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Consumer Electric Mobility Education-EVOLUTION and ATRAVEL

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Executive Summary

With the U.S. Department of Energy's (DOE) support, Argonne National Laboratory has developed two consumer education tools: EVOLUTION [1] and ATRAVEL to help the general public to 1) understand the different electric-drive technologies and mobility choices; 2) charging technologies; 3) energy, environmental and cost benefits of driving electric vehicles or taking other transportation modes based on their own driving pattern, charging availability, and travel needs. EVOLUTION starts with consumers' purchase considerations—such as purchase price—and compares the monetary and environmental benefits of various passenger electric-drive vehicles and equivalent conventionally-fueled models. ATRAVEL examines trip cost, convenience, and environmental impact of private vehicle versus other travel options including transit, ridehail/share, carshare, bicycle, e-scooter, for a given trip origin and destination. Such tools integrated information from the Alternative Fuels Data Center (AFDC), FuelEconomy.gov, U.S. Energy Information Administration websites, and others in one convenient platform to provide the most recent information about electric-drive and conventional powertrain types, weekly updated regional fuel price, public charging locations, and available federal and state incentives by make and model. EVOLUTION has been reported by several media and has been used in local events such as auto shows through the U.S. DOE funded Midwest EVOLVE EV Showcase project [2]. ATRAVEL is still under development and will be completed in the end of 2019.

1 Introduction

More than 25 years ago, the U.S. DOE began the voluntary, Clean Cities program to build a market for alternative fuels across the United States [3]. The City of Atlanta was the first city designated by DOE and had a coalition of just seven stakeholders, e.g. the local utility, transit, and city that signed a memorandum of understanding with the Federal government to grow primarily its natural gas vehicle market. Today, nearly 90 coalitions, covering 83% of the U.S. population, are designated and represent partnerships with 13,000 stakeholders from the public and private sector, building the market for each of the alternative fuels and clean, vehicle technologies. In total, coalitions have assisted in putting 1.1 million alternative fuel vehicles on the road. Moreover, since 1993, Clean Cities coalitions have consistently increased their energy use impact each year for a cumulative impact in energy use equal to nearly 8 billion gasoline gallon equivalents (GGEs).

The success of the DOE program relies on the activities of coalitions, each led by a coordinator, to mobilize stakeholders, such as fleets; fuel suppliers; local and state governments; technology providers (such as engine, vehicle, system, and component manufacturers); training facilities; and universities to work together to adopt or support the adoption of cleaner vehicle technologies and petroleum reduction practices. In addition to fleets, coalitions now reach an unprecedented number of consumers with the rapidly growing market of electric-drive vehicles.

As was the impetus for the voluntary program, the Energy Policy Act of 1992, also called for DOE to provide public education on alternative fuels. The AFDC, prior to the internet, provided a repository of technical documents from DOE and its laboratories on alternative fuels sent upon request. Upon the arrival of the internet, the AFDC houses databases of helpful information, such as alternative fuel station locations and incentives by state available to fleets and consumers at a click of a button and have application programming interface (API) connections with station providers, for instance, to keep information timely. Furthermore, as the Clean Cities program grew, the national laboratory system developed for the AFDC a variety of tools, which captured the laboratories' unbiased analysis from data and highly sourced material used to formulate outputs, e.g. total cost of ownership (TCO). Laboratory staff did not only demonstrate these tools to multiple audiences, but coordinators furthered the reach of these tools in their communities to stakeholders and consumers. Two examples of Argonne's consumer education tools supporting Clean Cities coalitions are EVOLUTION and ATRAVEL, which is under development.

Since the first NISSAN LEAF and Chevy VOLT were sold in the U.S. in December 2010, more and more electric vehicle models are now available in the market. Currently, there are about 40 different passenger electric-drive vehicles models, both plug-in hybrid electric and all electric or battery electric vehicle in the U.S. market [4]. Meanwhile, all major auto makers claimed to accelerate their electrification R&D plan to bring over dozons of models to the market in next 10 to 20 years. However, often the general public lacks much of the basic understanding of the vehicle technologies and charging technologies. Many consumers are not aware of the various model availabilities, price ranges and charging capabilities. During this same time of electric vehicle market growth, the U.S. DOE developed tremendous information about charging locations, electric vehicle characteriscs, local fuel prices and the energy and environmental benefits of electric vehicles. Such information is available on many federal websites. However, many consumers do not know such information exists, not to mention using this information to understand and compare the potential benefits of electric-vehicle technologies. **EVOLUTION** starts with consumers' purchase considerations—such as purchase price—and compares the monetary and environmental benefits of various passenger electric-drive vehicles with equivalent conventionally-fueled models based on consumers' own driving pattern, charging availability, temperature effects, and fuel/electricity price.

