Positioning High-speed Rail to Lower Energy Use, Greenhouse Gas Emissions, & Transportation Costs

MIKHAIL V. CHESTER
ASSISTANT PROFESSOR
CIVIL, ENVIRONMENTAL, & SUSTAINABLE ENGINEERING
ARIZONA STATE UNIVERSITY

HSR.TRANSPORTATIONLCA.ORG
Phase 1: San Francisco to Los Angeles
Phase 2: Sacramento to San Diego
Life Cycle Assessment

- Mode Shifting
- Emerging Technologies
- Emerging Fuel Mixes
Life Cycle Assessment

VEHICLES
(Manufacturing & Maintenance)

INFRASTRUCTURE
(Construction, Maintenance, Rehabilitation, & Operation)

ENERGY PRODUCTION
(Primary fuel extraction, Processing, & Transport)

SUPPLY CHAINS
Transportation
Life Cycle Assessment

- VEHICLES
  - Manufacturing
  - Maintenance

- INFRASTRUCTURE
  - Material production
  - Construction activities
  - Maintenance
  - Rehabilitation

- ENERGY PRODUCTION

- SUPPLY CHAINS

Video frame source: California High Speed Rail Authority
Transportation Life Cycle Assessment

- VEHICLES
  - Manufacturing
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  - Material production
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  - Maintenance
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Transportation Life Cycle Assessment

- **VEHICLES**
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  - Material production
  - Construction activities
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- **ENERGY PRODUCTION**

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- VEHICLES
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- ENERGY PRODUCTION

- SUPPLY CHAINS

Video frame source: Arizona State University W.P. Carey School of Business
Phase 1: San Francisco to Los Angeles
Phase 2: Sacramento to San Diego
<table>
<thead>
<tr>
<th>Life Cycle Grouping</th>
<th>Automobiles/Buses</th>
<th>Air</th>
<th>Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Manufacturing       | • Vehicle \ Manufacturing  
• Battery Manufacturing  
• Transport to Point of Sale | • Aircraft \ Manufacturing  
• Engine Manufacturing | • Train  
• Transport to Point of Sale |
| Operation           | • Propulsion  
• Idling | • APU / Startup / Taxi Out / Takeoff / Climb Out / Cruise / Approach / Landing / Taxi In | • Propulsion  
• Idling |
| Maintenance         | • Typical Maintenance  
• Tire Replacement  
• Battery Replacement | • Aircraft \ Maintenance  
• Engine Maintenance | • Typical Train Maintenance  
• Train Cleaning  
• Flooring Replacement |
| **Infrastructure**  |                  |     |      |
| Construction        | • Roadway | • Airport  
• Runway/Taxiway/Tarmac | • Track  
• Station |
| Operation           | • Roadway Lighting  
• Herbicide Use | • Airport Energy  
• Runway Lighting  
• Deicing Fluids  
• Ground Support Equipment | • Track, Station, and Parking Lighting  
• Herbicide Use  
• Train Control  
• Miscellaneous (Escalators, Equipment) |
| Maintenance         | • Roadway Maintenance | • Airport  
• Runway/Taxiway/Tarmac | • Track and Station Maintenance |
| Parking             | • Curbside Parking | • Airport Parking | • Dedicated Parking |
| Energy Production   |                  |     |      |
| Extraction, Processing, & Distribution | • Gasoline/Diesel/Natural Gas Extraction, Processing, & Distribution | • Jet Fuel Extraction, Processing, & Distribution | • Raw Fuel Extraction and Processing, Electricity Generation, Transmission & Distribution |
Environmental Indicators

Energy

Air Emissions
- SO\textsubscript{x} Respiratory irritant, acid deposition
- CO Asphyxiant
- NO\textsubscript{x} Respiratory irritant, smog
- VOC Photochemical smog, cancerous
- PM Respiratory and cardiovascular damage

Greenhouse Gases
- CO\textsubscript{2}, CH\textsubscript{4}, N\textsubscript{2}O

Others
- Water, labor, costs, toxics, hazardous, etc.

