Inside Energy

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RE: Electric Vehicles v. Internal Combustion Engines
DATE : 9/25/19 **David T. Stevenson, Director**

There are a wide range of studies comparing full battery electric vehicles (EV) to conventional vehicles with internal combustion engines (ICE) in terms of environmental benefits and cost. This study takes into account lifetime vehicle emissions considering battery manufacturing, and battery charging using a typical system mix of emissions from the PJM regional grid along with transmission and charging losses. EVs may save essentially zero carbon dioxide emissions. At best, a 4 ton savings would cost up to $5,300 a ton. The value of reducing emissions from other strategies range from $2 to $100/ton. Emissions of criteria air pollutants, such as, oxides of nitrogen, and fine particles are slightly larger for EVs. Studies suggest CAFE standards have already raised the cost of a new light duty vehicle by $4,000 to $6,000 per vehicle. CAFE fines and Zero Emission Vehicle credits are having a minimal impact on vehicle prices. The total negative economic impact of electric vehicles may average about $73 billion a year over the next decade.

Section 1, Emissions EV v. ICE

The Chevrolet Bolt and the Honda Fit are both hatchbacks, and are basically compact vehicles. The Bolt uses a 60 KWh battery weighing 960 pounds, for a range between charges of 238 miles, similar to a base model Tesla Model 3. A cradle to grave comparison in carbon dioxide emissions between the Bolt and the Fit in the PJM regional electric transmission area shows the Bolt will save essentially zero emissions. At bests a 4 ton saving would cost $5,300/ton (Table 2). For comparison, the September, 2019 Regional Greenhouse Gas Initiative cap and trade auction valued emission allowances at about $5/ton, the highest proposed legislation in Congress was about $100/ton, and recent EPA calculations estimate the Social Cost of Carbon in 2035 at $2 to $9/ton. The cost would be slightly lower in some region transmission areas, and higher in others.

We note studies by others show varying amounts of battery manufacturing emissions[1]. Studies from Carnegie Mellon, the Manhattan Institute, and Energy Ventures Analysis show greater emissions from EVs, especially when the higher average price of vehicles is considered along with its consequence of keeping older, less efficient vehicles on the road longer. Others, such as the Union of Concerned Scientists, indicate EVs save on life time emissions assuming cleaner sources of electricity, but will emit 6 tons more in the manufacturing process. A Swedish report, "The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries", summarizes a number of studies and determined battery manufacturing emissions will average 150-200 kg CO_2-eq/kWh which translates to between 9.9 to 13.2 tons of carbon dioxide per Bolt.

Table 1: 2019 Chevrolet Bolt v. 2019 Honda Fit subcompact hatchbacks

Specification	Bolt	Fit
MSRP	$36,620	$18,160
Weight	3,563 lbs.	2,568 lbs.
Dimensions	69.5" x 194"	67" x 161"
Mileage Rating	3.6 miles/KWh	36 mpg

Source: manufacturer's websites as of Sep. 2019

Key assumptions:

- Vehicle life – Bolt equal to its battery warranty of 8 years/100,000 miles, Fit 15 years based on typical ICE vehicles. In the U.S. battery packs are most likely to be landfilled. In Europe battery packs are currently incinerated with elemental cobalt, nickel, and copper recovered. Bolt is using a nickel rich lithium ion battery with Cobalt/Manganese/Nickel cathode, which most likely contains 6 kg cobalt worth $222, 51 kg of nickel worth

$918, and 10 kg of copper worth $60, for a total recoverable material value of $1200. The cost of transportation, incineration, and metal processing for battery re-use may not make recovery worthwhile at this time.