In later years, emerging transportation trends, such as shared mobility, connection and automation have reshaped the transportation system, and how people travel. The Energy Efficient Mobility Systems (EEMS) program funded by the U.S. DOE envisions an affordable, efficient, safe, and accessible transportation future in which mobility is decoupled from energy consumption. With the emergence of new mobility solutions, consumers have an expanding set of options for personal travel. However, there is limited information on how these transportation modes may work for individuals, depending on location and travel patterns. To educate consumers, Argonne National Laboratory is developing the **ATRAVEL** Tool to allow them to examine travel and ownership costs of private vehicles as compared to other travel options including transit, ridehail, and carshare.

2 Methodology

EVOLUTION: Education on E-Drive Vehicles

There are several consumer education tools available about electric vehicles and their potential benefits. We have reviewed them and summarized their strengths and gaps in Table 1. The major research gaps are 1) existing tools require consumers to know which electric models are available to choose and compare with conventional models; 2) do not integrate all the necessary information from available Federal websites and give consumers concise information; and 3) do not educate the climate impact on electric-drive vehicle range and how vehicle efficiency and range could be affected by driving cycles. Our objectives were to develop a web-based tool to 1) assist consumers in choosing and comparing different powertrain through education; 2) support DOE programs by connecting existing information to consumer choice; and 3) utilize research results on performance of alternative fuel vehicles. EVOLUTION starts with consumers' purchase considerations—such as purchase price—and compares the monetary and environmental benefits of various passenger electric-drive vehicles and equivalent conventionally fueled models. The new education tool helps consumers compare the cost of owning different electric-drive powertrain technologies, as well as the environmental impact of these vehicles. Figure 1 shows the front page of EVOLUTION which explains the difference between a hybrid-electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) graphically before users begin the tool. EVOLUTION can be accessed through computer, tablets, and smartphones by the following link: https://evolution.es.anl.gov/ [1].

Table 1: Summary of EV Education Tools

	Information Provided				Inputs/Defaults						Outputs					
Tools	All LDV models (including all PEV)	Vehicle Prices	EVSE Availability, type	Customized MPG	Usage Pattern	Daily mileage	Long Distance Travel	% Highway travel	Charging Frequency	Gas and Electricity Prices	Energy Consumption	Fuel Cost	Total Ownership Cost	Greenhouse gas emissions	Criteria pollutants	Model Suggestions
My Plugin Hybrid Calculator					×	×	×	×	×	×	×	×				
AFDC Vehicle Cost Calculator	×	×			×	×	×	×	×	×	×	×	×	×		
UC Davis GreenLight EV Explorer	×			×	×	×		×	×	×		×				
Sierra Club		×	×	×	×	×	×	×	×							×
Go Electric Drive		×	×													×
My GreenCar (GPS Tracking)		×		×	×	×		×		×	×	×	×	×	×	×
Nyserda EV Calculator					×	×					×	×	×	×		×
UC Davis Analytic Tool to Support the Implementation of EV Programs		×		×	×	×	×	×	×	×		×	×			
EVolution	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×

Figure 1: Front page of EVOLUTION-Education on E-Drive Vehicles

Argonne designed a six-step interactive process which leads to customized results and information for each user, shown in Figure 2. In step 1, consumers will enter their budget and preference without any preknowledge of the various electric-drive vehicle powertrains and model availability. Based on the user's inputs, in step 2 the tool filter all satisfied vehicles models by powertrain types, HEV, PHEV, BEV and conventional. The vehicle purchase price used in the tool accounts for Federal incentives by make/model but not state incentives. Besides a conventionally-fueled vehicle, a user could choose one model from two of these three advanced vehicle powertrains. In step 3, by entering a user's zip code, local gasoline and electricity prices, as well as default daily and annual travel information will appear. Users can modify to generate more customized results. In step 3, the tool presents education information about how annual fuel costs vary by location, driving/charging needs, and climate.

