EV Infrastructure and Grid Impacts

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Infrastructure
Public Infrastructure Needs

- US public charging infrastructure lags behind other countries, even if the infrastructure bill is realized
- This doesn’t immediately imply a problem, since we have more off-street parking than most (most BEVs will leave home with a full tank of electricity on most days), but...

<table>
<thead>
<tr>
<th>Chargers per 100 EVs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>13</td>
</tr>
<tr>
<td>China</td>
<td>18</td>
</tr>
<tr>
<td>EU</td>
<td>9</td>
</tr>
<tr>
<td>US</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: IEA Global EV Outlook 2021
BEV Adoption is Limited by Parking

Most US **households** have some off-street parking

But only ~half of US **vehicles** have reliable off-street parking at an owned residence

So, a complete fleet transition is likely unrealistic without major infrastructure changes

Public Infrastructure Needs

- For those who depend on public chargers, level 2 chargers in retail parking lots aren’t going to cut it

- Even the highest speed charging may create long queues at service stations

https://afdc.energy.gov/fuels/electricity_infrastructure.html

https://www.tesla.com/supercharger
Public Infrastructure Priorities

1. High speed charging along **interstates** to enable long distance BEV travel
   - Many charge points eventually needed (more than gas pumps) to manage queuing during peak travel holidays
   - Many will go underutilized during other periods

2. High speed charging in **neighborhoods** where households depend on public chargers
   - Renters and dense areas
   - But, high speed charging creates challenges for the grid
   - Partial vehicle automation could make slower charging more realistic for queuing and juggling vehicles
Impact
Life Cycle Assessment

- What are the emissions impacts of EV charging?
- Why do different studies produce different answers?

Some major reasons

1. They answer different questions (attributional / consequential)
2. They take on different scopes (emission sources, types, ...)

<table>
<thead>
<tr>
<th>Study</th>
<th>Vehicle type</th>
<th>Regional resolution</th>
<th>Life cycle scope</th>
<th>Electricity source and emissions</th>
<th>Utility factor or VMT pattern</th>
<th>Driving conditions</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neale et al. (2015) [12]</td>
<td>BEV</td>
<td>eGRID subregions</td>
<td>Life Cycle</td>
<td>Attributional</td>
<td>Average emission rate for gasoline vehicles in each subregion</td>
<td>Homogeneous EPA combined</td>
<td>Homogeneous EPA combined</td>
</tr>
<tr>
<td>Achumbhhi et al. (2015) [13]</td>
<td>ICV, BEV</td>
<td>NERC region</td>
<td>Life Cycle</td>
<td>Consequential</td>
<td>Regional emission estimates for current, average emission rates for future</td>
<td>Homogeneous Based on CBEEI data</td>
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</tr>
</tbody>
</table>

...
Life Cycle Assessment Questions

- **Attributional**
  - “What emissions are an EV associated with or responsible for?”
  - Requires value judgments: how to assign responsibility?, system boundary, allocation of emissions to co-products

- **Consequential**
  - “How will emissions change if we adopt more EVs or EV policy?”
  - Requires estimating counterfactual scenarios, usually uncertain
Marginal Emission Factors

- Marginal emission factors provide a snapshot estimate of consequential emissions from small changes in load.
Consequential Emissions

- **Consequential emissions** are typically the question of interest for policy or adoption – what will be the effect of an action?

- **High uncertainty**: Need to estimate the difference in grid emissions, over time, with vs. without EV adoption or policy.

- If the change in load is small, **marginal emission factors** (now widely accessible) provide a snapshot estimate of consequential emissions.

![Diagram of Electricity Marginal Factors Estimates](https://cedm.shinyapps.io/MarginalFactors/)
Some modelers prefer to use attributional methods and average emission factors because consequential emissions are uncertain.

This answers a different question and implies a value judgment.

If we want to know the effect of an action (EV adoption or policy) on emissions, the uncertainty is there whether we model it or not – better to estimate it than ignore it.
EV Benefits Vary

- The relative consequential GHG benefits of EVs depend considerably on:
  - Which specific vehicle designs are compared
  - Regional grid mix
  - Driving patterns
  - Climate

V2G Has Benefits and Costs

- V2G and utility-controlled charging can reduce costs of electricity generation.
- However, it can do so by increasing utilization of coal plants at night, increasing consequential emissions damages.
- Public cost of emissions can outweigh generation savings.

Coal is Key

- Back in 2016 we estimated that a Tesla in the PJM region created 2-3x the emissions costs of a gasoline vehicle, largely due to SO2 from coal.

- We predicted that would change by now due to coal retirement.

- We’re working on a new study to see if it did.

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Take Away

- Public charging infrastructure strategy should target high speed chargers on interstates and neighborhoods with limited off-street residential parking
- Emissions implications of EVs depend on the question being asked. Consequential analysis is appropriate for policy impact assessment
- Emissions implications of EVs depend substantially on regional factors and vehicle design
- V2G can reduce generation costs, sometimes at the expense of increased health and environmental costs
- Coal retirement is key to EVs being in society’s interests