- Trade in value – Bolt is assumed to be zero since it will need a new battery pack quoted at $15,734 excluding labor according to GM when the 100,000 mile warranty runs out. There may also be a charge to dispose of the 960 pound battery. We assume it will be landfilled at a cost of about $200. An 8 year old Fit has an estimated resale value of $3,752 according to the Kelly Blue Book for a vehicle in the most common condition.
- Registration - Titling a new vehicle may require a higher document fee, or sales tax payment (4.5% assumed). The Bolt owner may pay an extra $833 fee on the $18,500 higher purchase price.
- Finance Charge – The Bolt owner may pay an extra $2,292 over five years for finance charges on the higher purchase and registration cost assuming a 4.5% interest rate.
- Maintenance – Same except Fit will need 19 oil changes @ $55 each (actual quote), and air filters will be changed 3 times @ $25 each (actual quote) for a total of $1120. The Bolt has regenerative brakes, but also weighs 1000 pounds more than the Fit, and so it is assumed brake and tire wear will be the same.
- Fuel use – The Bolt will charge mostly at home, and will use 27,778 KWh of electricity at a net rate of $0.096/KWh at the current Delmarva residential time-of use rate for EVs (0.056/KWh) plus $11.70 a month customer charge for a separate meter, or $2,667 in fuel cost, plus $1,305 for a Level 2 home charger, for a total cost of $3,972. The Fit will use 2,778 gallons of gasoline at $2.60/gallon for a fuel cost of $7,222.
- CO2 Emissions - The Bolt will use 27,778 KWh of electricity which emits 1.19 pounds/KWh (0.933 pounds/KWh PJM Systems Mix[3] marked up 21.5% for transmission and charging efficiency losses[4]), or 16.5 tons of CO_2. In addition, reports summarized above estimate manufacturing of the EV will emit between 6 to 13 tons more than a mid-size ICE vehicle for total emissions of 22.5 to 29.5 tons. The Fit will use 2,778 gallons of gasoline which emits 18.9 pounds/gallon of E10 gasoline[4], or 26.2 tons of CO_2. The lifetime emissions savings of the Bolt may range between -3.3 and 3.7 tons, or an average of essentially zero savings.
- Tax credits – Only eight states have EV tax credits, and the federal tax credit is waning for Tesla. GM, and soon for Ford. For example, the Bolt received a $7,500 federal tax credit last year, but that drops to $1,875 Oct 1, and disappears at the first quarter of 2020. Tax credits are ignored in this analysis. While tax credits reduce the cost for the EV owner, the full cost of the vehicle still diverts money that could be spent elsewhere. Tesla responded to the loss of $3,750 in federal tax credits by reducing the price of the Model 3 by $3,000.
- Lost Fuel Tax revenue – Federal and state fuel taxes on gasoline and diesel fuel fund highway construction. The Bolt will avoid $1,150 in fuel taxes, but will partially make that up with higher registration fees ($833 in this example). Some states are adjusting registration fees to collect the difference, or are considering switching to a mileage fee instead of a gas tax. As of now this is an advantage for the Bolt, but shows up in the gasoline price of the Fit.

Table 2: Cost differential of the Bolt and Fit after 8 years

Cost Item	Bolt	Fit
Net Initial Cost	$36,620	$18,160
Finance Charge Difference	$2,292	
Fuel Cost	$3,972	$7,222
DMV Document Fee Difference	$833	
Engine oil, oil filter, air filter		$1,120
Resale Value	$200	($3,752)
Total Cost	$43,917	$22,750
Net Cost	$21,167	
Cost/Ton of 4 tons CO2 saved	$5,292/ton	

Source: author calculation from above assumptions

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Two major vehicle air pollutants can impact health, oxides of nitrogen (NO_2) and fine particulate matter ($PM_{2.5}$). Health impact studies conducted by the EPA show 90 to 95 percent of the negative health impacts of these pollutants are related to fine particles. EPA Tier 3 tail pipe emission standards established in 2014 will limit fine particle pollution to 0.7 pounds over 100,000 miles of driving in vehicles built between 2019 and 2025. By comparison, The PJM system mix for 2019 year to date indicates an electric vehicle using about 28 megawatt-hours of electricity over 100,000 miles will emit about 20.7 pounds of sulphur dioxide per KWh when adjusted for efficiency losses. One study[5] suggests the sulphur dioxide emissions might convert to 1 to 1.9 pounds of fine particles, up to about twice as much as the gasoline powered vehicle, and would still leave 19 pounds of sulphur dioxide pollution. Likewise, meeting the EPA emission standards will lead to average NOX emissions of about 11.3 pounds for gasoline powered vehicles compared to about 16.6 pounds for the EV using the adjusted PJM systems mix. In addition, on our worst days, fine particle ambient air levels are running only about half of national standards, and NO_2 is running about two-thirds of the standard, so no health impacts are expected.

