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Identifying Alternative Fuel Vehicle Potential in New York State

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“Please note that although the research problem addressed in this report was recommended by staff members of New York State Department of Transportation (NYSDOT), the views and opinions expressed in this report are those of the authors and do not necessarily reflect the official policy or position of NYSDOT. Assumptions made within the analysis do not reflect NYSDOT’s positions.”

Executive Summary

"New York is committed to putting clean vehicles on the road to reduce harmful emissions and build a vibrant clean energy economy." – Governor Andrew Cuomo

In May of 2014, Governor Andrew Cuomo signed on to the Multi-State Zero Emission Vehicle Action Plan (ZEV Plan). As part of this plan, New York has agreed to put approximately 800,000 zero emission vehicles (ZEVs) on the road by 2025. While the plan focuses primarily on zero emission vehicles, the analyses conducted here were expanded to include additional alternative fuel vehicle (AFV) types. This includes ethanol and biodiesel, since these are the fuel types that could also contribute to the future stock of AFVs in New York State (NYS). Multiple fuel options are potentially important for the long-term sustainability of the transportation sector. This research provides information about New York's alternative transportation fuel options for passenger vehicles from a sustainability point of view. The goal of this project is to better inform the DOT and policymakers about New York's AFV options. As this may help them determine which AFV types enhance sustainability in the transportation sector. The analyses conducted also serves to inform policymakers about ways to encourage the adoption of these alternative fuel vehicles (AFVs) once the best fuel options of NYS have been identified.

In order to determine which fuel types might be the most sustainable for New York in the near-term, first the options that could feasibly achieve widespread adoption by 2025 were selected. Each of the fuel types were then compared based on their life cycle greenhouse gas (GHG) emissions, cost of ownership, and fueling infrastructure. Additionally, the barriers to adoption were identified and a policy analysis was conducted to demonstrate how New York is currently addressing these barriers in comparison to other states.

Comparing the vehicles based on their life cycle GHG emissions, we broke the analysis down into two segments: emissions associated with the production and use of the fuel and emissions associated with the manufacture and disposal of the vehicle itself. The results show that most of the alternative fuel vehicles produce fewer GHG emissions than conventional vehicles, with the exception of E85 vehicles, though there is some debate arguing that emissions for E85 vehicles should be lowered to account for the carbon absorbed during the growing of the feedstock. The analysis also revealed that electric vehicles (EVs) are the least emitting type of vehicle, in part due to the fact that New York tends to get its electricity from hydropower and cleaner-burning natural gas rather than coal. Thus, the cleaner electricity supply makes EVs an even more attractive option for New York from a carbon emissions standpoint.

Though the alternative fuel vehicles generally produce fewer greenhouse gas emissions when compared to gasoline cars, not all of the AFVs performed as well when emissions of other air pollutants were analyzed. However, further study is needed to assess whether or not widespread adoption of AFVs might increase the level of these non-GHG air pollutants to harmful levels.

While emissions are important to society as a whole, they are not as important to a consumer as costs, so a cost of ownership analysis was also conducted. To determine the total cost of owning an alternative fuel vehicle over its entire lifetime, the initial cost, annual costs, and scrap value of each vehicle type were considered. A partial sensitivity analysis was then conducted to determine how fluctuations in fuel prices might alter the relative costs of ownership. The analysis revealed that alternative fuel vehicles are generally cheaper to own than conventional vehicles, with EVs being the least costly.

Though alternative fuel vehicles, particularly EVs, are shown to produce fewer greenhouse gas emissions and cost the consumer less in the long-run, there are significant barriers to adoption that prevent consumers from purchasing AFVs. One of the most prominent of these barriers is range anxiety, which means that drivers are reluctant to own an alternative fuel vehicle out of fear of being stranded because they cannot easily and quickly refuel at a nearby station.

Though range anxiety is a known problem, its magnitude in NYS was not fully understood. Therefore, a gap analysis utilizing Geographical Information Systems (GIS) software was needed to visually show where the gaps in the infrastructure are in order to identify areas where consumers might experience range anxiety. The analysis revealed large numbers of electric charging stations in the state that make EVs convenient for everyday driving needs. However, conventional gasoline and biofuel compatible vehicles certainly have an advantage for longer trips, as they can refuel at virtually any gas station. Though there are fewer biodiesel and ethanol stations throughout the state, infrastructure gaps are actually fewer compared to electric vehicles because, biofuel cars can drive longer ranges as flex fuel vehicles.

While range anxiety is certainly a prominent issue, it is not the only barrier to adoption. High upfront costs and low public awareness about AFVs also slow adoption rates. To address these barriers, a policy survey was conducted. First, an overview of NYS and federal policies and programs showed there are numerous incentives, but most focus on plug-in hybrids (PHEVs) and EVs. Perhaps more importantly, the majority of incentives and programs concentrate on reducing the costs of ownership, with relatively few focused on improving the fueling infrastructure or raising consumer awareness.

Continuing the survey, policies and programs from other states were researched to determine if there were any lessons New York could learn about encouraging the adoption of AFVs. Other states, such as Washington, Oregon, and California have had success addressing some of the key barriers to adoption by providing incentives and programs to promote the fueling infrastructure as well as promoting consumer awareness. For example, the three states have come together to form the West Coast Electric Highway, which is a network of fast charging EV stations. These other states have not limited their focus to just EVs either, as Washington has a number of policies to promote the production and sale of biofuels. From an awareness-raising perspective, California has been a leader by not only targeting consumers directly but also educating car salesmen, politicians, and other key influencers of consumer opinion.

