The Electrification Futures Study: Transportation Electrification

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Council of State Governments
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nrel.gov/EFS
The Electrification Futures Study

- Technology cost and performance (December 2017)
- Demand-side adoption scenarios (June 2018)
- dsgrid model documentation (August 2018)
- Supply-side evolution scenarios (2019)
- Impacts of electrification (2019)
- Electricity system operations (~2020)
- Value of demand-side flexibility (~2020)

Note: Future work scope is tentative
EFS Methodology

Three electrification scenarios developed to assess isolated impacts of electrification

- Reference
- Medium
- High

- Projections are designed to gain insight and are not forecasts or predictions

Sales shares determined from a combination of expert judgment based on current trends & consumer choice models
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EFS Methodology
Current State of Transportation Electrification

• Electricity currently plays a minor role in the transportation sector
• In 2017:
  – Less than 1% of energy use within transportation came from electricity
  – Less than 2% of sales for light-duty vehicles were plug-ins
• But the transportation sector is evolving...
A Rapidly Changing Landscape

**States, cities and companies unveiling a frenzy of new electric vehicle commitments**
- Greentech Media

**Investments** in electrified vehicles announced to date (Jan 2018) include at least $19 billion by automakers in the U.S., $21 billion in China and $52 billion in Germany
- Wired

**Battery costs projected to drop** from $209/kWh in 2017 to $70/kWh in 2030
- Bloomberg New Energy Finance

**Chicago Transit Orders 20 Proterra Electric Buses**
- InsideEVS

As of October 2018, one million plug-in vehicles have been sold in the United States, with over 20,000 sales per month
- Argonne National Laboratory

**General Motors believes the future is all-electric** and announced 20 fully electric models by 2023
- Wired

**Tesla’s electric semi truck:** Elon Musk unveils his new freight vehicle
- Tesla
Transportation sector results

• 2050 U.S. transportation fleet (High scenario):
  • **240 million** light-duty plug-in electric vehicles
  • **7 million** medium- and heavy-duty plug-in electric trucks
  • **80 thousand** battery electric transit buses
• Together these deliver up to **76%** of miles traveled from electricity in 2050
• 138,000 DCFC stations (447,000 plugs) and 10 million non-residential L2 plugs for light-duty vehicles
2050 U.S. electricity consumption increases

- **Medium** +932 TWh (20%)
  - 810 TWh transport
- **High** +1,782 TWh (38%)
  - 1,424 TWh from transport
Electricity consumption profiles

- Vehicle electrification increases annual consumption and peak loads
- Buildings electrification has a larger impact on load shapes
  - Space and water heating demands increase winter peak loads
Charging Flexibility

• Flexible EV charging can increase load factors, leading to:
  • Reduction in infrastructure needs (e.g., peaking capacity)
  • More economic efficient dispatch (e.g., increased utilization of lower-cost generation options)
  • Potential for increased reliability
• This depends on the level of flexibility

• Current EFS analysis efforts include the impact of demand side flexibility

Preliminary Results—Do Not Distribute, Quote or Cite
Additional EV charging considerations outside the scope of EFS

• **Uncoordinated charging** may lead to high demand peaks, requiring distribution infrastructure upgrades

• Electrification of medium- and heavy-duty vehicles may create **new demand locations** (e.g. along major highways, in remote areas, and in industrial zones), including **fleet charging** locations

• Growth in **fast charging** will further increase these power requirements

• **Autonomous** vehicles and **transportation network companies** may further alter consumption profiles for EVs

Future Uncertainty

• Will **battery costs** continue to decline, and will battery **performance** continue to improve?

• How might **consumer preference**—range anxiety, acceleration, automation—and technology development evolve?

• Will **charging infrastructure** enable or impede electrification?

• How will **ownership models**—for vehicles and chargers—evolve and impact utility planning? How might **utility-controlled charging** and **vehicle-to-grid services** affect energy use and adoption?
Thank you
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All EFS reports and accompanying data can be found at www.nrel.gov/efs

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Key Transportation Insights from EFS

• Significant opportunities exist for electric vehicles, in part because electricity currently provides <1% of total transportation energy needs
• Light-duty plug-in electric cars and trucks drive the greatest overall electrification impact in all scenarios
• But electric freight trucks can play a major role, particularly for short-haul applications and in more transformational scenarios
• Transit buses are prime candidates for electrification
Technology adoption and energy transitions generally follow characteristic **S-curve shape**

- **Invention** → **Innovation** → **Niche Market** → **Pervasive Diffusion** → **Saturation** → **Senescence**
Foundational technology data

- Three technology advancement trajectories (slow, moderate, rapid) for buildings and transportation technologies
- Literature-based summary of industrial electrotechnologies

Key Technologies:
- Light-duty and heavy-duty vehicles, buses (multiple range PHEVs and BEVs)
- Air-source heat pumps (including cold-climate ASHPs)
- Heat pump water heaters
Commercial ASHPs installed cost and efficiency projections

Levelized cost of driving (2020 Moderate)
Electricity share of final energy **doubles** from 2016 to 2050 under the High scenario.

*Note: Sector definitions and scope differ slightly between Historical and Modeled data.*
Incremental Electricity Growth

- Annual electricity consumption (top) and incremental growth from Reference (bottom) driven by transportation.
Electrification leads to energy savings

- Greater efficiency of electric technologies yields reductions in final energy consumption by up to 21% (High scenario), relative to the Reference
- Technology improvements could lead to even greater savings
- Impacts to primary energy will depend on generation mix

Note: Does not include all activities, e.g., petroleum refining and extraction excluded
• Domestic onsite fuel use reductions: 74% gasoline, 35% diesel, 37% natural gas in 2050 (High scenario)
• Expands opportunities for greater fuel use for power generation, fuel exports
### Impact of End-Use Efficiency

#### Annual Electricity Consumption (TWh)

<table>
<thead>
<tr>
<th></th>
<th>2016</th>
<th>2050 Reference</th>
<th>2050 Medium</th>
<th>2050 High</th>
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<td></td>
<td>Rapid</td>
<td>Moderate</td>
<td>Slow</td>
<td>Rapid</td>
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<tr>
<td>Transport</td>
<td>7.5</td>
<td>78</td>
<td>88</td>
<td>101</td>
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<tr>
<td>Residential</td>
<td>1,418</td>
<td>1,462</td>
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<tr>
<td>Commercial</td>
<td>1,379</td>
<td>1,751</td>
<td>1,755</td>
<td>1,762</td>
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<tr>
<td>Industrial</td>
<td>1,084</td>
<td>1,405</td>
<td>1,405</td>
<td>1,406</td>
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<tr>
<td><strong>Total</strong></td>
<td>3,889</td>
<td>4,696</td>
<td>4,722</td>
<td>4,772</td>
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#### Percent (%) of Final Energy

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<td>Rapid</td>
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<tr>
<td>Transport</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Residential</td>
<td>45</td>
<td>44</td>
<td>45</td>
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<tr>
<td>Commercial</td>
<td>53</td>
<td>62</td>
<td>62</td>
<td>62</td>
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<tr>
<td>Industrial (excluding refining)</td>
<td>15</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>19</td>
<td>23</td>
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