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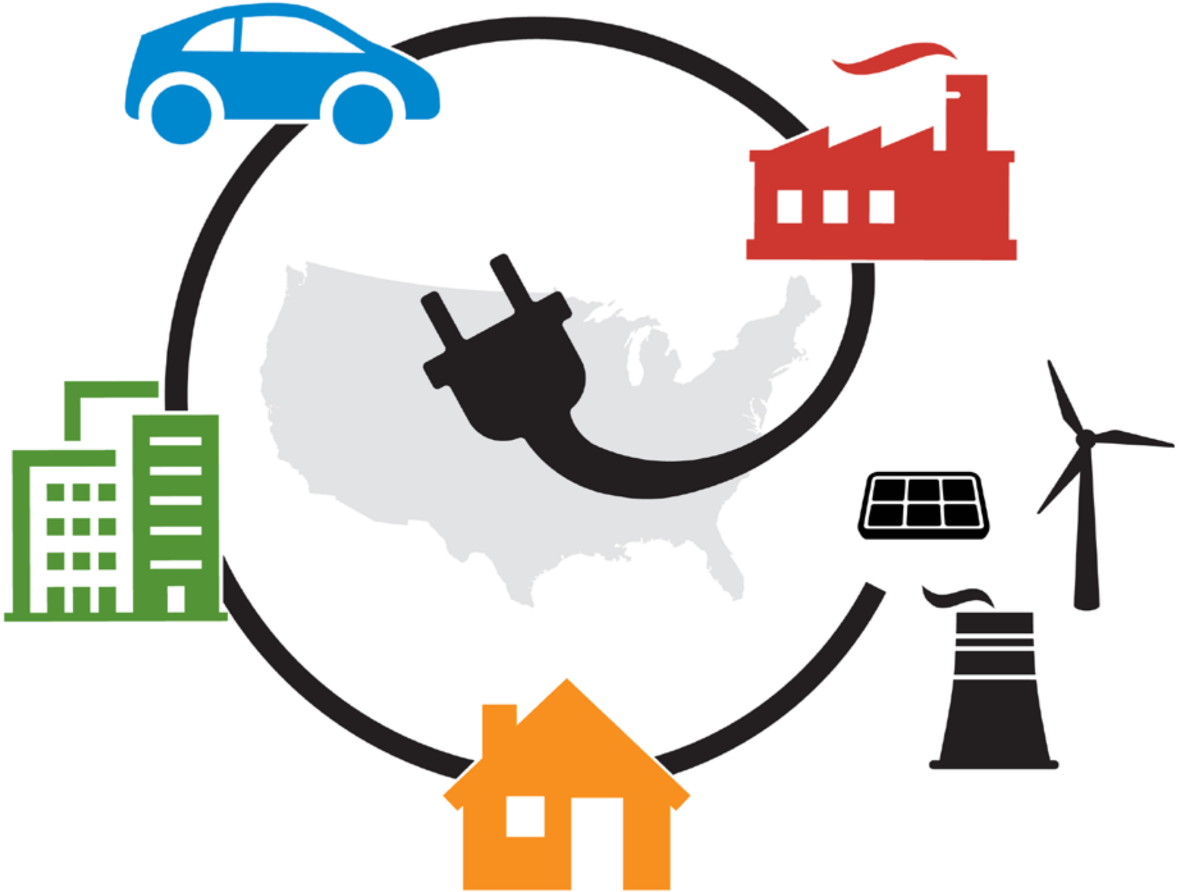
The Electrification Futures Study: **Transportation Electrification**



Paige Jadun

Council of State Governments National Conference
Cincinnati, Ohio
December 7, 2018
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)