Contents

Key Abbreviations

Abbreviation	Secondary Abbreviation	Definition
AFV		Alternative fuel vehicle
ARFVTP		Alternative and Renewable Fuel and Vehicle Technology Program
B or BD		Biodiesel, a biofuel typically derived from lipid containing plant materials
	B20	Biodiesel 20%; a fuel mixture that consists of 20% biodiesel and 80% diesel
	B100	Biodiesel 100%; a fuel that consists of 100% biodiesel with no gasoline or diesel mixed in
BAU		Business as usual
BEV		Battery electric vehicle, also known as electric vehicle (EV); a vehicle powered entirely by an electric
		battery charged from the grid
CO2e		Carbon dioxide equivalent, a normalized unit for greenhouse gas global warming potential
CNG		Compressed natural gas; an alternative fuel that consists of methane (CH_4) stored at high pressures
CPI		Cost performance index
DOE		United States Department of Energy
DOT		Department of Transportation, specifically the New York State Department of Transportation
E or ETOH		Ethanol, an organic alcohol compound used as a biofuel, often derived from starchy, cellulosic plant materials (i.e. biomass) such as corn, sugar cane, etc. Ethanol-gasoline blends of 10% (E10) are common under U.S. EPA Renewable Fuel Standards, and increased ethanol percentages are targeted. The blending is generally compatible with vehicles manufactured after 2001.
	E20	Ethanol 20%; a fuel mixture that consists of 20% ethanol and 80% gasoline
	E85	Ethanol 85%; a fuel mixture that consists of 20% ethanol and 15% gasoline
EIA		Energy Information Administration
EPA		Environmental Protection Agency
EV		Electric vehicle; equivalent to BEV
FCV		Fuel cell vehicle
FFV		Flex fuel vehicle; a vehicle that can use conventional gasoline or any ethanol mixture up to E85
GGE		Gasoline gallon equivalent; the amount of alternative fuel equal in energy to a gallon of gasoline
GHG		Greenhouse gas; any atmospheric gas that is known to increase the effect of global climate change
GIS		Geographic information systems
GREET		Greenhouse gases, Regulated Emissions and Energy use in Transportation; a life cycle analysis model developed by Argonne National Laboratory to evaluate the emissions of alternative fuels associated with fuel production all the way until the fuel is consumed by a vehicle.
HEV		Hybrid electric vehicle; a vehicle that uses both an electric motor and a gasoline engine but is powered mainly by the gasoline engine. The electric motor is charged on-board through processes such as a regenerative braking and does not charge with electricity from the grid.

Abbreviation	Secondary Abbreviation	Definition
HOV		High occupancy vehicle
ICE		Internal combustion engine
		SI – refers to spark ignition engines, which typically run on gasoline fuels.
		CI – refers to compression ignition engines, which typically run on diesel fuels.
LCA		Life cycle analysis
LPG		Liquefied petroleum gas, also known as propane
MPG		Miles per gallon
NPV		Net present value
NYISO		New York Independent System Operator
NYPA		New York Power Authority
NYS		New York State
NYSERDA		New York State Research and Development Authority
MY		Model year
PHEV		Plug-in hybrid electric vehicle; a vehicle that uses both an electric motor and a gasoline engine; battery is charged with electricity from the grid.
PEV		Plug-in electric vehicle
RFS		Renewable fuel standards
TCI		Transportation and Climate Initiative
WCEH		West Coast Electric Highway
ZEV		Zero emission vehicle
ZEV MOU		Zero emission vehicle memorandum of understanding

INTRO:
ASSIGNMENT, SCOPE & GOAL

Scope

This memorandum provides a New York State (NYS) specific analysis and assessment of NYS's alternative fuel vehicle (AFV) future with particular focus on the Zero-Emissions Vehicle Multi-State Action Plan (ZEV Plan). Although the ZEV Plan addresses only those vehicles that have zero tailpipe emissions, such as electric and hydrogen fuel cell vehicles, this memorandum addresses a broader range of AFVs, specifically, those that will likely contribute most significantly to the future stock of AFVs in NYS. The scope of this memorandum includes: (1) A review of various alternative fuel choices and vehicles; (2) An impact analysis that includes a life-cycle greenhouse gas (GHG) emissions analysis, health impact analysis, and a lifetime cost of ownership analysis of the various alternative fuel choices; (3) A gap analysis that assesses the AFV infrastructure that currently exists in NYS and where that infrastructure could be augmented to provide a more conducive environment for greater adoption of AFVs; and (4) The policy environment that exists in NYS and other states pertaining to alternative fuel vehicles. The results of the research and analysis presented in this memorandum can serve to inform policymakers as well as consumers regarding NYS's AFV future and potential.

Specialized consumer-oriented materials were also produced. They aim to inform consumers' decisions vis-a-vis the purchase of AFVs. This consumer guide will offer a concise discussion of various AFV considerations including: infrastructure availability and requirements; lifetime cost-of-ownership; governmental incentives and rebates; potential barriers to adoption; and other reflections that may be important to a vehicle consumer.

Background – ZEV Multi-State Action Plan

On May 29, 2014, NYS Governor Cuomo joined the governors of seven other states in signing the ZEV Action Plan. The ZEV Plan represents a commitment by the eight participating states to help develop a consumer market to enable the deployment of 3.3

million zero-emission passenger vehicles by 2025. The vehicle technologies that are being pursued under the ZEV Plan are pure battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel cell vehicles (FCVs).

