ENERGY INNOVATION
POLICY & TECHNOLOGY LLC

www.energyinnovation.org
98 Battery Street; San Francisco, CA 94111
jeff@energyinnovation.org

THE FUTURE OF ELECTRIC VEHICLES IN THE U.S.

BY JEFFREY RISSMAN ● SEPTEMBER 2017

The transportation sector is a major energy consumer, accounting for roughly 29% of primary energy use in the United States. 80% of this energy is for on-road vehicles, which are predominantly powered by petroleum gasoline or diesel. Unfortunately, petroleum-powered vehicles have a number of downsides. They are inefficient: a typical gasoline car converts only 17%-21% of the chemical energy in the fuel into useful work. Petroleum fuels are expensive per unit energy compared to other fuels, and they would be even more so if the U.S. government did not subsidize oil production by more than $4 billion per year. They emit carbon dioxide (CO_2), causing global warming. And vehicle emissions are the biggest contributor to particulate pollution: tiny particles that lodge in people's lungs and kill 200,000 Americans each year.

Given their host of problems, petroleum-powered vehicles are ripe to be reformed, by making them far cleaner and more efficient, or, better, displaced. However, petroleum-powered vehicles are a mature technology, benefitting from decades of refinement and economies of scale that have driven down costs. It is not enough for a new technology to have the *potential* to be cheaper and better-performing than petroleum-powered vehicles. To compete effectively, electric vehicle technology must climb its own learning curve, driving down costs and improving performance, to the point where it is more attractive than petroleum-powered vehicles.

Battery electric vehicles (EVs) are on track to achieve this break-out. They already enjoy a number of advantages:

- EVs are three times as efficient as gasoline vehicles: 59%-62% of the electrical energy is converted into power to turn the wheels. Their efficiency means that they cost little to operate: a typical electric vehicle can travel 43 miles for $1 worth of electricity. This is about one fourth of the fuel cost of typical 2016 gasoline-powered cars and SUVs.
- EVs have far fewer moving parts than vehicles with internal combustion engines, so they are more reliable and require less maintenance.
- EVs can accelerate faster than gasoline cars, for a variety of engineering reasons.
- The electricity for EVs can be generated using zero-emissions technologies, such as solar PV, wind, hydro, or nuclear power, saving lives and reducing climate change impacts.

Given these advantages, why don't most new car sales today consist of EVs? One reason is price: though EV costs are falling rapidly, and battery costs could decline to $73 per kilowatt-hour in

2030 according to Bloomberg New Energy Finance (BNEF), it is still cheaper to purchase a fossil fuel-powered car.

