Appendix D. Electric Vehicle Consumption

Independent Statistics and Analysis
U.S. Energy Information Administration

www.eia.gov
U.S. Department of Energy
Washington, DC 20585

Disclaimer

This appendix presents EIA's most recent experimental estimates for EV electricity consumption and provides an overview of the methodology used to construct them in the technical notes. These estimates are based on models and are subject to model error. We advise data users to exercise caution when incorporating these data in their analyses. EIA is releasing these estimates to solicit comments on the potential uses of the data, the methodology, and possible enhancements that would be most valuable. EIA plans to regularly reassess whether methodological improvements need to be made, based on this feedback and internal evaluations, before adopting the new estimates as official statistics assured to meet the same high data quality standards applied to EIA's traditional statistical products. Comments may be directed to InfoElectric@eia.gov.

Methodology

The model estimates monthly light-duty electric vehicle (EV)[1] consumption of electricity for each state based on the number of EVs, average number of miles driven on electricity, and EV fuel economy. Adjustments are made based on data availability from various input sources, to bring lagged data up to the current reporting period, and to adjust national and regional data down to state-level estimates.

The modeling methodology is hierarchical and is composed of a top-level model having components that are estimated using sub-models, which are described in the subsequent sections of this report. The top-level model is based on the average electricity consumed by nameplate (vehicle make and model) and model year in a state and month multiplied by the number of EVs for a particular nameplate and model year in that state and month. Lower-level sub-models estimate the number of EVs based on EV registrations and sales data and the average monthly EV consumption of electricity by EV nameplate and model year based on average estimated monthly vehicle miles traveled on electricity, a utility factor, EV fuel economy, and a weather correction factor.

The top-level model is defined as follows:

$$kWh_{s,m} = \sum_{np=1}^{NP} \sum_{my=1}^{MY} \left(EV\ stocks_{s,m,np,my} * EV\ kWh_{s,m,np,my} \right)$$

where:

$kWh_{s,m}$ is the total consumption in kilowatt-hours (kWh) by EVs in state s and month m

$EV\ stocks_{s,m,np,my}$ is the number of on-road EVs in state s and month m for EV nameplate np and model year my

$EV\ kWh_{s,m,np,my}$ is the average electricity consumed in kWh by EV nameplate np from model year my in state s and month m

MY is the number of model years for each EV nameplate np

NP is the number of nameplates for light-duty EVs listed on fueleconomy.gov

[1] Light-duty battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) are vehicles weighing less than 8,500 lbs including passenger cars and light trucks.

Vehicle stocks

This sub-model estimates the number of EVs in the top-level model using monthly EV registration and sales data for each state. Registrations rather than cumulative sales are preferred because they account for scrappage and represent the stock of licensed vehicles. Because monthly registration data by state, nameplate, and model year are not available for recent months, estimated monthly sales values by state, nameplate, and model year are cumulatively added to the most recently available end-of-year registration data to create monthly registration estimates for each state, nameplate, and model year.

Specifically, this sub-model is defined as follows:

$$EV\ stocks_{s,m,np,my} = EV\ registrations_{s,m_0,np,my} + \sum_{m_t=m_0+1}^{m} (EV\ sales_{m_t,np,my} * sales\ state\ allocation_{s,m_l})$$

where:

$EV\ registrations_{s,m_0,np,my}$ is the number of registered EVs by state s, EV nameplate np, and model year my by the end of the month m_0 (December of the latest available historical year for state registration data)

$EV\ sales_{m_t,np,my}$ is the national-level EV sales in month m_t for EV nameplate np and model year my

$sales\ state\ allocation_{s,m_l}$ is the share of total new EV registrations in state s in the most recently available new EV registration data month m_l

Sales state allocation shares are calculated as follows:

$$sales\ state\ allocation_{s,m_l} = \frac{new\ EV\ registrations_{s,m_l}}{\sum_{s=1}^{S} new\ EV\ registrations_{s,m_l}}$$

where:

$new\ EV\ registrations_{s,m_l}$ is the number of new EVs registered by state s in the most recently available new EV registration data month m_l

S is all fifty U.S. states and the District of Columbia

In more recent months where sales data must be used, monthly EV scrappage and EVs moving between states are not considered in the model.

