Travel Demand and Charging Capacity for Electric Vehicles in Rural States: A Vermont Case Study

Lisa Aultman-Hall, Justine Sears, Jonathan Dowds and Paul Hines
September 16, 2011
Why electric vehicles (EVs)?

1. Greenhouse gas benefits
2. Reduce dependence on foreign oil
3. May reduce fuel costs
Scope:
I. Will Vermont’s distribution of EVs be clustered?
II. Can EVs meet Vermonters’ travel needs?
III. Placement of charging stations
IV. Spatial patterns in travel demand: are there areas where EV adoption should not be encouraged?
Data:
I. Vehicle registration and home address (DMV)
II. Vermont road network
III. Travel data: where people go, where they live, how far they drive (National Household Travel Survey)
IV. E911: geocoded location of Vermont’s buildings
I. Spatial distribution of EVs in VT

Predicting the spatial distribution of EVs:

use the current distribution of registered vehicles
(n= ~550,000)
and registered hybrids
(n=~5,000)
I. Spatial distribution of EVs in VT

Two definitions of hybrid clusters:

1. Links with 10+ hybrids/road link mile and > 5% hybrids
2. Links with 3+ hybrids and > 5% hybrids
**I. Spatial distribution of EVs in VT**

<table>
<thead>
<tr>
<th>Urban Area</th>
<th>Urban Cluster</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>32</td>
<td>33</td>
</tr>
</tbody>
</table>
| Total HEV clusters= 106

<table>
<thead>
<tr>
<th>Urban Area</th>
<th>Urban Cluster</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>313</td>
<td>297</td>
</tr>
</tbody>
</table>
| Total HEV clusters= 900
Conclusions: Currently, hybrids are clustered.

Future distribution of EVs and electricity demand may also be clustered, including in rural and suburban areas.
II. EV substitution

Can EV’s meet Vermont’s travel demand?

• Vermont National Household Travel Survey (n=1,600 households)
• Units of observation: home-based tours daily vehicle travel

Assumptions:
• EV range is 40 miles
• Our sample of daily driving patterns is representative of general driving patterns
• Work is a good place for charging stations
II. EV substitution

N= 1,926 vehicles

69% vehicle substitution with no work place charging

84% vehicle substitution with 100% work place charging

Is daily VMT > 40 miles?

No

63%

Good candidate

Yes

Is longest tour > 40 miles?

Yes

Is work on tour?

Yes

Is charging available at work?

Yes

Is longest trip leg > 40 miles?

Yes

Poor candidate

No

Good candidate

No

Poor candidate

No

Good candidate

Home for > 1 hour to charge?

Yes

Poor candidate

No

Good candidate

6%

0-15% (depends on availability of work place charging)
II. EV substitution

Conclusions
69% of vehicles could have been an EV on their given travel day
Up to 84% with work place charging
Up to 94% with widespread away-from-home charging
III. Placement of Charging Stations

Characteristics of ‘ideal’ charging station

- parking structures already equipped with electricity infrastructure (e.g., lighting)
- destinations where trip distance and/or dwell time are long (recreation, tourism, work places)
- robust electric grid/smart grid capability

Places of work are an obvious place to charge EVs. Are there others?
III. Placement of Charging Stations

Are there clusters of non-work tour destinations?

Identified:
150 vehicles that made tours > 40 miles
104 stops with a 60 minute dwell time

Where did they go?
39% recreation
22% shopping
15% meals out
Conclusions:

- Most tours include a stop at work; work = good charging station location
- Recreation and shopping may have potential to meet other away from home charging needs
IV. Spatial Patterns in Travel Demand

Vehicle miles driven → additional electric energy required

How does someone’s home location affect their vehicle travel?

Model two dependent variables:
home-home tour length
daily vehicle miles driven
What affects vehicle tour length and total daily travel?

- commercial density
- residential density (continuous and categorical)
- distance to city center
- retail access ($\sum \frac{1}{d^{1.7}}$)
- life cycle

<table>
<thead>
<tr>
<th># Households</th>
<th>1,359</th>
</tr>
</thead>
<tbody>
<tr>
<td># Vehicles</td>
<td>1,926</td>
</tr>
<tr>
<td>Mean tour length (miles)</td>
<td>32.3 ± 38.7</td>
</tr>
<tr>
<td>Mean daily VMT (miles)</td>
<td>36.5 ± 40.6</td>
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</table>
## IV. Spatial Patterns in Travel Demand

### Model Results

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variables</th>
<th>R²</th>
<th>F</th>
<th>p</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total miles traveled</td>
<td>Census designation, life cycle, commercial density at 10 km</td>
<td>0.04</td>
<td>6.43</td>
<td>&lt;0.001</td>
<td>1,926</td>
</tr>
<tr>
<td>Miles traveled on longest tour</td>
<td>Census designation, life cycle, commercial density at 10 km</td>
<td>0.03</td>
<td>4.17</td>
<td>&lt;0.001</td>
<td>1,926</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Independent variable</th>
<th>Parameter estimate</th>
<th>F</th>
<th>p</th>
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</thead>
<tbody>
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<td>Total miles traveled</td>
<td>Census designation</td>
<td>8.84</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>Life cycle</td>
<td>6.21</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>Commercial density at 10 km</td>
<td>-0.7</td>
<td>3.53</td>
<td>0.06</td>
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<tr>
<td>Miles traveled on longest tour</td>
<td>Census designation</td>
<td>7.19</td>
<td>&lt;0.001</td>
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<td>Life cycle</td>
<td>2.75</td>
<td>&lt;0.001</td>
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<td>Commercial density at 10 km</td>
<td>-0.4</td>
<td>7.70</td>
<td>0.06</td>
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</tbody>
</table>


Conclusions:

Variability in tour length and daily travel is high → difficult to characterize using environmental variables
General Conclusions:

- Results suggest EVs can meet much of Vermont’s travel demand
- Clustering may be a problem in suburban and rural areas
- Vehicle travel is highly variable in the state
Questions?