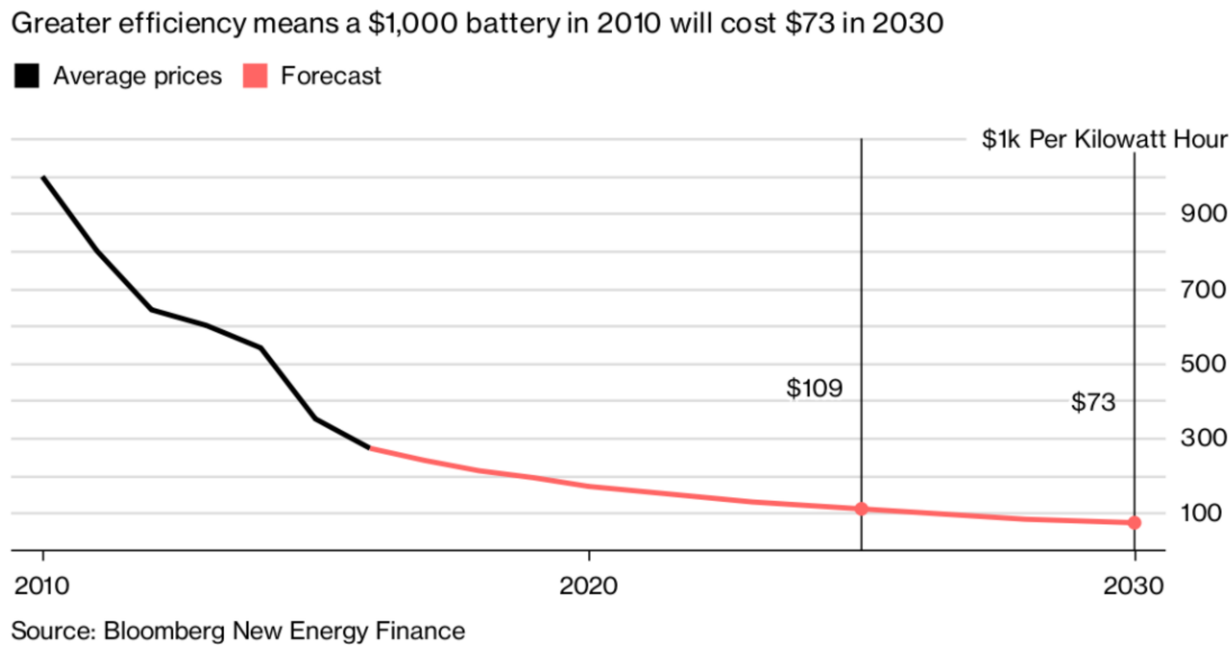

Figure 1. Historical and projected battery prices per kilowatt-hour.

Additionally, not all regions have abundant EV charging infrastructure, and some people (such as people without an off-street parking space) may have difficulty charging their vehicles at home. Nonetheless, there are signs of strong demand for EVs among some consumer segments. U.S. EV sales have grown an average of 32% annually from 2012-2016 and 45% over the year ending June 2017.

Policymakers, desirous of the public health and environmental benefits of EVs, are using a variety of policies to help promote them. Examples include subsidies for EV buyers, access to restricted travel lanes on highways, and public charging infrastructure deployment.

Accordingly, the big question for the future of the U.S. transportation sector is: How fast will EVs gain market share, what penetration will they achieve, and how will these things be affected by external factors, such as high or low petroleum fuel prices, or strong or weak government policy support?

A TOOL FOR ESTIMATING THE FUTURE U.S. VEHICLE FLEET

Energy Innovation has recently released an updated version of the Energy Policy Simulator (EPS), a computer model that assesses the impacts of dozens of policies on emissions, cost/savings, early deaths from particulate pollution, and more. For this version, the transportation sector has been completely rebuilt, including updated data sources and more powerful calculations. The Energy Policy Simulator can now estimate the composition of the future U.S. vehicle fleet, both in the business-as-usual (BAU) case, as well as in scenarios with a variety of relevant policies (such as a carbon tax, vehicle fuel economy standards, EV subsidies, an EV sales mandate, a low-carbon fuel standard, and more).

Figure 2 compares the EPS's projections of EV sales as a share of sales of all U.S. light-duty vehicles (LDVs; meaning cars and similar vehicles) to projections from the U.S. Energy Information Administration's [Annual Energy Outlook 2017]() (the "no Clean Power Plan" side case) and Bloomberg New Energy Finance's [Electric Vehicle Outlook 2017]().