Figure 2 Interactive process leads to customized results and information

Step 4 first shows how often the user needs to charge their selected models (step 2) based on daily travel needs (step 3). Then, the tool presents the charging availability surrounding the zipcode entered in step 3 in an interactive map and asks whether the user could charge at workplace or any of the public locations (shown in the map). The climate where a user resides and commute time help the tool factor how often the user needs to charge each type of plug-in electric vehicle. The map showing public chargers by location and demonstrates potential charging availability for users. All default information is provided to users to simplify the tool's experience.

Step 5 shows the TCO of three selected models by year based on the travel and charging pattern entered in previous steps. Certain assumption about down payment and interest rates are included. Note: the vehicle is considered as having no residual value at the end of 15 years of life. Detailed assumptions are documented on the webpage. Users could compare the cost by year and identify the payback period. Before showing the TCO by year by model, step 5 also shows federal tax credits available for the models selected in step 2, if available, and possible state incentives. Finally, in step 6, the user can compare the differences in annual fuel costs, emissions, and petroleum consumption between the three selected models and to be able to print out the summary of their results. Table 2 summarizes the references of major assumptions and information used in EVOLUTION.

Table 2 Summary of References of Major Assumptions and Information in EVOLUTION

Information/Assumption	Resources	Note
Gasoline/Electricity Price	Energy Infromation Administration	By region [5, 6]
Travel Pattern	National Household Travel Survey (NHTS) 2017	By population density [7]
Charger Locations	Alternative Fuel Data Center	By zipcode [8]
Vehicle Characteristics (MSRP, MPG, range, etc)	Fueleconomy.gov	By make/model [9]
Federal/State Incentive	Alternative Fuel Data Center	By make/model [10]
Charging level (Level 1, 2 and DCFC)	Alternative Fuel Data Center	By level [11]
On-road electric range	Argonne National Laborotary	Average of selected models tested [12]
TCO calculation	Alternative Fuel Data Center	Consistent with the cost calculator on AFDC [13]
Electricity Generation Mix	Energy Infromation Administration	By region [14]

ATRAVEL:

ATRAVEL's goal is to allow the user the ability to detail travel behavior in order to determine the cost, time, and environmental implications of the modes available to that individual user. Numerous data sources are used to estimate these impacts based on location and mode. The key factors analyzed include location and travel patterns, vehicle ownership versus other mode costs, and environmental impacts of each mode.

Location and travel pattern

A consumer's location and travel pattern will greatly determine the availability, cost, time, and environmental impact of private vehicle ownership as compared to other transportation modes. In ATRAVEL, Google Maps provides the platform to enter specific trips, see Figure 3, while generating the trip's distance and travel time for private vehicles, transportation network company (TNC) rides, transit buses and rail, bicycling, and walking.