The ZEV Plan includes 11 key “actions” that participating states should take in order to promote the ZEV Plan objectives. These actions largely target the three primary objectives of (1) developing a market for ZEVs, (2) providing a welcoming regulatory environment for ZEV vehicle adoption, and (3) improving the ZEV owner experience. Many of the actions relate to the promotion and enablement of the fueling and charging infrastructure that is currently lacking but would be required if ZEV adoption were to increase.[1]

The ZEV Plan traces back to the signing of the zero-emission vehicle memorandum of understanding (ZEV MOU) by the governors of the eight participating states in October 2003. The ZEV MOU has since evolved into an action plan that reflect advances in AFV technologies, environmental considerations and other factors and has been replaced by the ZEV Plan.

The states signatories to the ZEV Plan are California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont. New Jersey and Maine have also committed to the ZEV framework but have not formally signed on as participants.[1]

Background to Alternative Fuel Choices

Biodiesel

Biodiesel (B20) is a cleaner burning alternative to petroleum diesel fuel that serves as a renewable “drop-in” fuel. As opposed to other alternative fuels, the use of biodiesel in vehicles with diesel engines does not require any major vehicle or engine modifications. Biodiesel is available in a number of varieties, representing the different ratios of biodiesel to petroleum diesel. The most common variety of biodiesel is B20, a blend of 20% biodiesel, 80% petroleum diesel. In the US, diesel is used primarily in larger commercial vehicles and less so in passenger vehicles.[2]

Biodiesel is typically produced from vegetable oil and to a lesser extent from yellow grease, animal fat, and used cooking oils. The overwhelming majority of biodiesel in the US is derived from soybean oil. Through a trans-esterification process, the feedstock molecules are rearranged to closely resemble diesel fuel. Most often, methanol and a catalyst are introduced to the feedstock oil to stimulate this reaction. Although biodiesel can be used in its pure form, it is typically blended with traditional petroleum diesel to produce various biodiesel blends. [2] Although biodiesel fuel production is not a new technology, there have been recent advances in expanding the range of feedstocks that can be used to produce the fuel.

Electric Vehicles

BEVs are powered by electricity drawn from off-board electricity generation assets and stored in onboard batteries. The electrical

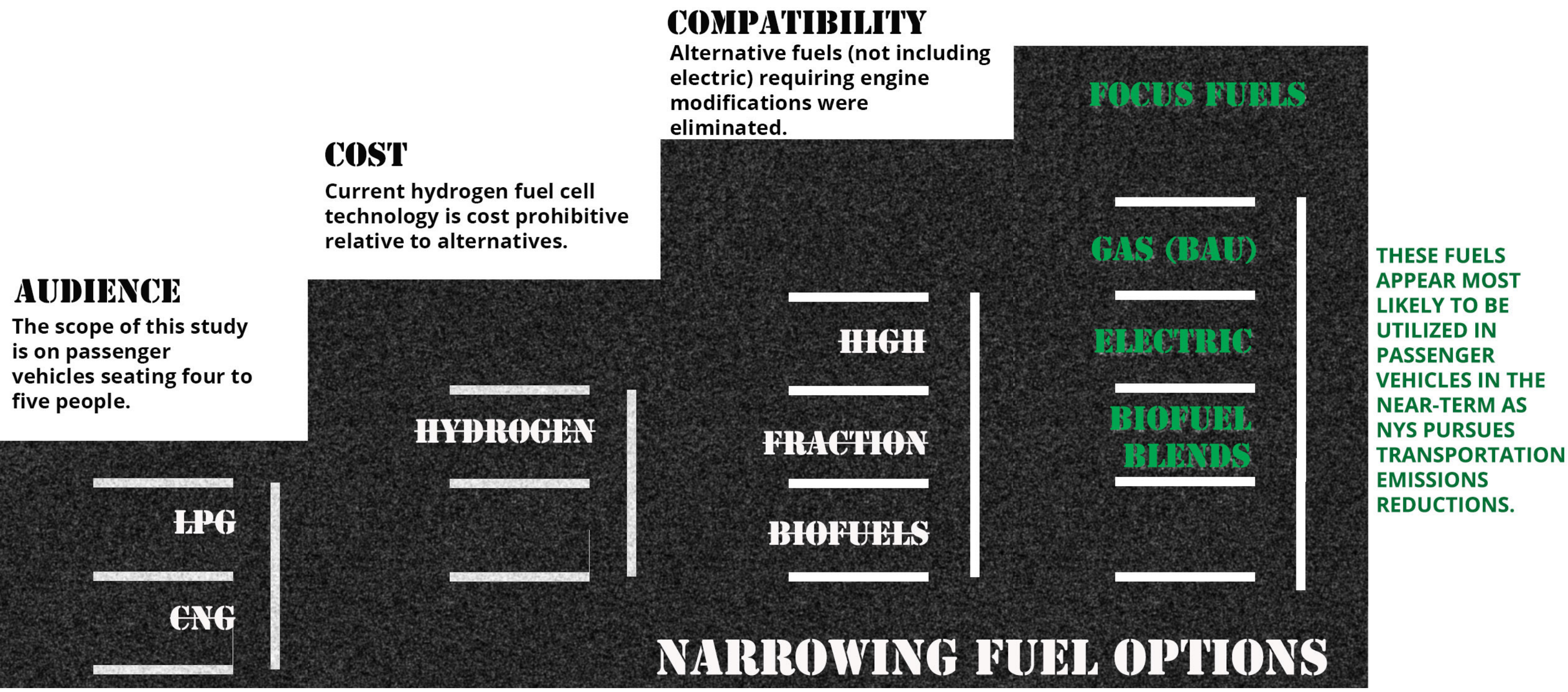


Figure 1 Selection of Feasible Fuels

energy stored in onboard batteries is transformed by electric motors into kinetic energy for vehicle propulsion. As there is no combustion onboard, BEVs have no tailpipes and accordingly, no tailpipe emissions. However, there are emissions associated with the off-board generation of electricity, unless such generation is exclusively from renewable sources. The specific carbon intensity of electricity generation will vary depending on when and from which electricity grid the BEV is charging. The efficiency of the vehicle in converting electrical energy to propulsion will likewise impact the carbon intensity of vehicle operations.[3]