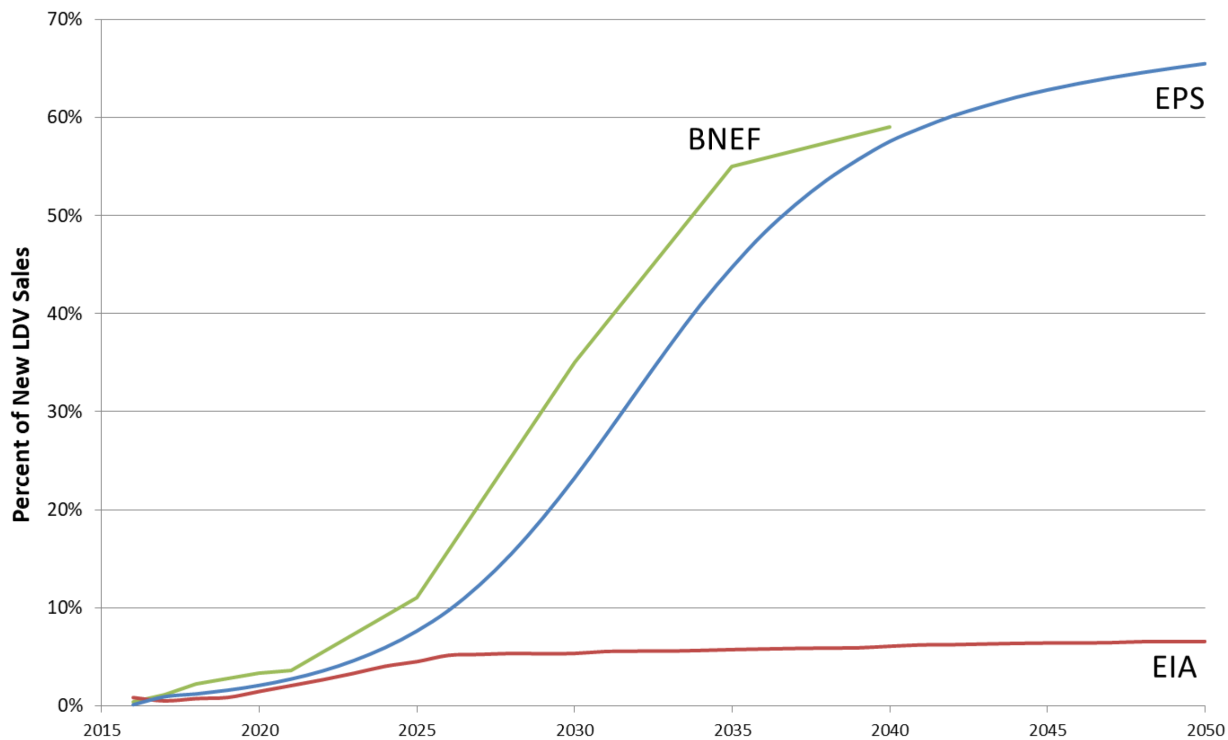

Figure 2. Projections of U.S. market share of EVs from three sources: the Energy Policy Simulator (EPS) 1.3.1 BAU case, the Energy Information Administration (EIA) Annual Energy Outlook 2017 "No Clean Power Plan" side case, and the Bloomberg New Energy Finance (BNEF) Electric Vehicle Outlook 2017.

BNEF projects a slow increase through 2021, faster through 2025, and then a dramatic acceleration through 2035, by which point, well over half of all new LDVs sold will be EVs. The EIA projects a very slow increase through 2026 and that the share will remain essentially flat after that point. Our EPS projection is closer to that of BNEF. The EPS projects a slower start than BNEF, but with similarly rapid growth in EV market share after 2026. By 2050, EVs are projected to make up 65% of new U.S. LDV sales.

FACTORS AFFECTING EV UPTAKE

In addition to making BAU projections, the EPS can help identify factors that will significantly affect the rate of EV uptake. This information is important for policymakers who wish to accelerate EV adoption and for investors who want to understand whether the emerging economic and policy landscape will be favorable for EVs.

EV PURCHASE PRICE

In the BAU case, the EPS uses input data from the Energy Information Administration's 2017 Annual Energy Outlook for the current price of EVs. We use the figure for "midsize cars" with 100-mile range, $39.5k, because this price is in line with the cost of today's popular EVs (even EVs with 200+ miles of range). The Chevrolet Bolt and Tesla Model 3 have MSRPs starting from $35-37k. (However, note that the average cost of these vehicles will be higher, as many consumers will opt for various options. For example, a larger battery and full self-driving capability will push the price of a Tesla Model 3 to $53k. But some consumers will opt for less-expensive EVs with shorter ranges.) To estimate costs in future years, the EPS uses an endogenous learning curve, which means that cost declines are driven by cumulative EV sales. This allows us to model the effects of EV-promoting policies on EV prices out through 2050.