Human Health and Environmental Impact Potentials
- Respiratory: SOx, NOx and PM\textsubscript{2.5}
- Acidification: SOx and NOx
- Photochemical Smog Formation: CH\textsubscript{4}, CO, VOC, and NOx
- Eutrophication Potential

Positioning High-speed Rail to Lower Energy Use, Greenhouse Gas Emissions, and Transportation Costs
Uncertainty

Future vehicle technologies

Future energy mixes

Ridership uncertainty produces a range in per-PKT performance

- Challenges: Adoption period, full adoption (typical peak and off-peak)
- Without a strong understanding of ridership, breakeven points can be more illustrative of environmental tradeoffs
Greenhouse Gas Emissions in Grams CO$_2$e per PKT

- 35mpg Sedan
  - Vehicle Operation: 5
  - Vehicle Manufacturing: 1
  - Vehicle Insurance: 1
  - Infrastructure Maintenance: 1
  - Energy Production: 1

- Future WECC-RPS, 670 Seats
  - Vehicle Operation: 670
  - Vehicle Manufacturing: 150
  - Vehicle Insurance: 160
  - Infrastructure Maintenance: 100

- Boeing 737-800
  - Vehicle Operation: 670
  - Vehicle Manufacturing: 150
  - Vehicle Insurance: 160
  - Infrastructure Maintenance: 100
Greenhouse Gas Emissions in Grams CO₂e per PKT

Human Health and Environmental Impact Potentials per PKT

Greenhouse Gases (grams CO$_2$ eq)
- 35mpg Sedan
- Future WECC-RPS, 670 Seats
- Boeing 737-800

Respiratory Effects (mg PM$_{2.5}$ eq)
- 35mpg Sedan
- Future WECC-RPS, 670 Seats
- Boeing 737-800

Acidification (grams H+ moles eq)
- 35mpg Sedan
- Future WECC-RPS, 670 Seats
- Boeing 737-800

Smog Formation (tonnes O$_3$ eq)
- 35mpg Sedan
- Future WECC-RPS, 670 Seats
- Boeing 737-800

- Vehicle Operation
- Vehicle Manufacturing
- Vehicle Maintenance
- Vehicle Insurance
- Infrastructure Construction
- Infrastructure Operation
- Infrastructure Maintenance
- Infrastructure Parking
- Infrastructure Insurance

### Long-run per PMT Rankings

<table>
<thead>
<tr>
<th>Impact Potential</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Auto</td>
</tr>
<tr>
<td>End-use Energy</td>
<td><img src="image" alt="Ranking" /></td>
</tr>
<tr>
<td>Greenhouse Gases</td>
<td><img src="image" alt="Ranking" /></td>
</tr>
<tr>
<td>Respiratory Effects</td>
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<tr>
<td>Eutrophication</td>
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- **Lowest** (Green) indicates the lowest impact.
- **Middle** (Red) indicates a moderate impact.
- **Highest** (Yellow) indicates the highest impact.
Footprinting (per PMT)

Consequential (Corridor Effects)

Greenhouse Gas Payback in Million Tonnes

CAHSR Authority Business Plan Medium Forecast

Decade 1
Decade 2
Decade 3
Decade 4
Decade 5
Decade 6
Decade 7
Decade 8
Decade 9
Decade 10

Payback Sensitivity

AUTO  HSR  AIR

CAHISR Impact Reduction Strategies

<table>
<thead>
<tr>
<th>Midsize (670 Seat) Trains</th>
<th>GHG Emissions in kg CO₂eq/VKT</th>
<th>NOx Emissions in g/VKT</th>
</tr>
</thead>
<tbody>
<tr>
<td>WECC-2010</td>
<td>-</td>
<td>12% ↓</td>
</tr>
<tr>
<td>WECC-RPS</td>
<td>10</td>
<td>17% ↓</td>
</tr>
<tr>
<td>WECC-RPS (Emission Control)</td>
<td>15</td>
<td>22% ↓</td>
</tr>
<tr>
<td>100% Renewables</td>
<td>20</td>
<td>41% ↓</td>
</tr>
</tbody>
</table>

- Vehicle Operation
- Vehicle Manufacturing
- Vehicle Insurance
- Infrastructure Construction
- Infrastructure Operation
- Infrastructure Maintenance
- Infrastructure Insurance
- Infrastructure Parking

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<thead>
<tr>
<th></th>
<th>Today</th>
<th>2040 without HSR</th>
<th>2040 with HSR</th>
</tr>
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<tbody>
<tr>
<td>Auto VMT</td>
<td>324 billion</td>
<td>517 billion</td>
<td>511 billion</td>
</tr>
<tr>
<td>Air VMT</td>
<td>65 million</td>
<td>107 million</td>
<td>80 million</td>
</tr>
</tbody>
</table>
Cost-effectiveness of GHG Reductions in California

mchester@asu.edu

hsr.transportationlca.org

mikhailchester