Published

Ongoing and Planned

Note: Future work scope is tentative

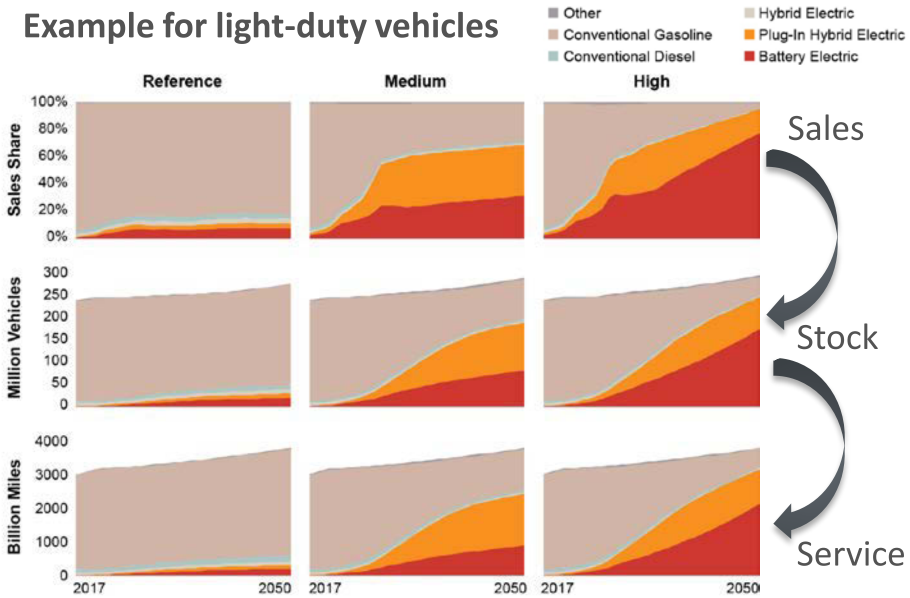
EFS Methodology

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

Example for light-duty vehicles



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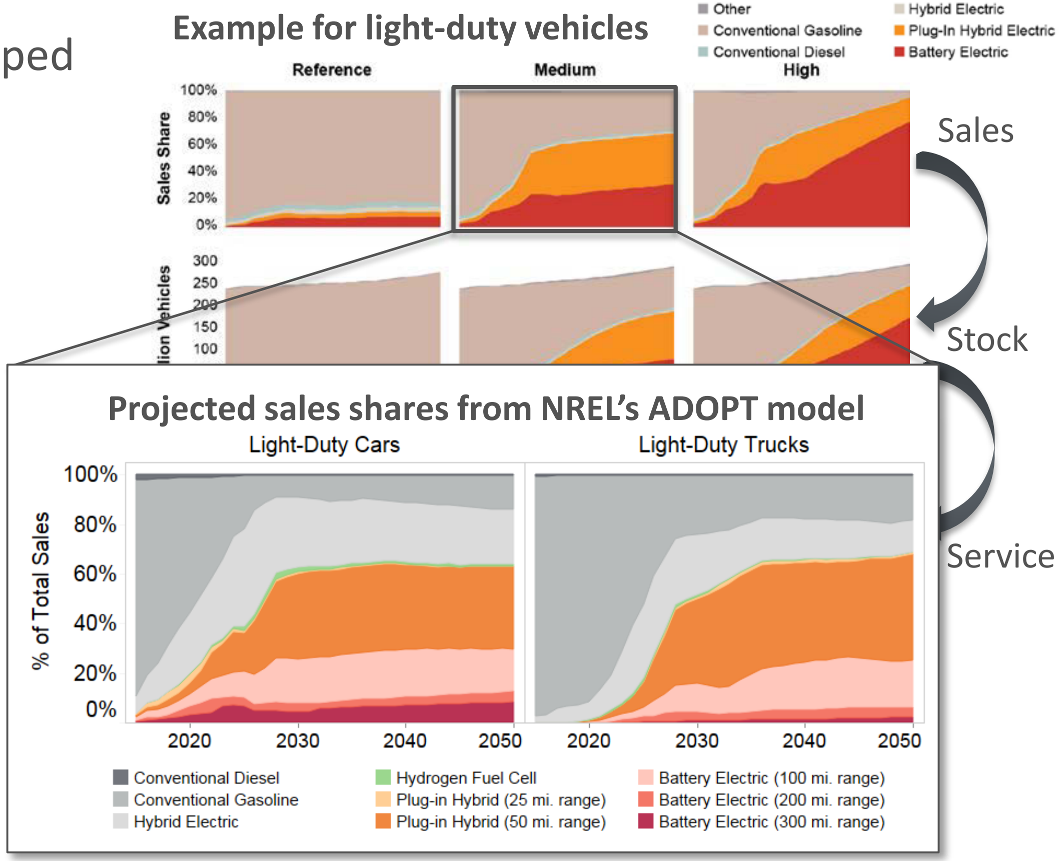
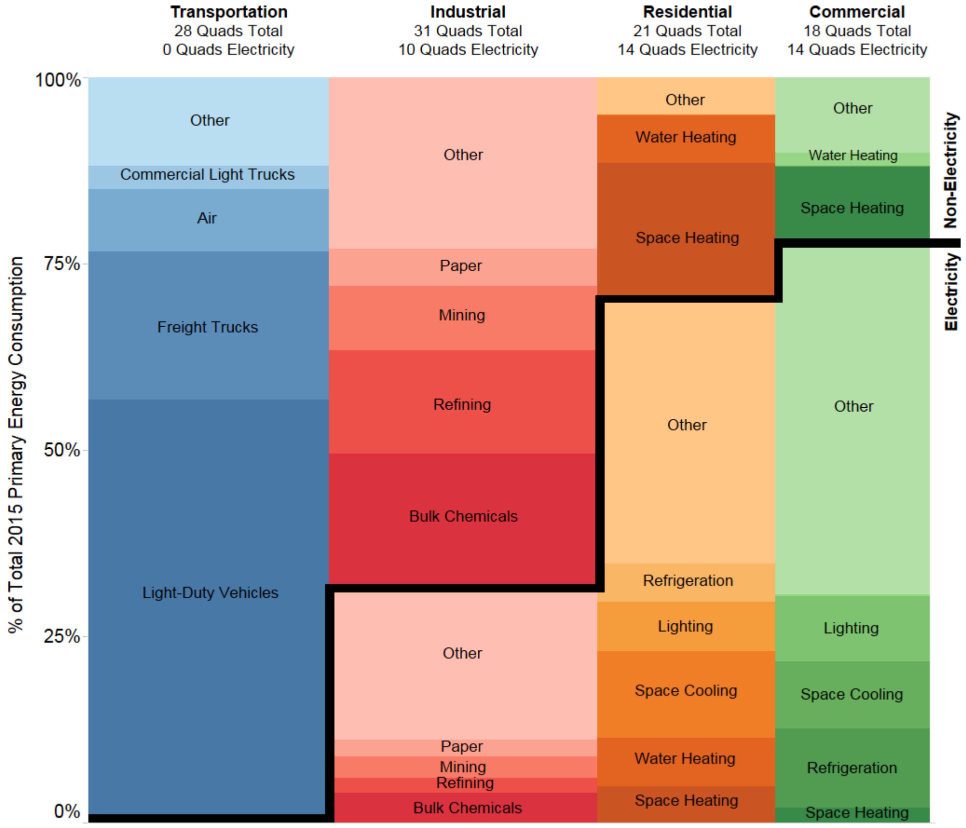


