The Electrification Futures Study: Transportation Electrification

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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
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
EFS Methodology

Three electrification scenarios developed to assess isolated impacts of electrification:

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- High

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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 unveil a frenzy of new electric vehicle commitments
- Greentech Media

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

**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

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
Vehicle electrification dominates incremental growth in annual consumption

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**

- **Load Duration Curve**
  - Reduction of peak load with high 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
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
Used in EFS modeling and available for download

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
Estimated **fuel use** reductions

- 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)

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<tr>
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<th>2016</th>
<th>2050 Reference</th>
<th>2050 Medium</th>
<th>2050 High</th>
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<td>Transport</td>
<td></td>
<td>Rapid</td>
<td>Moderate</td>
<td>Slow</td>
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<td>7.5</td>
<td>78</td>
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<td>Commercial</td>
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<tr>
<td>Industrial</td>
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<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>Slow</td>
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<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>Residential</td>
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<tr>
<td>Commercial</td>
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<td>62</td>
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<tr>
<td>Industrial (excluding refining)</td>
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<td>23</td>
<td>23</td>
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<tr>
<td><strong>Total</strong></td>
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