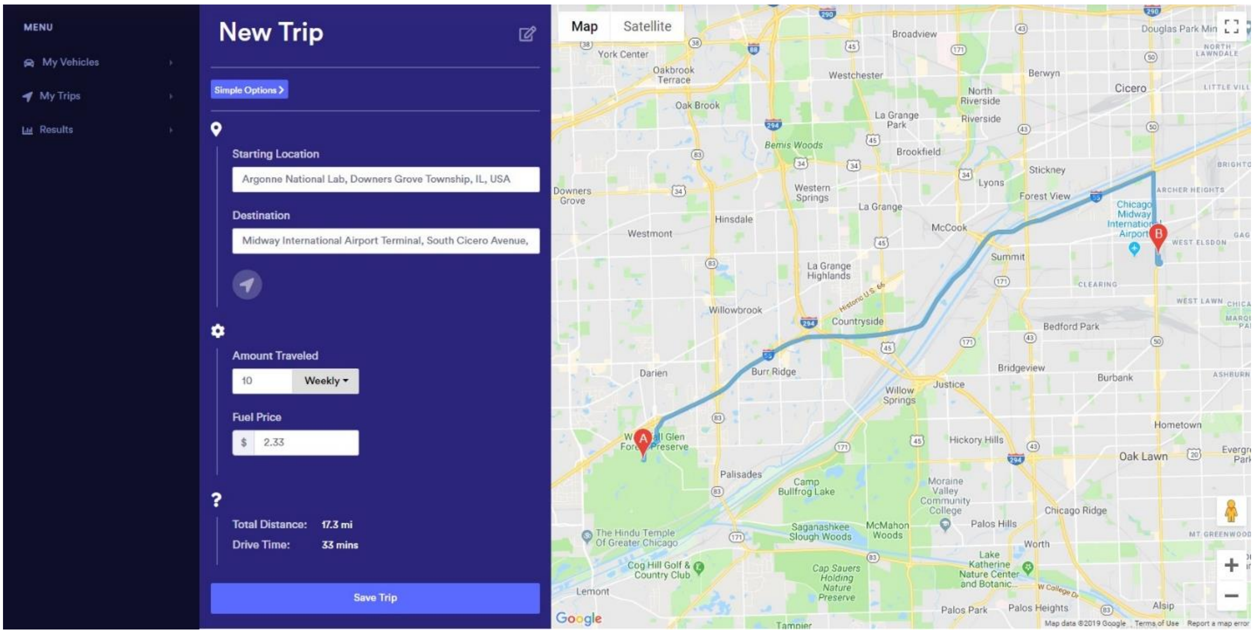

Figure 3 – ATRAVEL User Interface

Annual vehicle trips cover a wide range of trip purposes including commuting, shopping, errands, and recreation. As ATRAVEL is meant for educational purposes, we do not expect users to enter a detailed travel diary. Therefore, we ask users to enter their most common trips, e.g. commuting accounts for 24% of household vehicle trips and 30% of vehicle miles [15]. ATRAVEL uses Local Area Transportation Characteristics for Households (LATCH) dataset developed by the U.S. Bureau of Transportation (BTS) to provide additional vehicle trip and mileage data based on the user's census tract to supplement user inputs. The BTS generated the LATCH data using both National Household Travel Survey and American Community Survey (ACS) [16].

Costs

The cost of owning and operating a vehicle is impacted by several factors, including depreciation, financing, fuel, maintenance, insurance, and parking costs. ATRAVEL is based on a vehicle's TCO data from Argonne's Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool (AFLEET), while supplementing specific depreciation costs based on the user-selected make and model [17]. In addition, parking costs, which are not included in AFLEET, are estimated using data from sources including a data published by INRIX [18].

Costs for other modes come from a variety of data sources. In ATRAVEL, we use fixed fare/fee and variable time and mileage costs by city using data from Ridester [19]. TNCs use surge pricing when there is a high demand for rides, but not enough drivers to satisfy them. Due to the limited data on surge pricing frequency, we do not include those charges at this point. Carshare costs depend on the provider but usually include a monthly/annual flat fee to join the service and a hourly charge while renting the vehicle. In ATRAVEL, we estimate costs using provider data such as ZipCar and Car2Go.

Transit costs for a wide range of agencies were estimated using data from the American Public Transit Association (APTA) Public Transportation Fare Database, which provides information on both single-trips and monthly passes [20]. Bike and scooter sharing costs are estimated from major providers including Divvy, Lime, and Bird. The cost of these services depend on the provider and can include monthly/annual passes, as well as variable and fixed single trip pricing.

Environmental

The use of different transportation modes have different environmental impacts depending on factors such as fuel type, fuel efficiency, and vehicle occupancy factors. The ATRAVEL Tool is based on the AFLEET Tool to calculate the energy use and emission impacts of passenger vehicle and transit bus use for different fuels, and is supplemented by data from the Argonne GREET Model for transit rail use [17]. The fuel type and fuel efficiency of specific vehicle models are collected from the FuelEconomy.gov website, while that data is collected from the National Transit Database (NTD) for specific agency's transit bus and rail fleets. In addition, occupancy factors are derived from the NHTS for private vehicles and the NTD for each agency's bus and rail fleet. Vehicle occupancy data is limited for ridehailing in specific cities, but a five-city study estimated that 61% of the vehicle-miles had a passenger, while a study of San Francisco found that the average number of passengers was 1.8 [21].