EV electricity consumed

This sub-model estimates the average electricity consumed by nameplate (vehicle make and model) and model year in a state and month, which is used in the top-level model. It uses the average EV miles travel multiplied by the vehicle's fuel economy and a weather correction. The weather correction is applied because both cold and hot temperatures significantly decrease battery efficiency, increasing electricity consumption per mile traveled.

Specifically, this sub-model is defined as follows:

$$eV\ kWh_{s,m,np,my} = \sum_{d=1}^{D_m} (weather\ correction_{s,d} * kWh\_per\_mile_{np,my} * avg.eVMT_{s,m,np,my}/D_m)$$

where:

$weather\ correction_{s,d}$ is the vehicle fuel economy correction for state s on day d based on the average daily high and low temperatures recorded at a state representative airport and the effect that average temperature has on the EV range due to decrease in battery efficiency calculated by Geotab

$kWh\_per\_mile_{np,my}$ is the combined city and highway vehicle fuel economy that is estimated by the U.S. Environmental Protection Agency (EPA) for EV nameplate np and model year my

$avg.eVMT_{s,m,np,my}$ is the average vehicle miles traveled on electricity in state s during month m for EV nameplate np and model year my, which is estimated using the sub-model described in the next section

D_m is the total days in month m

Electric vehicle miles traveled

This sub-model of the EV electricity consumed sub-model estimates the average EV miles traveled on electricity in each state for each month by EV nameplate and model year. Data for EV miles traveled are only available at the census division level and for certain powertrains. To account for these issues, the model uses census-division-level EV travel data assigned to component states for the five powertrain categories, EV100, EV200, EV300, PHEV20, and PHEV50, as used in the EIA National Energy Modeling System (NEMS) Transportation Sector Demand Module[2]. Because data for EV miles traveled are only available on an annual basis, and with a lag, monthly EV miles traveled by state are based on the year-over-year change in total state-level vehicle miles traveled. The EPA combined city and highway utility factor is also applied to include only the portion of travel that uses electricity.

Specifically, this sub-model is defined as follows:

$$avg.eVMT_{s,m,np,my} = adjusted\ avg.VMT_{s,m_r,np,my} * current\ month\ adjustment_{s,m} * utility\ factor_{np,my}$$

with m_r being the same calendar month as m but in the most recent EV odometer data year

where:

$adjusted\ avg.VMT_{s,m_r,np,ny}$ is the adjusted average EV miles traveled in state s in month m_r of the reference year for which the latest odometer data are available for EV nameplate np and model year my

$current\ month\ adjustment_{s,m}$ is a temporal adjustment for state s to the adjusted average VMT from month m_r of the most recent EV odometer data year to the current month m

$utility\ factor_{np,my}$ is the portion of EV miles traveled that uses electricity only for EV nameplate np and model year my; the utility factor equals 1 for BEV and is less than 1 for PHEVs

[2] U.S. Energy Information Administration (July 2022), Transportation Sector Demand Module of the National Energy Modeling System: Model Documentation, pg. 136-137.

Since EV odometer data are only produced annually at the census-division level and can lag by more than one year, the data needs to be adjusted to monthly values for individual states to create monthly estimates. The following adjustment converts the yearly data to an average monthly value in that same reference year and converts it from a census-division-level value to a state-level value. Since EV odometer data are only available by powertrain categories, the model uses these categories to represent their underlying EV nameplates and model years.

$$adjusted\ avg.VMT_{s,m_r,np,my} = avg.VMT_{cd,y_r,pt} * \left(\frac{all\ VMT_{s,m_r}}{\sum_{m_r \in y_r} all\ VMT_{s,m_r}} \right), \forall [s \in cd\ \&\ (np,my) \in pt]$$

where:

$avg.VMT_{cd,y_r,pt}, \forall [s \in cd\ \&\ (np,my) \in pt]$ is the average EV vehicle miles traveled in census division cd, representing all component states s, for the most recent EV odometer data year y_r by powertrain category pt, where this value is constant for all EV nameplates np and model years my in a powertrain category pt

