LONG-TERM TRANSPORTATION ELECTRICITY USE CONSIDERING AUTONOMOUS VEHICLES: ESTIMATES & POLICY OBSERVATIONS

Dr. Peter Fox-Penner, Will Gorman, & Jennifer Hatch
Boston University Institute For Sustainable Energy
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These slides are designed to accompany live presentation. For a more complete explanation, please see the corresponding paper at http://www.bu.edu/ise/what-we-are-working-on/. Please cite using the title on this title page and link to the paper.
WHAT WAS OUR MOTIVATION?

Two Dimensions of the 2050 U.S. Energy Future: Distributed Generation Vs. Total Power Use

Band of Likely U.S. National Average DG

Source: Fox-Penner et al. BU Institute for Sustainable Energy

Canada 2015 Deep Decarbonization Pathways Project
Vermont 2016 Comprehensive Energy Plan
Italy DDPP 2015 Energy Efficiency Scenario
Germany DDPP 2015 90% GHG
Multnomah County 2015 Climate Action Plan
US 2015 Deep Decarbonization Pathways Project
US Actual 2015
HUGE NUMBER OF DISRUPTIVE CHANGES IN TRANSPORTATION

- TESLA – VEHICLE ELECTRIFICATION
- SELF-DRIVING CARS
- CONNECTIVITY + VIRTUAL REALITY
- LYFT – MOBILITY ON DEMAND
- CAR SHARING
- INTEGRATED MOBILITY SYSTEMS
- WALKABLE URBANISM
CONCEPTUAL APPROACH

\[
\left( \text{Number of EVs on the road} \right) \times \left( \text{Annual Average miles per EV} \right) \times \left( \text{EV Efficiency} \right) = \text{EV Power Use}
\]

- Influenced by ICE-EV competition, policy mandates, vehicle lives, and changes to the “ownership model”
- Influenced by development patterns and lifestyle and “ownership model”
- Influenced by technological improvements, mandates, and autonomous vehicle penetration
EV PROJECTIONS
IMPACT OF FULLY AUTONOMOUS VEHICLES

• Importantly, we assume all AVs are electric and connected to smart systems. These are near-term exaggerations but likely correct by 2050

• AVs cause 40% Increase in driving by 2050
  o Commuters
  o Underserved Populations
  o Long-Distance Trips

• Increase in near-term congestion $\rightarrow$ increased pressure on infrastructure

• Long-term changes
  - Less pavement $\rightarrow$ better cities
  - Much lower energy use
The Path of AV Electricity Use?

AV Energy Path: The (As-Yet) Mysterious Interdependence

AV Infrastructure Requirements and Costs

Operational & Physical Vehicle Efficiency

Penetration of AVs over time

Electricity use for AVs

2050
“SHARING” AND NEW OWNERSHIP MODELS: SMALL TWH IMPACTS BEYOND WHAT’S ALREADY IN

- Non-pooled Dynamic Ridesharing (eg Uber) → VMT effects captured by the +40% VMT from AVs (caveat: empty miles)
- Traditional Carpooling → too small to impact total VMT
- Car-Sharing → no change in total miles driven
- Pre-Autonomy Pooled DRS → 0
- Seamless Mobility Systems (21st century mass transit) → 2% reduction in VMT
WILDCARDS THAT COULD MOVE DEMAND

• Road Pricing and Infrastructure Costs
  • Could reduce VMT by 10-42%
• Electronic Substitutes for travel (eg augmented reality)
  • Very little literature, no significant demonstrable effect
• Urban Redesign
  • Difficult to achieve above 2% reduction in VMT
• Only road pricing included in our Policy Scenario
## Electricity Consumption Summary – LDVs Only