3 Results and Conclusions

EVOLUTION was officially released in February 2018 and has been used in several major showcase events such as Chicago Auto Show, Twin Cities Auto Show to educate interested consumers, before or after test-driving an electric vehicle. The tool has been reported by several media outlets such as Charged, Green Car Congress, NGT News, Midwest EVOLVE, and Renewable Energy Magazine. The tool was demonstrated in several Midwest EVOLVE showcase events. The tool was also presented to SMART Columbus, Tesla, briefings to several utilities and received positive reviews. There is an electric-drive powertrain to fit anyone's driving needs. As an example, Figure 4 shows the TCO of three selected models by year. The payback period for this user to drive a BWM i3 (60 Amp-hr battery) and Fusion Energi Plug-in Hybrid is 8 years comparing to a Toyota Camry. Please note the results vary by driving/charging pattern, as well as fuel price and fianancial assumptions. Figure 5 shows the comparison of annual gasoline usage, fuel cost, and GHG of selected models.

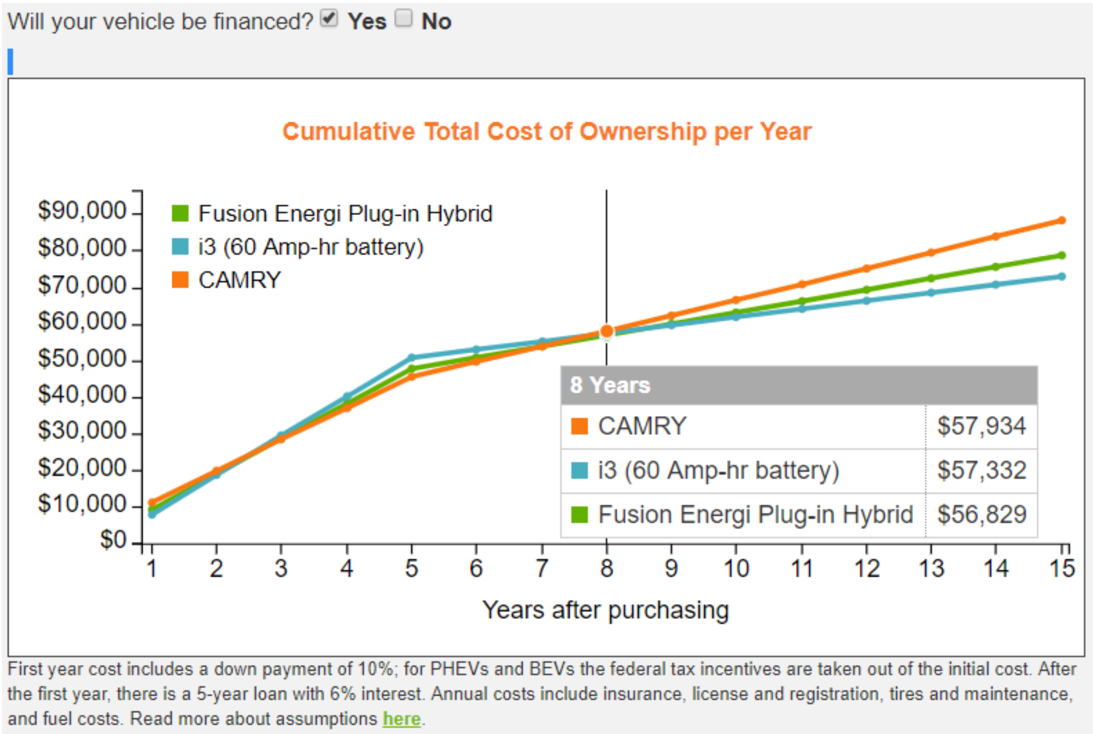

Figure 4 Total Cost of Ownership by Model and Year

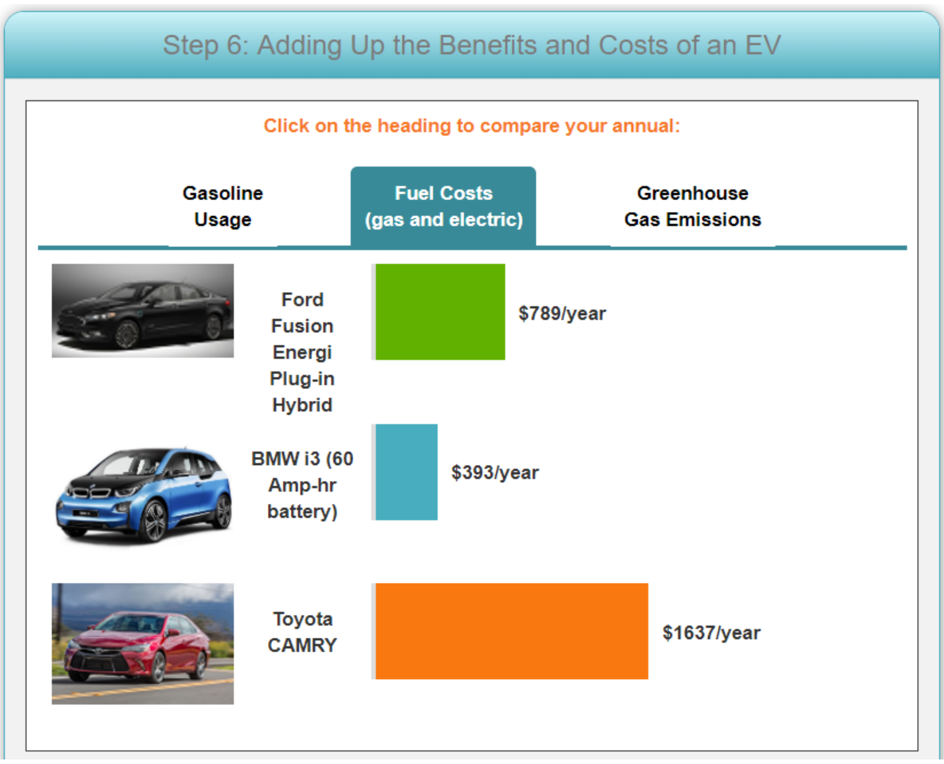

Figure 5 Comparison of Annual Gasoline Usage, Fuel Cost and GHG of Selected Models