Current State of Transportation Electrification

- 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**
– Reuters

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

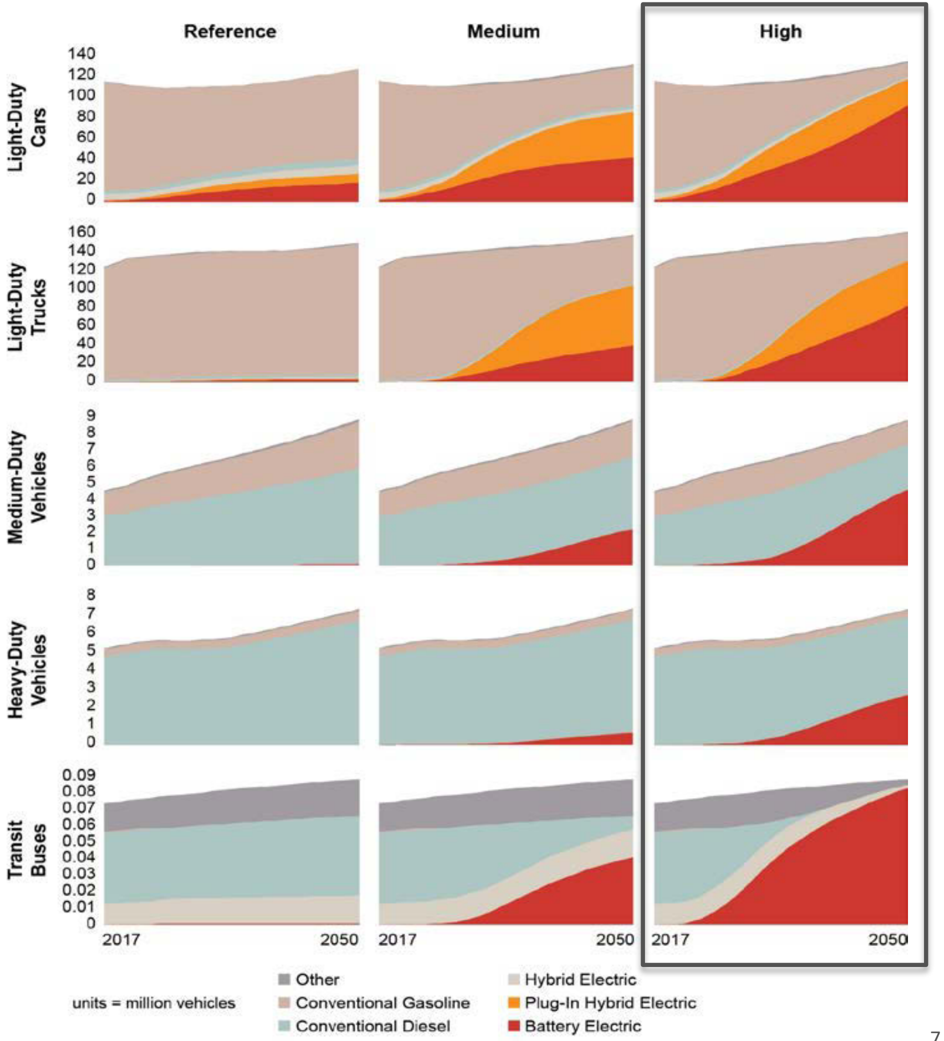
Battery costs projected to drop from $209/kWh in 2017 to $70/kWh in 2030
-Bloomberg New Energy Finance

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

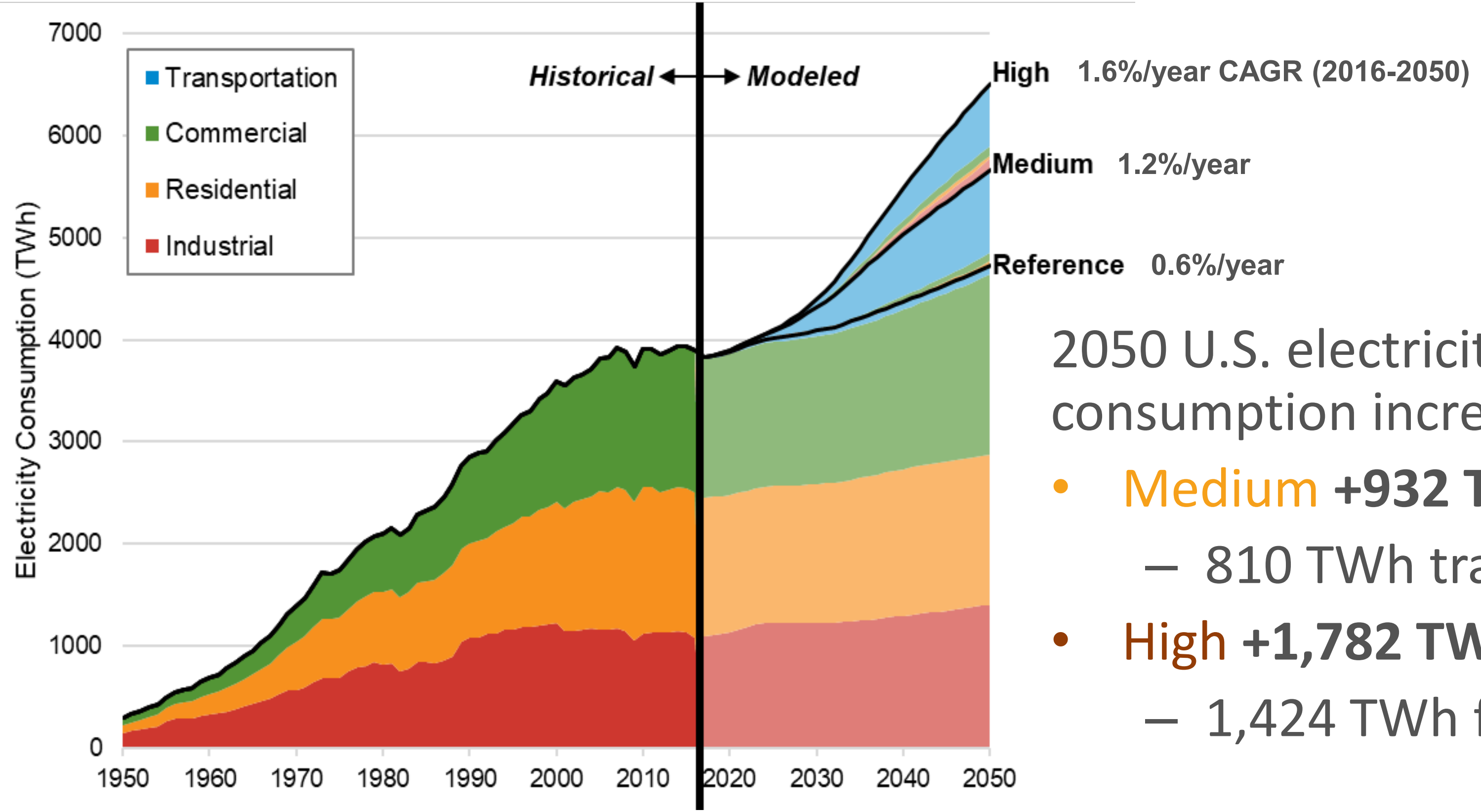
Tesla's electric semi truck: Elon Musk unveils his new freight vehicle
– Tesla