However, future EV costs are not well-known, so it can be advantageous to consider cases in which EV costs decline more than predicted in the BAU case. Figure 3 compares three scenarios: our BAU scenario, a scenario in which the purchase price of EVs is reduced by 20% relative to BAU in 2050, and a scenario in which the price decline is 40%. Price declines relative to BAU are phased in linearly from 2017 through 2050.

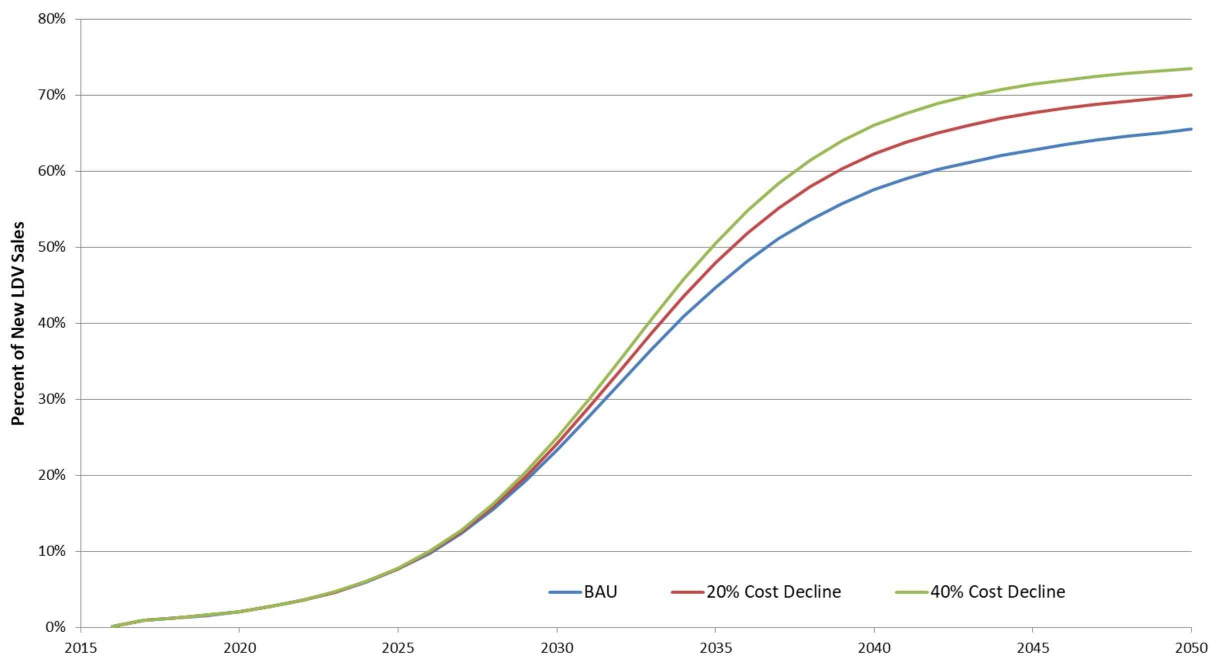

Figure 3. EVs' share of U.S. LDV sales under three scenarios: BAU, a gradual cost decline reaching 20% (relative to BAU) in 2050, and a cost decline reaching 40% in 2050.

The upfront purchase price of EVs is a significant determinant of market share. A 40% cost decline relative to the BAU case increases market share from around 65% to around 74% in 2050. Though helpful for boosting market share, cost declines are not sufficient to cause market share to approach 100% by 2050, as there exist non-cost factors (such as the long distances and limited availability of charging stations in rural areas or the inability of some car buyers to charge an EV at home) that limit EV deployment.