The ATRAVEL Tool is still under development; however, preliminary results show that in cases of low vehicle usage, the use of ridehail can be cost-effective as compared to private vehicle ownership (see Figure

4). The case of Detroit stands out as it has high vehicle ownership costs due to its average annual insurance rates being $5,400 as compared to the national average of $1,400 (The Zebra 2018).

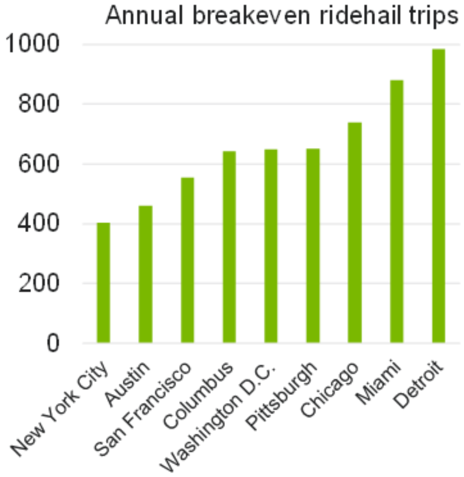

Figure 4 Breakeven ridehail trips as compared to vehicle ownership in selected cities

In Figure 5, the U.S. average annual petroleum use and greenhouse gas (GHG) emissions of passenger car, sports utility vehicle (SUV), and transit bus use is presented for different fuel types. The results for transit buses are on a per-passenger basis using the 11.2 passenger assumption from GREET. Gasoline powered passenger cars and SUVs have higher petroleum use and GHGs as compared to gasoline hybrid electric vehicles (HEVs), while EVs have the lowest. For transit bus use, diesel has the highest petroleum use, while CNG and EVs have the lowest. Diesel and CNG transit bus use has similar GHG emissions, while EV has the lowest. When comparing across modes, transit bus use has lower petroleum use and GHGs, while SUV use has the highest.