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



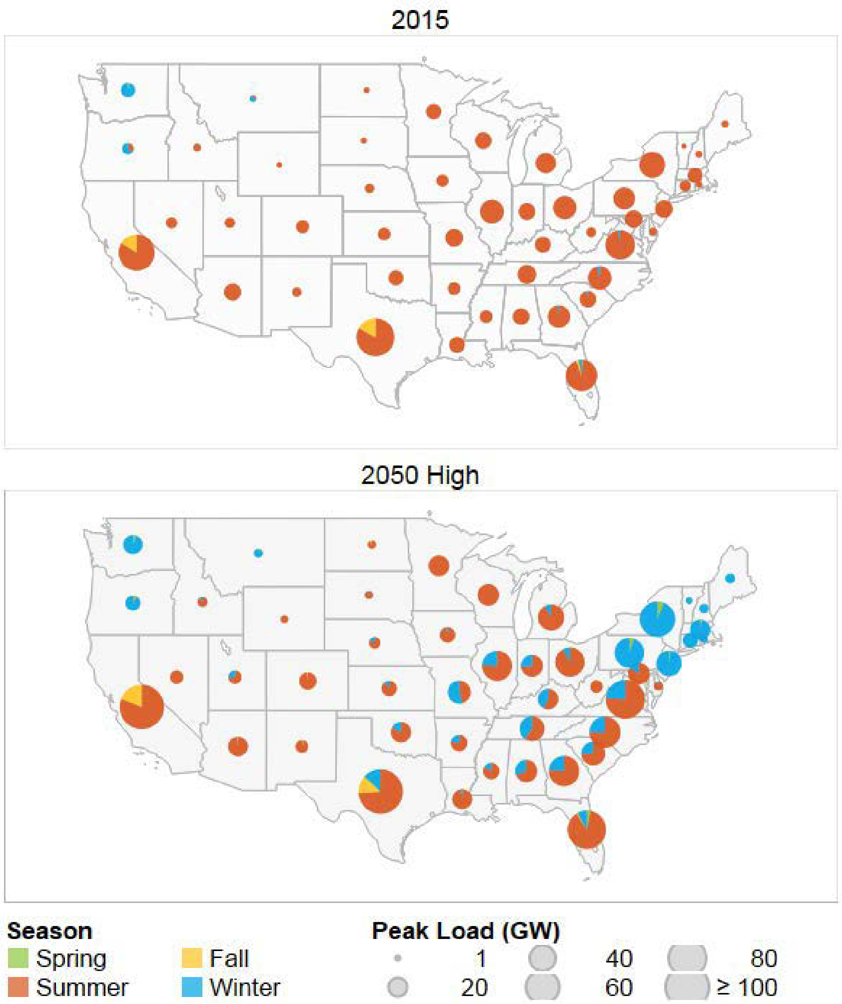
2050 U.S. electricity consumption increases