PETROLEUM PRICES

Future petroleum fuel prices cannot be predicted with precision, as they depend on many factors in the global oil market, including production levels in foreign countries, the availability of cost-effective unconventional oil in the U.S., the extent to which other countries adopt unconventional production techniques, and the advance of oil production technology. The Energy Information Administration accounts for this uncertainty by publishing "low" and "high" oil price scenarios, alongside their reference scenario, in the Annual Energy Outlook. Figure 4 compares EV market share under these two scenarios and the BAU scenario, as calculated by the EPS.

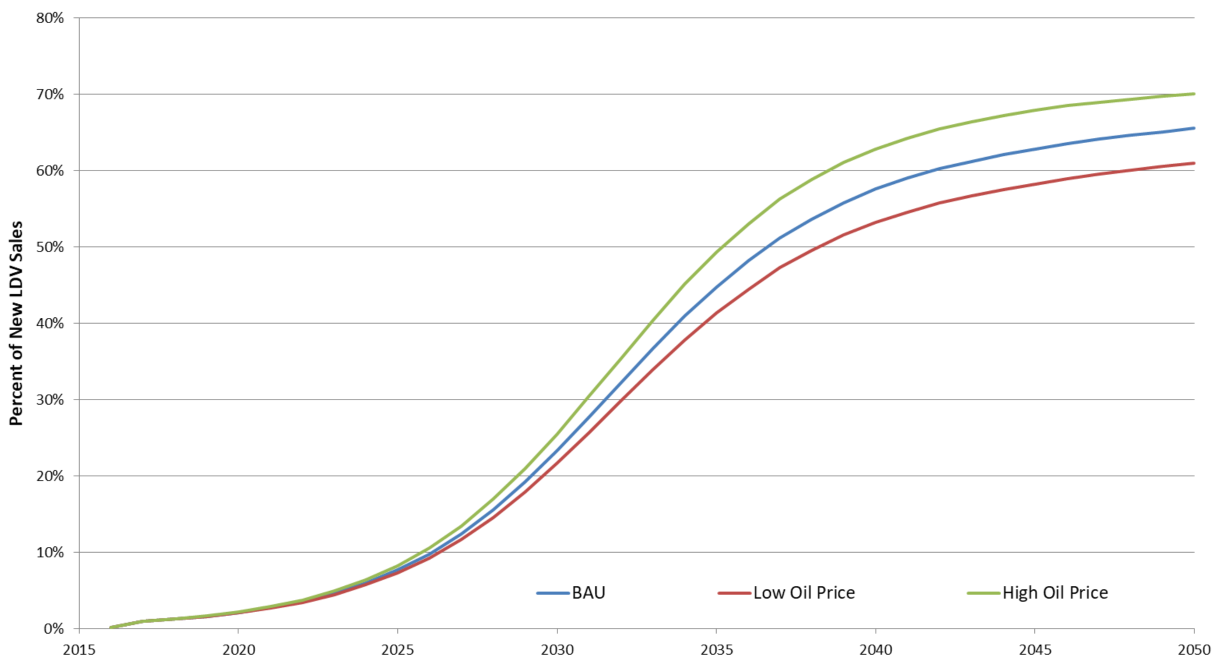

Figure 4. EVs' share of U.S. LDV sales under three scenarios: BAU, low oil prices, and high oil prices. The oil prices in these three scenarios match those used in the corresponding scenarios from the EIA Annual Energy Outlook 2017.

Petroleum prices that fall on the high end of EIA expectations increase the market share of EVs from 65% to 70% in 2050. Conversely, lower-than-expected oil prices could decrease EV market share to 61% in 2050.

Note that the EPS discounts future fuel costs and savings at an aggressive 7% per year, reflecting the short time horizons of typical passenger LDV buyers when considering fuel costs and savings. The use of a lower discount rate would increase the predicted change in EV market share in the high and low oil price scenarios.

FUEL ECONOMY STANDARDS ON GASOLINE LDVS

Fuel economy standards require carmakers to improve the efficiency of new gasoline-powered LDVs they sell. Fuel economy standards are one of the most cost-effective policies for achieving emissions reductions in the transportation sector in the near term (one to two decades). However, improving the efficiency of gasoline LDVs means that owners need to buy less fuel over the lifetime of these vehicles, which erodes the fuel cost advantage that EVs enjoy. Accordingly, fuel economy standards that improve gasoline LDV efficiency slightly slow EV adoption (Figure 5).