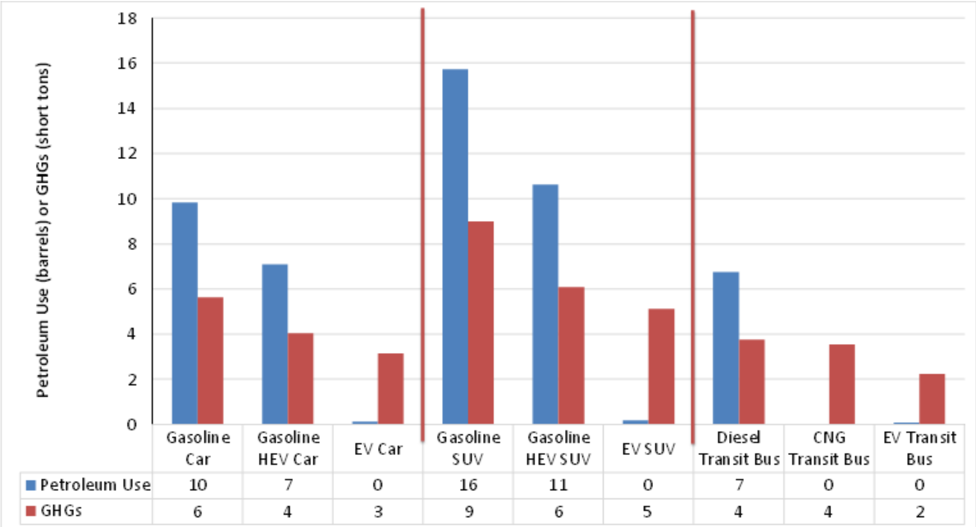

Figure 5 U.S. average annual petroleum use and GHG emissions of car, SUV, and transit bus use

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References

[1] Y. Zhou, *EVOLUTION*, Argonne National Laboratory, https://evolution.es.anl.gov/

[2] Midwest EVOLVE Showcase Program, https://www.midwestevolve.org/

[3] Clean Cities Coalition Network, U.S. Department of Energy, https://cleancities.energy.gov/about/

[4] Argonne National Laboratory, Light Duty Electric Drive Vehicles Monthly Sales Updates, https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates Energy Information Administration, Annual Energy Outlook 2018, https://www.eia.gov/outlooks/aeo/, Feburary 2019.

[5] Weekly Retail Gasoline and Diesel Prices, Energy Information Administration, https://www.eia.gov/petroleum/gasdiesel/

[6] Electric Power Monthly, Energy Information Administration https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

[7] 2017 National Household Travel Survey, U.S. Federal Highway Administration, https://nhts.ornl.gov/.

[8] Alternative Fuel Data Center, Electric Vehicle Charging Station Locations https://www.afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC

[9] Find a Car, U.S. Environmental Protection Agency, Fueleconomoy.gov

[10] Alternative Fuel Data Center State Law and Incentives, https://afdc.energy.gov/laws/state

[11] Alternative Fuel Data Center Alternative Fuel Locator, https://afdc.energy.gov/stations/#/find/nearest

[12] Downloadable Dynamometer Database, Argonne National Laboratory, https://www.anl.gov/es/downloadable-dynamometer-database

[13] Alternative Fuel Data Center Vehicle Cost Calculator, https://afdc.energy.gov/calc/

[14] Energy Information Administration Electricity Data Brower: https://www.eia.gov/electricity/data/browser/

[15] N. McGuckin and A. Fucci. 2018. Summary of Travel Trends: 2017 National Household Travel Survey. FHWA-PL-18-019, Federal Highway Administration.

[16] BTS. 2018. Methodology for 2017 Local Area Transportation Characteristics for Households, US DOT. https://www.bts.dot.gov/latch/latch-methodology-2017

[17] Burnham, A. 2018. User Guide for AFLEET Tool 2018. Argonne National Laboratory https://greet.es.anl.gov/files/afleet-tool-2018-user-guide

[18] Cookson, G. Pishue, B. 2017. The Impact of Parking Pain in the US, UK and Germany, INRIX

[19] Ridester. 2019. Uber and Lyft Fare Estimators, https://www.ridester.com

[20] APTA, 2017. Public Transportation Fare Database https://www.apta.com/resources/statistics/pages/otheraptastatistics.aspx

[21] Cramer J., Kruger, A. 2016. Disruptive Change in the Taxi Business: The Case of Uber, National Bureau of Economic Research Working Paper 22083 http://www.nber.org/papers/w22083

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