<table>
<thead>
<tr>
<th>CASE</th>
<th>YEAR</th>
<th>TOTAL NO. OF EV IN SERVICE</th>
<th>PORTION STOCK ELECTRIC</th>
<th>TOTAL NUMBER OF AV IN SERVICE</th>
<th>FLEET AVERAGE eVMT/ Vehicle (per yr)</th>
<th>FLEET AVERAGE EFFICIENCY (kWh/mile)</th>
<th>TOTAL TWh (% of 2016 use)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE HIGH</td>
<td>2015</td>
<td>406,076</td>
<td>0.2%</td>
<td>0</td>
<td>7,179</td>
<td>0.32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2025</td>
<td>16,890,719</td>
<td>6.5%</td>
<td>0</td>
<td>9,087</td>
<td>0.34</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>52,379,566</td>
<td>19.7%</td>
<td>3,182,833</td>
<td>10,290</td>
<td>0.35</td>
<td>187</td>
</tr>
<tr>
<td></td>
<td>2040</td>
<td>166,979,970</td>
<td>59.6%</td>
<td>65,615,683</td>
<td>13,420</td>
<td>0.33</td>
<td>742</td>
</tr>
<tr>
<td></td>
<td>2050</td>
<td>252,371,537</td>
<td>85.6%</td>
<td>180,263,265</td>
<td>16,927</td>
<td>0.27</td>
<td>1140 (26%)</td>
</tr>
<tr>
<td>POLICY CASE</td>
<td>2015</td>
<td>406,076</td>
<td>0.2%</td>
<td>0</td>
<td>7,179</td>
<td>0.32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2025</td>
<td>17,086,996</td>
<td>6.6%</td>
<td>0</td>
<td>8,508</td>
<td>0.31</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>52,378,548</td>
<td>19.7%</td>
<td>196,278</td>
<td>8,826</td>
<td>0.30</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>2040</td>
<td>166,928,240</td>
<td>59.6%</td>
<td>17,786,550</td>
<td>8,865</td>
<td>0.29</td>
<td>435</td>
</tr>
<tr>
<td></td>
<td>2050</td>
<td>251,932,162</td>
<td>85.5%</td>
<td>128,559,496</td>
<td>10,038</td>
<td>0.23</td>
<td>570 (13%)</td>
</tr>
</tbody>
</table>
EV STOCK OF CONVENTIONAL VEHICLES

High Case

Low Case
POOLING AND SHARING

Source: Susan Shaheen, Shared Mobility Past Present and Future, 2016
SCENARIOS BY LAYER

High Base

Policy Scenario

Base   EV VMT   AV VMT   EV EI   AV EI   $0.22 RP   Final Scenario
1166   116     565     -395   -235   -77         1140

Base   AV VMT   EV EI   AV EI   $0.24 RP   Other Policy   Final Scenario
1159   189     -410    -184   -160   -24         570
POLICY RECOMMENDATIONS

• Shift drivers – and later, single occupants of AVs -- out of SOVs and into either pooled rides or, much better, integrated multimodal on-demand mobility systems, via any number of policy tools;

• Encourage or require electric LDVs to become more efficient more quickly than otherwise, much as CAFE and ZEV standards have forced ICE fleet efficiency gains; or

• Harvest the vehicle and system efficiency improvements theoretically offered by AVs as soon as possible after they are introduced.
# ENERGY EFFICIENCY FROM AUTOMATION

<table>
<thead>
<tr>
<th>Effect</th>
<th>Impact</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Smoothing</td>
<td>-15%</td>
<td>50% reduction in technology improvements in EI for the first 10 years, then linear phase-in from 2035</td>
</tr>
<tr>
<td>Intersection Management</td>
<td>-4%</td>
<td>Linear phase-in for urban EVs starting in 2035 and fully implemented by 2055</td>
</tr>
<tr>
<td>Higher Average Speed</td>
<td>+8%</td>
<td>Linear phase-in from 2030-2035</td>
</tr>
<tr>
<td>Platooning</td>
<td>-2.5%</td>
<td>Linear phase-in from 2030-2035</td>
</tr>
<tr>
<td>Rightsizing/Weight Reduction</td>
<td>-50%</td>
<td>Phased in linearly at 1% per year or 1.5% per year starting in 2040</td>
</tr>
</tbody>
</table>
# AUTOMATION IMPACTS ON VMT

<table>
<thead>
<tr>
<th>EV on AV VMT Effect</th>
<th>Low</th>
<th>Timing</th>
<th>Impact</th>
<th>Timing</th>
<th>Later Modified for Sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Capacity Effect</td>
<td>0</td>
<td></td>
<td>+5%</td>
<td></td>
<td>no</td>
</tr>
<tr>
<td>Lower Time Cost for Driver (Intra- and Intercity)</td>
<td>+ 15%</td>
<td>per vehicle</td>
<td>+20%</td>
<td>Linear Phase in 2040-2050</td>
<td>no</td>
</tr>
<tr>
<td>Increased Access</td>
<td>+ 8%</td>
<td>per vehicle</td>
<td>+15%</td>
<td>per vehicle</td>
<td>yes</td>
</tr>
<tr>
<td>Total</td>
<td>+23%</td>
<td></td>
<td>+50%</td>
<td>per vehicle</td>
<td>yes</td>
</tr>
</tbody>
</table>