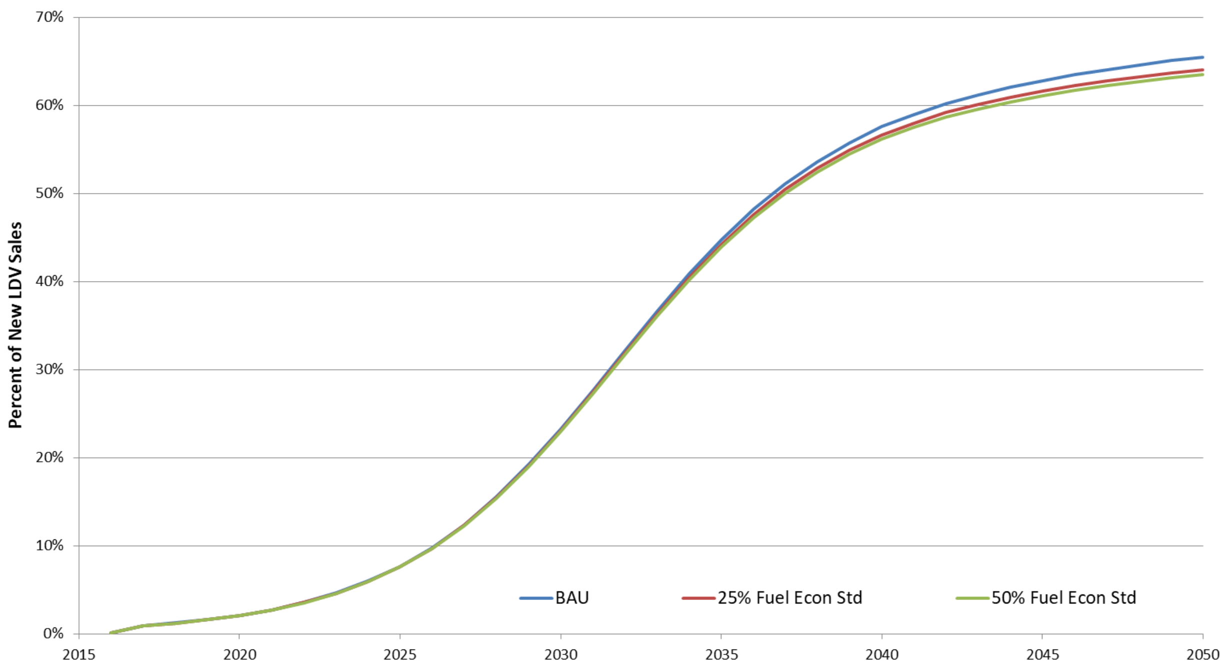

Figure 5. EVs' share of U.S. LDV sales under three scenarios: BAU, fuel economy standards mandating a 25% increase in miles per gallon traveled applied to gasoline LDVs (not to EVs), and a 50% increase in those fuel economy standards. The increases in fuel economy standards are phased in linearly from 2017 to 2050.

ELECTRICITY DEMAND FROM EVS

Electricity system planners wish to understand the impact that EVs will have on electricity demand. Figure 6 shows annual electricity demand from electric LDVs in two scenarios: the BAU scenario and the 40% cost decline scenario (first shown in Figure 3, above).