- 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

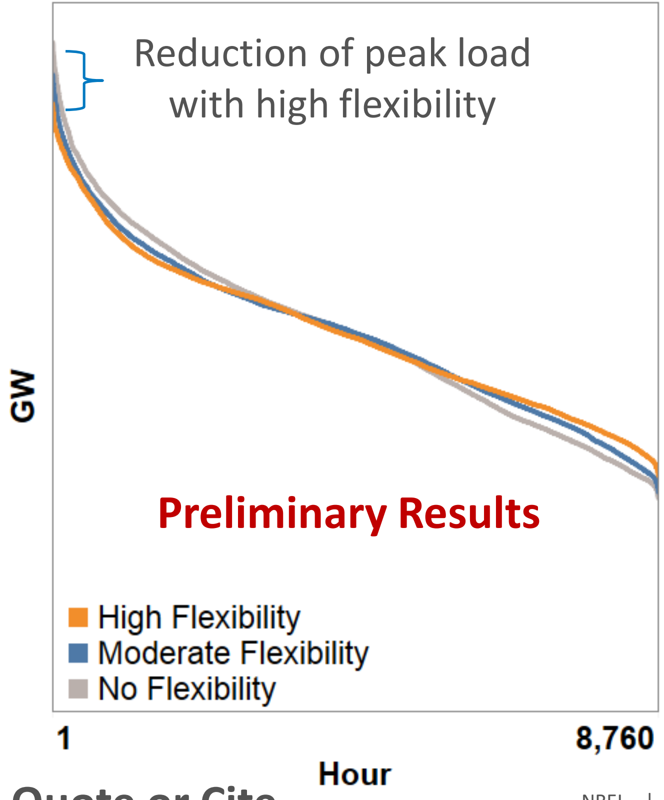


Charging Flexibility

- 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

Load Duration Curve



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

Muratori, Matteo. 2018. "Impact of Uncoordinated Plug-in Electric Vehicle Charging on Residential Power Demand." *Nature Energy* 3 (3): 193. https://doi.org/10.1038/s41560-017-0074-z.

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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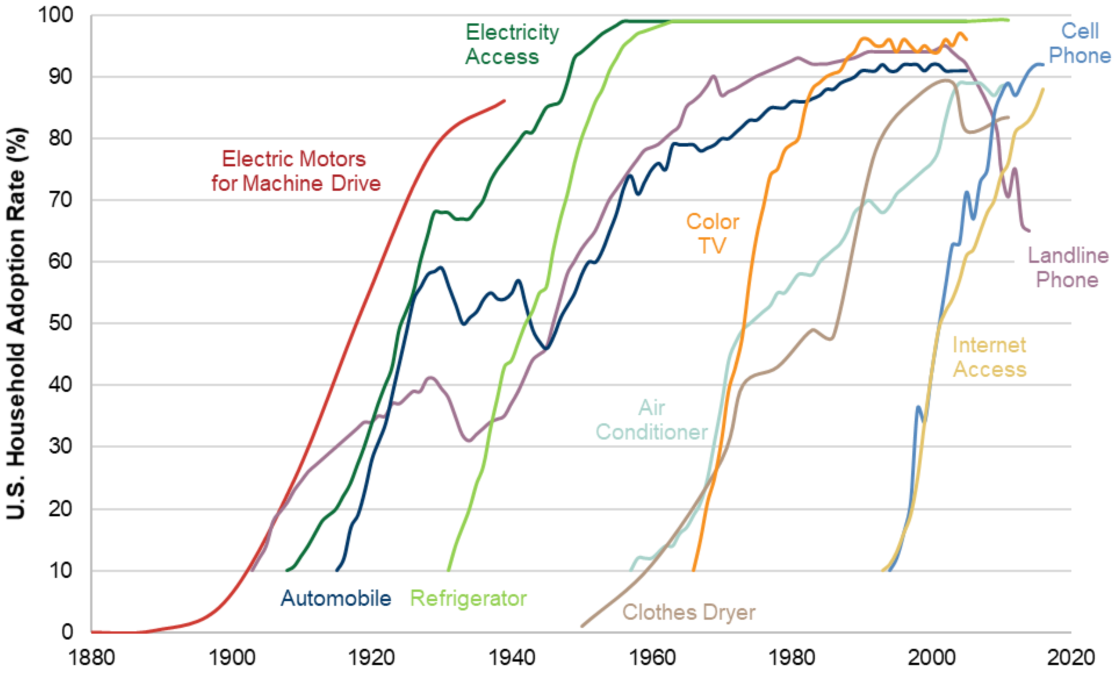
Additional Slides

Key Transportation Insights from EFS

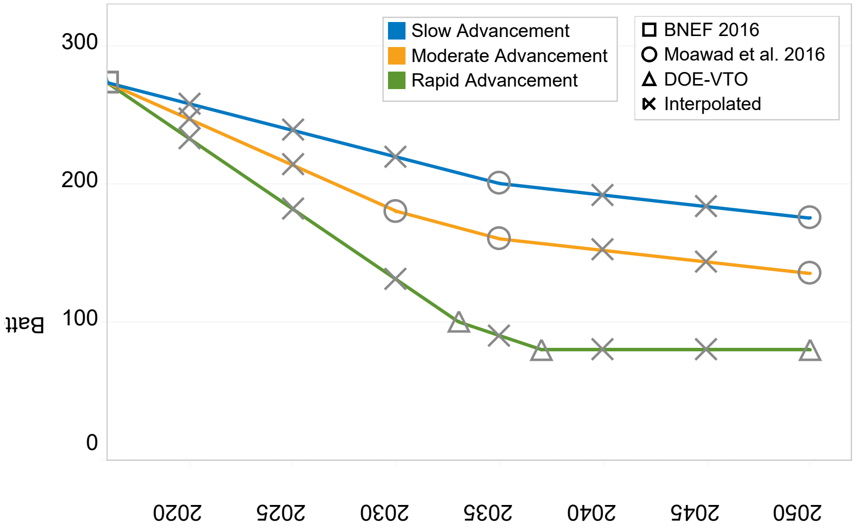
- Significant opportunities exist for electric vehicles, in part because electricity currently provides <1% of total transportation energy needs
- **Light-duty plug-in electric cars and trucks** drive the greatest overall electrification impact in all scenarios
- But **electric freight trucks** can play 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