Electricity is produced at generators across the region and is transmitted through the electric grid through a charger to the onboard battery of plug-in electric vehicles (PEVs). In NYS, electricity is generated from the combustion of fossil fuels and nuclear fission, as well as from renewable resources. Of NYS's net generation, natural gas and nuclear each supplied approximately 36%, hydroelectric approximately 20%, other renewables (including wind and solar) approximately 6%, with coal only comprising 1.6%.[4] The carbon intensity of the electricity generated will vary over the course of the year and even each day depending on which electricity generation assets are in operation at that time. As the intensity of electricity generation emissions rises with increased demand, charging one's BEV at noon on a sweltering summer day during peak demand will tend to generate more associated GHG emissions than doing so on a balmy spring evening during a time of minimal load levels, such as in the late night hours.

According to Elon Musk, Founder and CEO of Tesla Motors, "It is definitely true that the fundamental enabling technology for electric cars is lithium-ion as a cell chemistry technology…."[5] The various improvements in battery technology include higher energy density, decreased weight, faster recharging time, lower cost and the ability to sustain increased charge cycles have helped to erode many of the issues that have traditionally held back BEV production.

Hybrids

Hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) use traditional transportation fuel as well as electric motors powered by onboard batteries. Hybrids exist in two varieties, HEVs that exclusively employ mechanisms to convert otherwise wasted kinetic and heat energy into electrical energy that can be stored and later used in vehicle propulsion and PHEVs that in addition to the aforementioned mechanisms, can be plugged in to have their batteries charged from the grid. In both hybrid varieties, the availability of dual propulsion systems, internal combustion engines (ICEs) and electrical motors, typically allows the drive train and ICE to be smaller, weigh less, allowing the vehicle to achieve higher efficiency rates. The efficiency of hybrid vehicles surpasses that of traditional ICE vehicles and accordingly, tailpipe emissions are reduced on a per mile basis.[6]

The gasoline that is used to fuel hybrids is the same gasoline that is used to fuel ICE vehicles and as such, there are no difference in the methods of production and supply of this type of fuel for hybrid vehicles. Insomuch as PHEV's can also be "plugged in" and have their onboard batteries charged from external electricity generation resources, the production mechanism for this electricity is identical to the production process described above with regards to BEVs, though the overall battery size is less than a BEV.

The improved battery technologies that have enabled BEVs have also been instrumental in the development of hybrid vehicles. Developments in the field of regenerative braking, electric motor drive/assist, and automatic start/shutoff have also enabled hybrid vehicle development. Regenerative braking captures the kinetic energy that would otherwise be wasted in the braking process and converts that energy to electricity to be stored and used later to power the electric motor. The electric motor allows for the use of a smaller ICE as the electric motor will "assist" at times when additional power is required. The electric motor will also typically exclusively power the vehicle during low speed driving and short-range, if electrical charge is available. The automatic start/shutoff feature shuts the ICE off when the vehicle is not in motion and restarts the engine automatically when the driver depresses the accelerator.[7]

Ethanol

Ethanol is a gasoline additive that is produced from plant materials. The current gasoline mix in the US contains approximately 10% ethanol with other variants available that contain 20% (E20) through 85% (E85) ethanol. Incorporating a larger share of ethanol in transportation fuel assists displaces oil consumption and, according to some studies, reduces GHG emissions associated with transportation. An increasing number of vehicles are designed to operate on fuel with higher percentages of ethanol, and some vehicles ("flex fuel vehicles") can operate on wide varieties of ethanol-gasoline blends.[8]

Almost any plant can be used to produce ethanol. The biomass feedstocks used to produce ethanol in the US are typically domestically cultivated and primarily consist of corn. In other countries, such as Brazil, sugar cane is the primary ethanol feedstock. The type of feedstock used typically determines the method of production. Starch and sugar based feedstocks account for nearly all of ethanol production and are transformed using a process of biochemical conversion. The more prevalent and less costly method to process starch and sugar based feedstocks is a dry milling process where the feedstock is ground into flour and then allowed to ferment into ethanol. Advances in wet and dry milling technologies have allowed for the rapid expansion of ethanol production. Various advances throughout the process, from separation of feedstock components to enhanced enzymes have allowed improved yields at lower costs. Research and development is underway to continue to enhance ethanol production capabilities.[9] Advances in engine technology that allow vehicles to operate on a range of ethanol blends have also been instrumental to the wider adoption of ethanol fuel.

There is controversy over the increased use of food crops for ethanol conversion and increasing attention has been placed on the use of cellulosic feedstocks, including wood, grasses, and crop residue to produce ethanol. However, cellulosic feedstocks require significantly more energy and resources to process, though research is underway to make this process more economical.

Internal Combustion Engine

The mainstay vehicles of the US light duty transportation fleet are powered by internal combustion engines and fueled by motor gasoline. Motor gasoline on a national average contains 10% ethanol, blended into the US fuel supply pursuant to the Renewable Fuel Standard (RFS).[71] Through the process of combustion, the chemical energy contained in the gasoline is transformed into mechanical energy and the rotational force that drives the tires.