Notes:

1. Energy Ventures Analysis, July 10, 2019, Evaluation of the Colorado Zero Emission Vehicle Regulation, http://coratepayers.org/wp-content/uploads/2019/08/Energy-Venture-Analysis-Evaluation-of-the-Colorado-Zero-Emission-Vehicle-Regulation-ZEV-.pdf
   , Jenn et al., "Alternative Fuel vehicle Adoption Increases Fleet Gasoline Consumption and Greenhouse Gas e missions under United States Corporate Average Fuel Economy Policy and Greenhouse Gas Emissions Stand ards," Journal of Environmental Science and Technology, March 1, 2016. Carnegie Mellon University, Jonathan A. Lesser. The high Cost of Electric Vehicles. The Manhattan Institute, . https://www.manhattan-institute.org/html/shortcircuit-high-cost-electric-vehicle-subsidies-11241.html. May 2018, Union of Concerned Scientists, 2015, "Cleaner Cars Cradle to Grave", https://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions
2. The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries**,** file:///C:/Users/dtste/Documents/EV%20life%20cycle%20co2%20emissions%20IVL%20Swedish%20study.pdf
3. PJM Interconnection, LLC, Systems Mix November, 2017, to October, 2018, https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix
4. PJM Interconnection, LLC, Marginal Losses Implementation Training, 2007, 9.1 % transmission loss at 50 miles, https://www.pjm.com/~/media/training/new-initiatives/ip-ml/marginal-losses-implementation-training.ashx , University of Delaware, "Measurement of power loss during electric vehicle charging and discharging", Elpiniki Apostolaki-Iosifidou, 3/15/17, 12.4% at 40 amps, https://www.sciencedirect.com/science/article/pii/S0360544217303730#!
5. U.S. EIA, "How much carbon dioxide is produced from burning gasoline and diesel fuel?", https://www.eia.gov/tools/faqs/faq.php?id=307&t=11
6. Journal of Engineering and Environmental Science, May, 2008, "Characterization of PM2.5 and conversion of sulphur dioxide in inland areas of Taiwan", https://www.researchgate.net/publication/233517158_Characterization_of_PM25_and_conversion_rate_of_sulfur_dioxide_to_sulfate_in_inland_areas_of_Taiwan

Section 2, the impact of fines, Zero Emission Vehicle Credits, and higher vehicle cost

Fines for missing CAFE Standards

On July 12, 2019 the National Highway Traffic Safety Administration finalized its proposed rulemaking on the Federal Civil Penalties Inflation Adjustment Act freezing fines at $5.50 for each vehicle over each 0.1 mile per gallon over the CAFE Standard in a year instead of raising the fine to $14 as proposed by the Obama Administration. Auto manufacturers had already paid $890 million in fines as of 2014, on top of any money paid to purchase compliance credits. The Alliance of Automobile Manufacturers, and the Association of Global Automakers jointly petitioned NHTSA for reconsideration of the Obama rule in light of an expected expense of $1 billion a year from the higher fines (suggesting even the $5.50 fine was costing about $650 million a year with a range shown in Appendix A of the rule of about $400 million to $1.2 billion a year). With new vehicle sales averaging 17 million a year, the impact of the fines would average about $38/vehicle. The Final Rule can be found at this link, https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/cafe_civil_penalties_final_rule_07122019.pdf .

Zero Emission Vehicle Credits

California rules have resulted in significant trading of compliance credits. In 2016 Tesla reporting receiving $215 million in income from selling compliance credits, $280 million in 2017, and $103 million in 2018. ZEV credit income totaled only $15 million in 1Q2019, and notably in 2Q2019 all references to ZEV credits disappeared from Tesla financial reports. The trend appears to be to lower trading amounts as more auto manufacturers boost sales of EVs. It was learned Tesla received $201 million in Non-ZEV credit sales in 1Q2019 from 10K reports. The source of those sales is not fully understood.

CAFE driven cost/vehicle

Higher average fuel economy standards have already forced manufacturers to spend more in manufacturing costs/vehicle. A Heritage Foundation study, March 4, 2016, "Fuel Economy Standards Are a Costly Mistake" (https://www.heritage.org/government-regulation/report/fuel-economy-standards-are-costly-mistake) , found new car prices may have been $4,000 to $6,200 more expensive in 2016 because of the CAFE standards. Besides the economic damage of the higher prices, higher purchase prices encourage people to hold onto older, less efficient, and more polluting older cars for a longer time.

Total Economic Impact of CAFE Standards 2017 to 2026

Using US Energy Information Agency Annual Energy Outlook 2019 tables 39 and 53 forecast of BEV and Non-BEV sales and price trends starting with a cradle to grave cost differential of $21,167 for BEVs, and a $4,000 price premium for non-BEV, and fines from NHSTA final Rule Appendix A, The average negative economic impact will be about $72.8 billion.