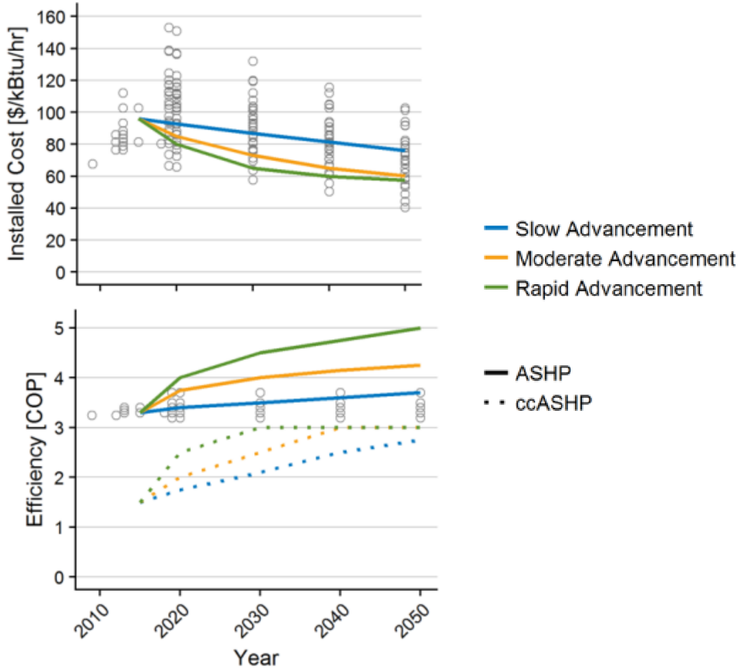


- Three technology advancement trajectories (slow, moderate, rapid) for **buildings** and **transportation** technologies
- Literature-based summary of **industrial** electrotechnologies

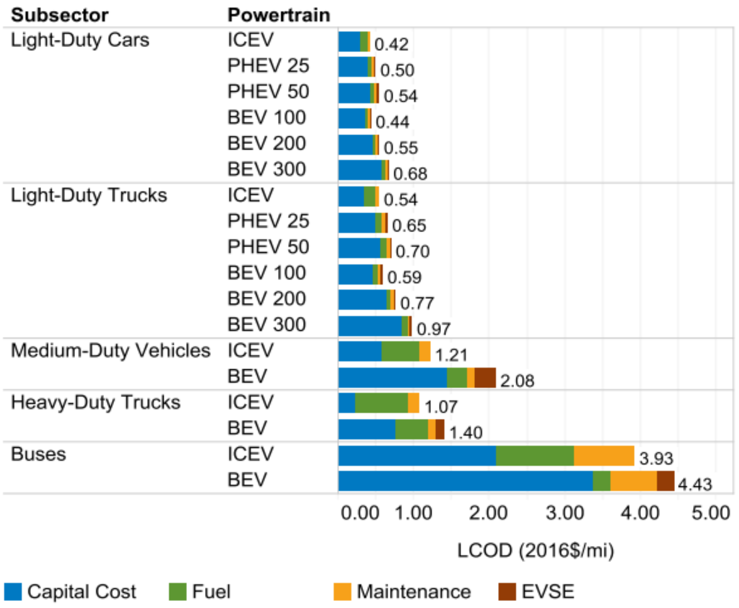
Key Technologies:

- 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**

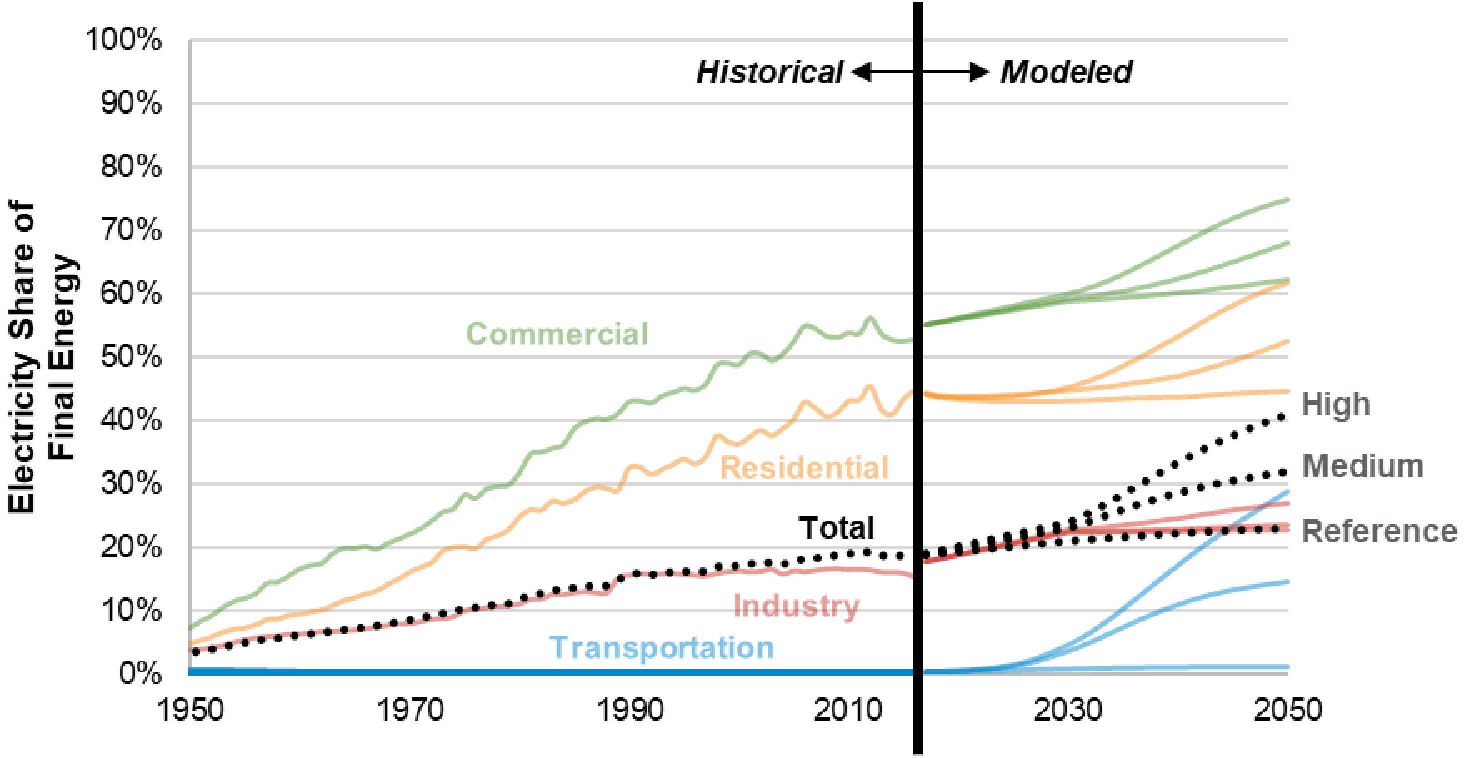


Commercial ASHPs
installed cost and efficiency projections



Levelized cost of driving (2020 Moderate)

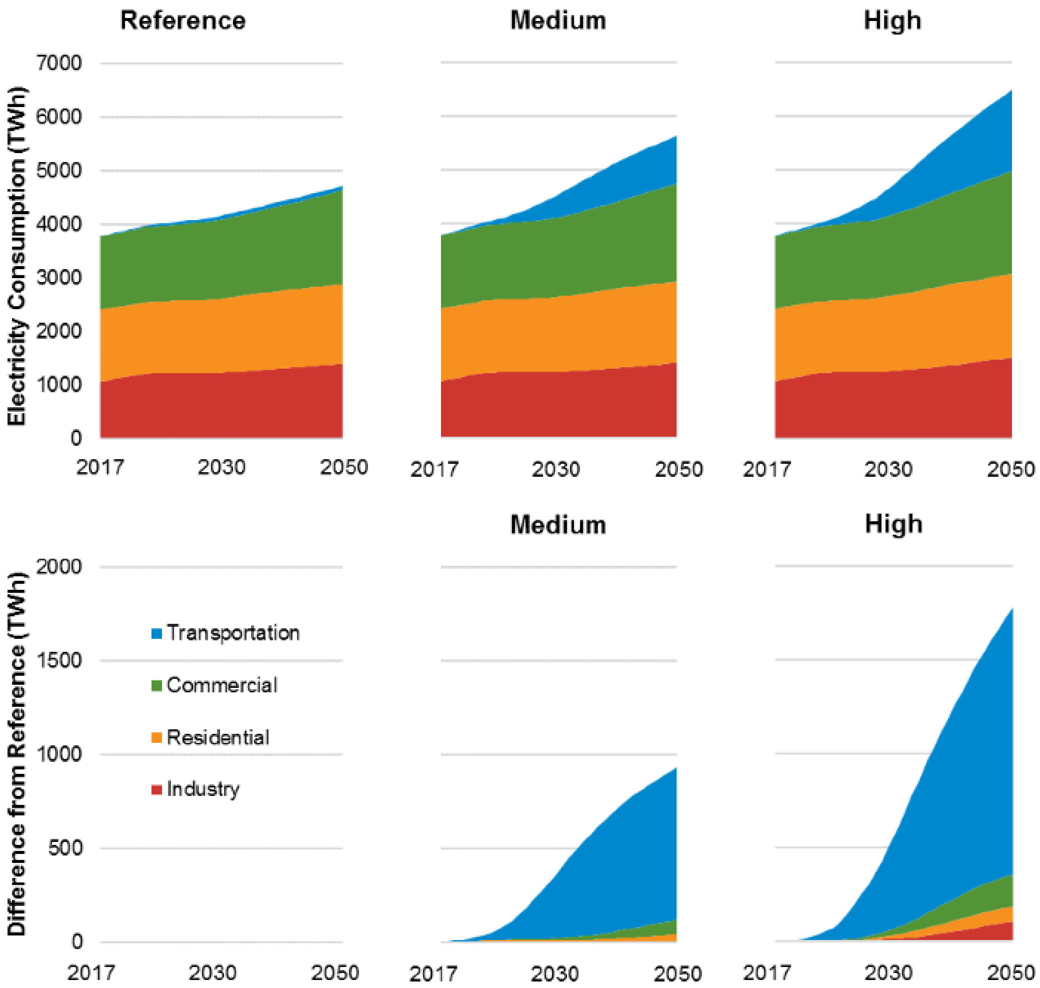
Electricity share of final energy **doubles** from 2016 to 2050 under the High scenario



Note: Sector definitions and scope differ slightly between Historical and Modeled data