Motor gasoline is a petroleum product, derived through the refinement of crude oil, a fossil fuel resource found in underground reservoirs. In recent years net imports of crude oil and petroleum products have steadily declined, from a recent average annual peak of 12.5 million barrels per day in 2005, to a 28 year low of 5.0 million barrels per day in 2014. This has largely been driven by a rise in the quantity of domestically produced crude oil.[10] Gasoline is transported in pipelines, trains, tankers, barges, and trucks to ultimately reach gas stations across NYS.

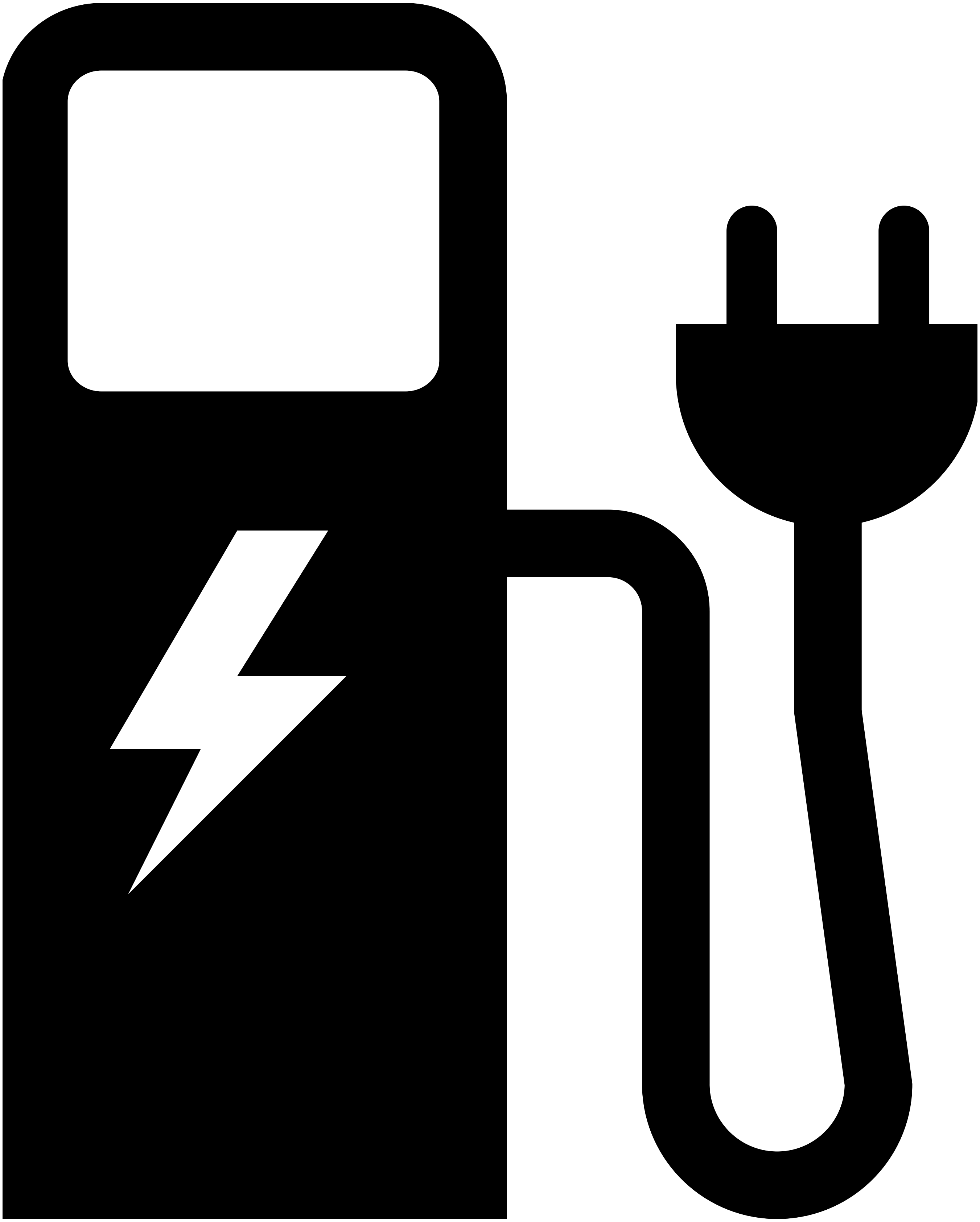
When gasoline is combusted, GHGs and other waste products are emitted. The Energy Information Agency (EIA) reports that in 2011, 33% of annual national CO2 emissions were emitted by the transportation sector, and in NYS, 40% of state CO2 emissions in 2011 were emitted by the transportation sector.[11] Emissions on a per mile basis vary greatly by vehicle and improved vehicle efficiency, measured in miles per gallon (MPG), help to reduce the relative emissions of a vehicle. Under the Corporate Average Fuel Economy (CAFE) regulations, the US Department of Transportation has been charged with enacting rules to increase the MPG efficiency of light duty vehicles in the US.[12] As a result of these CAFÉ standards, the average sales weighted fuel economy rating for new light duty vehicles in the US rose from 20.8 MPG in 2008 to 25.3 MPG in 2014, a rise of 22% in 6 years.[13] To the extent that vehicles become increasingly efficiency, associated emissions on a per-vehicle-mile basis should decline.

Auto Manufacturer Perspectives

State and federal policies driving improvements in transportation emissions and fuel economy will only be effective if vehicles are available for purchase at reasonable prices that meet the standards set by these policies. Programs like the ZEV Plan may indeed spur innovative state practices to increase adoption of ZEVs. Ultimately though, the initiatives discussed in this report that promote AFVs will be most effective in a marketplace where low or zero emission vehicles are available for consumer purchase at competitive prices. Automotive manufacturers will be looking at vehicle markets when deciding to allocate resources towards developing more affordable AFVs, so an examination of the public positions of major automotive manufacturers towards AFV development can lend better understanding of the direction of the AFV market.

