45</td>
<td>0.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Cost, $*</td>
<td>1.0</td>
<td>0.89</td>
<td>0.59</td>
</tr>
</tbody>
</table>
Summary

- Demonstrated ability to model vehicle speed/accel profiles relative to road type
- Constructed high-level powertrain model employing cycle metrics and vehicle state as inputs
- Applied model using real-world distribution of O/D pairs, demonstrating:
  - Aggregate energy savings of up to 4.6% for green routing (relative to passenger value of time)
  - Average energy savings of 3.3% for mode scheduling

Modest aggregate savings, but may be cost-effective
Overall Energy Impacts Analysis

A few more comments on operations related impacts...

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- Full cycle smoothing
- Efficient routing
- Efficient driving
- Platooning

Applicable across vehicle sizes; Class 8 line haul is lowest hanging

Negative Energy Outcomes

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- Faster travel
- More travel
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Platooning: Demonstrated Worldwide

**SARTRE** – EU (Sweden) 2009-Present

**ENERGY ITS** – Japan 2009-12

**KONVOI** – Germany 2005-09

**PIT** – Canada 2009

**PATH** – US (Includes Nevada) ’90s and ongoing

Slide courtesy of Steve Boyd, Peloton Technologies
Platooning Opportunities and Considerations

• Potential safety and comfort benefits
• Studies have shown fuel savings on the order of 10%
• Many factors can influence
  o Vehicle spacing
  o Cruising speed
  o Speed variation
  o Baseline aerodynamic package
  o Vehicle loading
  o Engine loading

NREL Evaluation of Peloton Platooning System over a Variety of Conditions (results pending)

Photo from Mike Lammert, NREL