$all\ VMT_{s,m_r}$ is the U.S. Department of Transportation Federal Highway Administration's total vehicle miles traveled in state s during month m_r for the most recent EV odometer data year y_r

The following factor adjusts the average EV miles traveled for the year-over-year change in monthly values since the reference month m_r (the most recent available year $y_r$of average EV odometer data) up through month $(m-12)$ (last available complete year of all VMT data for all months).

$$current\ month\ adjustment_{s,m} = \prod_{m_j=(m_r+\ n*12\ (n=0,1,2\ldots(\frac{(m-m_r)}{12}-1))}^{(m-12)} 1 + \frac{(all\ VMT_{s,m_{j+12}} - all\ VMT_{s,m_j})}{all\ VMT_{s,m_j}}$$

where:

$all\ VMT_{s,m_r}$ is the U.S. Department of Transportation Federal Highway Administration's total vehicle miles traveled in state s during month m_r for the most recent EV odometer data

Potential sources of model error

The following list consists of identified potential sources of error in the model-based estimates:

Vehicle stocks:

- For preliminary monthly estimates, monthly EV scrappage and EVs moving between states are not considered in the model.
- Since state EV registration data are lagged, cumulative EV sales are used to estimate monthly state EV registrations, which could cause an over- or under- estimation of the EV stocks within a state.

- Interstate movement of vehicle sales could cause an over- or under- estimation of the EV stocks within a state.
- EV scrappage is not considered, which could cause an over-estimation of electricity consumption if scrappage increases considerably.

Vehicle miles traveled:

- Average EV miles traveled at the state level are derived from census division level values.
- Average EV miles traveled by nameplate and model year are derived from powertrain categories.
- The utility factor does not account for the possibility that many short trips are taken which could result in only electricity being consumed in PHEVs.
- The utility factor does not account for the possibility a PHEV has not been plugged into an electric power source resulting in only gasoline being consumed.
- Variability in driving patterns within a powertrain category could cause an over- or under-estimation of electricity consumption.

Fuel economy:

- Fuel economy factors do not account for decreasing efficiency due to vehicle age and deferred maintenance.
- Fuel economy factors do not account for non-weather related degradation.

Schedule for preliminary and final published data

The estimates provide preliminary monthly estimates based on available data until various final annual data are received. Preliminary published monthly estimates for a given reference year will be finalized after the following:

- Final annual vehicle registration data, provided by a third-party source, being processed and available for the model to consume, which typically occurs with a 12 or 13-month lag from the end of the reference year.
- Final EV odometer readings, provided by a third-party source, being processed and available for the model to consume, which typically occurs with a 12 or 13-month lag from the end of the reference year.

This schedule is separate from the finalization of Electric Power Monthly numbers in the Electric Power Annual.

Data sources and references

The model relies on the following data sources and types of data to estimate electricity consumption for EVs:

- $EV\ registrations$ are third-party data from S&P Global Mobility Vehicles in Operation dataset based on state vehicle registration administrative data from the end of a calendar year.
- $EV\ sales$ are third-party data from Wards Intelligence.

- $new\ EV\ registrations$ are third party data based on state-level new electric vehicle registration administrative data compiled by the Alliance for Automotive Innovation using Information provided by S&P Global Mobility (2011-2018, November 2019-present) and Hedges & Co (January 2019-October 2019).
- kWh_per_mile are administrative data published by EPA on fueleconomy.gov.
- $weather\ correction$ uses research conducted by Geotab and daily high and low temperature readings at airports from the U.S. National Oceanic and Atmospheric Administration (NOAA).
- $avg.VMT$ are third-party odometer reading data from S&P Global Mobility.
- $all\ VMT$ are based on vehicle miles traveled from the U.S. Department of Transportation Federal Highway Administration's Traffic Volume Trends.
- $utility\ factor$ are administrative data published by EPA on fueleconomy.gov.

A full list of all light-duty electric vehicles can be found at fueleconomy.gov.