A 2014 motor vehicle industry review notes the continued research and development expenditures by manufacturers to produce new engine technologies to meet increasingly strict fuel economy standards. The review notes that while HEVs were once designed primarily for the lower-end economy-vehicle sector, major manufacturers are now investing in developing luxury or high performance HEVs. Furthermore, it appears that manufacturers see value in exploring alternative fuels beyond electric.[14] As mentioned in Figure 1, fuel cell technology continues to advance, but currently deployment is still cost prohibitive. However, other fuels, in particular biodiesel, present growth opportunities for passenger vehicle manufacturers.

Ford's Chief Executive, Bill Ford, has indicated that the company sees ramping up output of HEVs as too narrow in scope. The company intends to explore other alternative fuel choices to replace conventional gasoline.[15] Audi has recently announced a new carbon neutral diesel fuel technology, in which CO2 and water are feedstocks.[16] Leading auto manufacturers have many concepts for lower emissions vehicles, so the industry seems equipped to follow the trend away from gasoline.[17] Ultimately, successful sales and growing demand are likely to promote more AFV releases. As AFVs capture more market share for new car purchases, this space will become more competitive and auto manufacturers will be compelled to respond.



IMPACT ANALYSIS

Introduction to Impact Analysis

Since alternative fuel vehicles have only recently begun to achieve widespread adoption, aggregated data and statistics for AFVs are still limited. Therefore, for the following analyses, a specific car model was selected to represent the average car of each fuel type. The specifications (e.g. costs, MPG) for these "representative vehicles" will be used in the analyses, with the results generalized to represent the entire class of vehicle type. Table 1 indicates the car model chosen for each fuel type.

Table 1 Representative Car Models	
Fuel Type	Representative Car Model
Conventional	2015 Honda Civic
Hybrid	2015 Toyota Prius
Biodiesel	2014 Mazda 5 2.2L Diesel
Electric	2015 Nissan Leaf
Ethanol	2014 Ford Focus Sedan

Life Cycle Analysis

Methodology

One of the most crucial factors in determining which AFV types are the most sustainable choices in NYS is the cumulative GHG emissions attributable to that vehicle over the

These car models were chose as they represent popular AFV car models. These specific models also have noteworthy academic research indicating their life cycle carbon emissions, materials related health impacts, and financial analyses.

course of its lifetime. In order to make that determination, the leading academic research was integrated into an overall lifecycle analysis (LCA) of the GHG emissions attributable to each vehicle type. A LCA must account for all GHG emissions attributable to a product throughout the entire life of the product. In the case of a vehicle, this includes all emission relating to:

- Sourcing of raw materials for the vehicle and its components
- Manufacturing of the vehicle, including any energy used in that process
- Production of the fuel to be used by the vehicle, including emissions during extraction, processing, and delivery
- Use of the vehicle (i.e. tailpipe emissions)
- Eventual disposal of the vehicle

For each vehicle, one mile driven is used as the functional unit. GHGs are therefore reported in the unit of grams of carbon dioxide equivalent (CO2e) per vehicle mile. Since it is assumed that each vehicle has a lifespan of 150,000 miles, the per-mile GHG figure can be multiplied by 150,000 to determine the net GHG emissions attributable to the vehicle over the lifetime of the vehicle. Consistent with the other sections of this paper, vehicles are assumed to be four-door sedans, travel 10,000 miles per year and have a lifespan of 15 years. A representative vehicle, reflecting each vehicle class, was analyzed using specifications from the most recent vehicle model year. Refer to Table 1 for a listing of these vehicles.

The complete LCA of a vehicle can be broken down into two main phases. First, the fuel phase includes the GHG emission resulting from the extraction, refinement, transportation, fueling, and use of each vehicle's fuel source. This phase of the LCA is commonly referred to as the "well-to-wheels" phase, as most fuel for ICE vehicles is petroleum extracted from oil wells. Using the oil system as an example, the well-to-wheels phase of the LCA includes emissions attributable to the exploration and drilling of the oil wells, the transportation of the crude oil to the refinery, the refining of the crude oil, the transportation of the refined gasoline to the gas stations, and the combustion of the gasoline in the ICE vehicle.

Extensive work has been done to determine the GHG implications of the well-to-wheels phase, which has been compiled by Argonne National Labs in their Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) database.[18] All of the inputs to the GREET database are user-adjustable, and many were adjusted to reflect conditions specific to NYS. The changes made are listed below. Where not otherwise indicated, inputs were left at the default value in GREET 2014 database 10783. The adjusted variables below were those that could be both readily determined with specificity to NYS and are likely to have the highest impact on overall GHG emissions. However, further work can be done in order to more finely tune the GREET model to New York State's parameters.[19]

The following values in the GREET model were changed:

- Vehicle parameters were adjusted to reflect the chosen representative vehi-

It is important to note that using the current electricity mix used in NYS to calculate GHG emissions makes the implicit assumption that the wide-scale adoption of BEVs will not significantly alter the electricity mix. In the short term, it may be more proper to assume that all electricity for BEVs is generated using the marginal electricity generation units, usually natural gas fired plants. However, since the BEVs will not be phased in immediately, and the NYS electricity mix will continue to evolve over time, the current mix has been used as an approximation. BEV adoption should be taken into account when planning for the future mix of electricity generation, with renewable energy sources providing the additional electricity needed where possible.