Incremental Electricity Growth

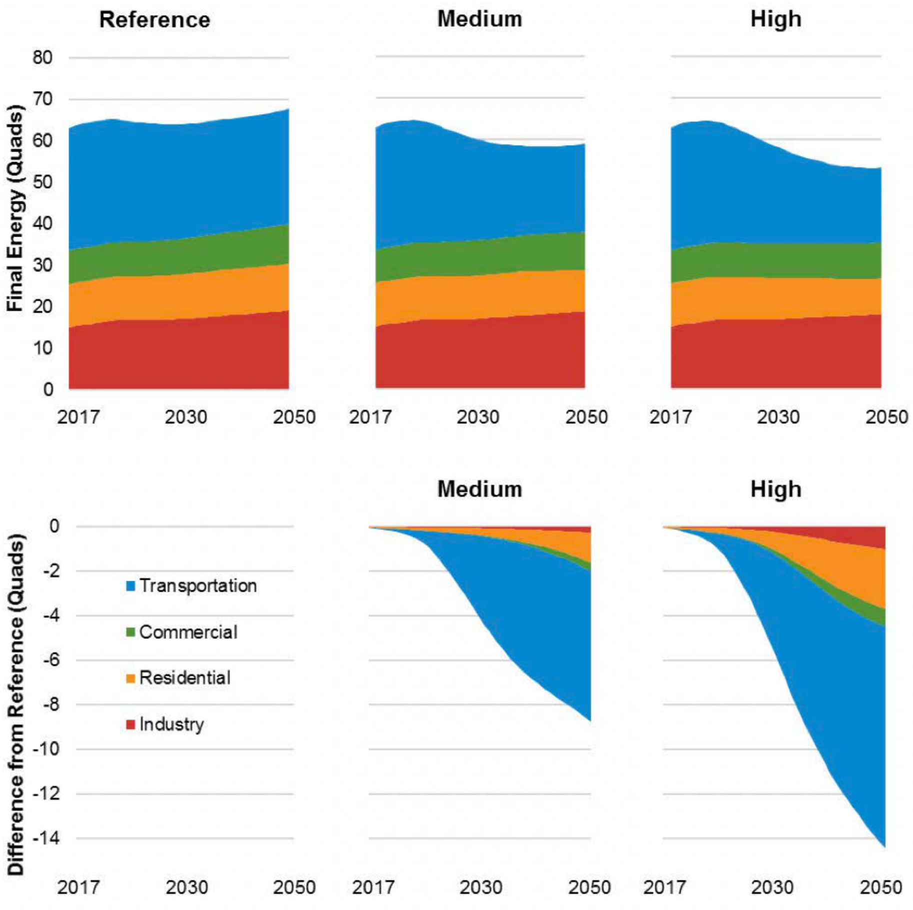
- Annual electricity consumption (top) and incremental growth from Reference (bottom) driven by transportation



Moderate technology advancement case shown

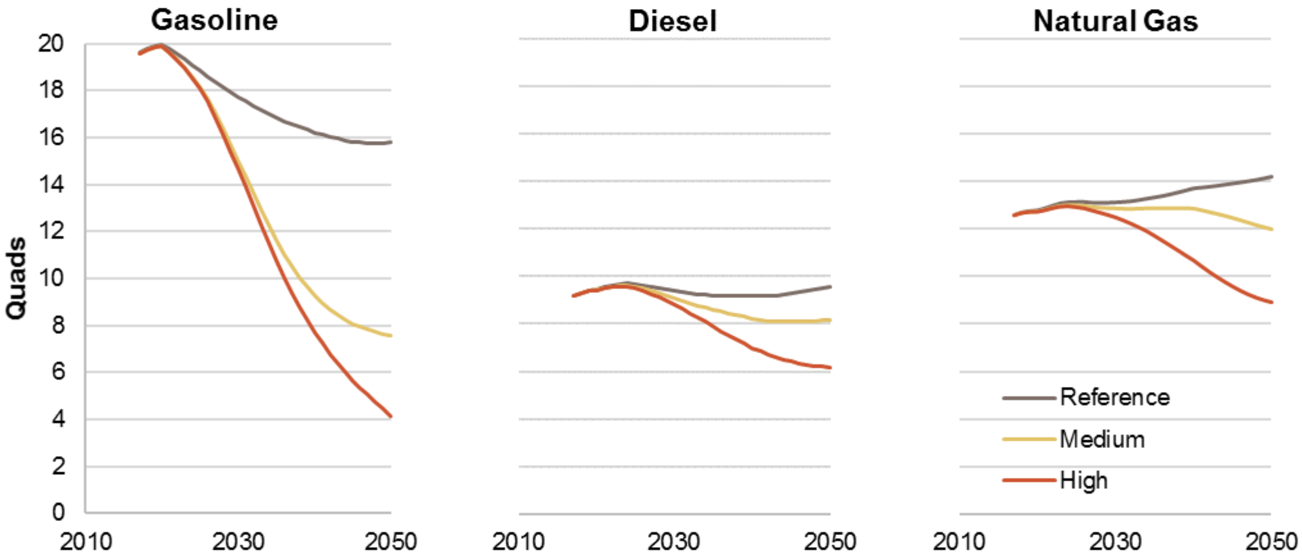
Electrification leads to **energy savings**

- 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)		2050 Reference			2050 Medium			2050 High		
	2016	Rapid	Moderate	Slow	Rapid	Moderate	Slow	Rapid	Moderate	Slow
Transport	7.5	78	88	101	809	898	1,019	1,365	1,512	1,712
Residential	1,418	1,462	1,474	1,503	1,481	1,518	1,589	1,491	1,551	1,657
Commercial	1,379	1,751	1,755	1,762	1,824	1,835	1,855	1,909	1,925	1,956
Industrial	1,084	1,405	1,405	1,406	1,405	1,406	1,408	1,515	1,517	1,520
Total	**3,889**	**4,696**	**4,722**	**4,772**	**5,520**	**5,656**	**5,871**	**6,280**	**6,505**	**6,846**

Percent (%) of Final Energy		2050 Reference			2050 Medium			2050 High		
	2016	Rapid	Moderate	Slow	Rapid	Moderate	Slow	Rapid	Moderate	Slow
Transport	0	1	1	1	13	14	16	27	29	31
Residential	45	44	45	45	52	52	53	61	62	63
Commercial	53	62	62	62	68	68	68	75	75	75
Industrial (excluding refining)	15	23	23	23	23	23	23	27	27	27
Total	**19**	**23**	**23**	**23**	**31**	**32**	**33**	**40**	**41**	**42**