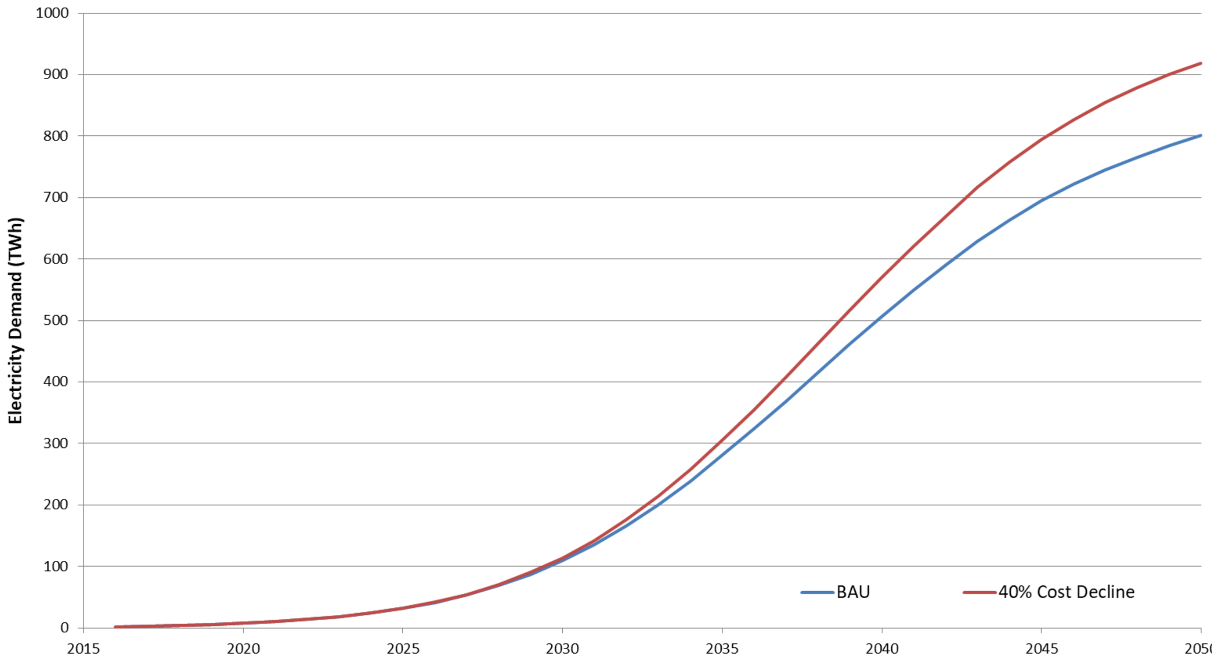

Figure 6. Annual electricity demand by electric LDVs in the U.S. in the BAU scenario and in a scenario with gradual cost declines reaching 40% of the BAU value in 2050.

Total U.S. electricity demand in 2050 is a little over 6,100 TWh in the BAU case and a little over 6,250 TWh in the case with 40% EV cost declines. Accordingly, electric LDVs represent roughly 13% of total electricity demand in the BAU case and almost 15% of total electricity demand in the cost decline case. Meeting these needs will likely not be a challenge in the United States. However, in some developing countries, large-scale EV deployment might require new generation and transmission resources. And in all countries, a large build-out of vehicle charging infrastructure will be required.

THE FUTURE OF MOBILITY

Due to declining EV costs, growth in charging station access, and increased familiarity and acceptance by the public, EVs will play an ever-greater role in the U.S. transportation sector. EVs are likely to represent at least 65% of sales in 2050, and with strong technology cost declines or high oil prices, could represent 70-75% of sales in that year. Tighter fuel economy standards on gasoline LDVs only slow EV adoption to a minor degree, so policymakers aiming to reduce pollutant emissions should consider using both fuel economy standards (to help drive down pollutants rapidly in the near-term) and EV promotion policies. Electricity demand from LDVs in 2050 will be significant and may require planning by electric utilities and regulators. A large build-out of EV charging stations will be required to achieve these projections.

EVs will be one of the success stories of clean energy: a technology that can take substantial market share from inefficient, polluting gasoline vehicles, despite having to compete on an uneven playing field (as oil producers are subsidized by the government, and the value of climate damages and human deaths caused by particulates are not reflected in the price consumers pay for gasoline). However, the right policy environment may accelerate the transition to EVs, saving money and lives.