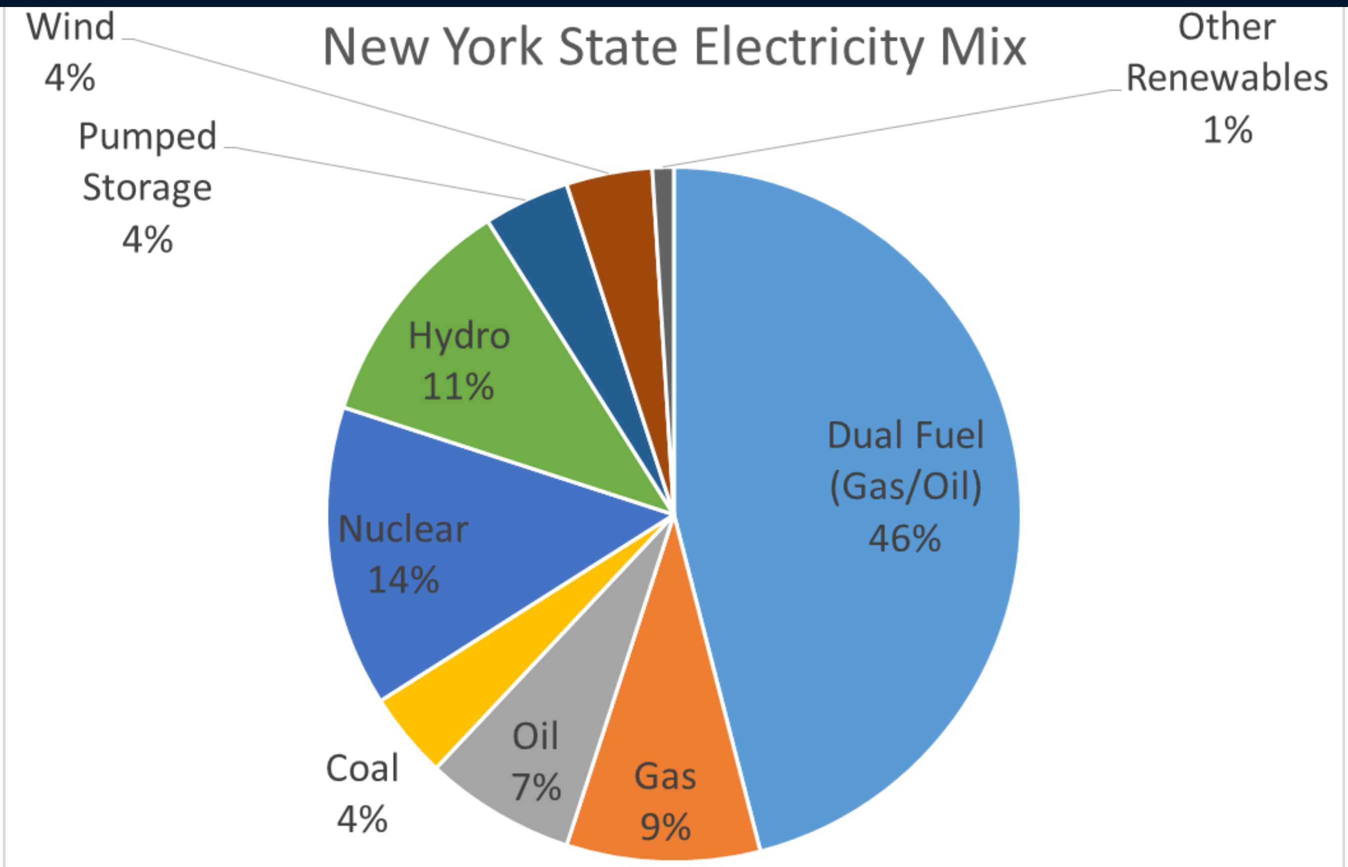


Figure 2 New York State Electricity Mix

cles, including the proportion of urban to highway miles driven (80% highway), miles per gallon equivalent (see Table 2), and average age (2014 and 2015 models).

- Total vehicle lifespan was adjusted to 10 years and 150,000 miles
- The electricity mix was changed to reflect values reported by the New York

For an example of further potential changes, it is recommended that the reader reference California's custom GREET model (California Air Resource Board, 2014). NYSERDA also developed a custom GREET model in 2007. This research was referred to but not used, due to changes in oil and gas production, NYS electricity mix, as well as their global warming implications.

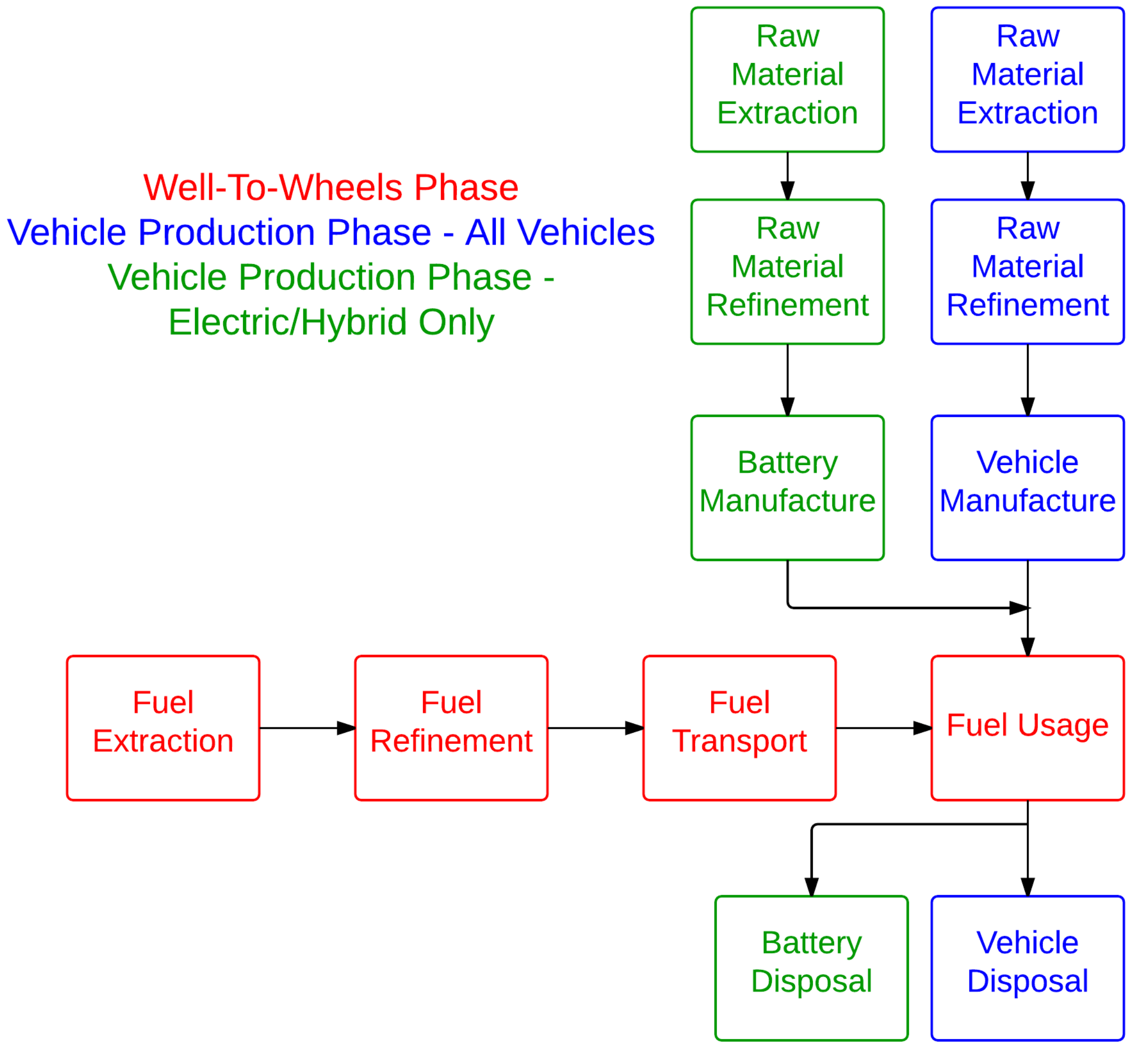


Figure 3 Visualization of Life Cycle Analysis Stages

Independent System Operator (NYISO) (Figure 1)

- The global warming potentials of methane and nitrous oxide were adjusted to reflect most recent IPCC 20-year values, including climate-carbon feedback (Table 3)

The second main phase of the overall LCA is the vehicle manufacturing and disposal phase. This phase accounts for all emissions attributable to the manufacturing of the

Table 2 Global Warming Potentials		
GHG Constituent	20-Year Global Warming Potential	100-Year Global Warming Potential
Carbon Dioxide	1	1
Methane	86	34
Nitrous Oxide	268	298

vehicle itself, including the extraction and transportation of any raw materials needed in the vehicle, as well as the emissions associated with the eventual disposal of the vehicle. This phase can be further broken down into two sub-phases: the manufacturing and disposal of the battery (if applicable), and the manufacturing and disposal of the rest of the vehicle. Because all vehicles under consideration in this report are four-door sedans, it can be assumed that the non-battery portion of the vehicles will be substantively identical across all vehicle types. Therefore, the differential in GHG emissions in the vehicle phase will come primarily from the addition of the larger battery to BEVs and HEVs, as emissions associated with ICE, flex-fuel E85, and biodiesel vehicles will be virtually identical for this phase. Figure 2 summarizes components of the complete LCA.

While the GREET model does include an assessment of the emissions attributable to the vehicle and battery manufacturing process (GREET 2.0), this portion of the GREET model is much less developed. Therefore, a survey of the robust body of academic and industry literature was conducted in order to compile previously calculated LCA's for this phase. Some of these previous studies use the GREET model while others utilize different data sources. This is feasible for the manufacturing and disposal phase of the LCA, because, unlike the rapidly improving fuel economies of all types of vehicles studied, emissions associated with battery manufacture and disposal do not change as dramatically with improved technology. Therefore, it is possible to use studies published over a wider range of dates. Additionally, the vehicles used in NYS are not necessarily manufactured in NYS, and so it is necessary to examine emissions associated with the manufacturing process from a wide array of manufacturing sites. The result is a much wider variety of comparable data sources available for review.

As in the well-to-wheels calculation, parameters in the LCA were changed to be consistent with the assumptions specific to this assessment wherever possible. More specifically, only studies that focus on standard 4-door sedans were used, and all studies were normalized so that the per vehicle lifetime mileage was 150,000 miles. The studies used to compile vehicle and battery GHG emissions are discussed briefly below:

- Gao & Winfield calculated the GHG emissions for three vehicle types; a Toyota Corolla (ICE), and Toyota Prius (HEV), and a Nissan Leaf (BEV).[20] The specifications from the 2012 models of these vehicles were used. The authors used the GREET 2.0 database to determine the manufacturing emissions. The study assumed a 160,000 mile lifespan for the vehicles, which was normalized to 150,000 miles for the purposes of this analysis.

- Helms et al. calculated the GHG emissions for three vehicle types; an ICE vehicle, a HEV, and a BEV.[21] In all three cases, they utilized the EcoInvent Database to determine manufacturing and disposal emissions for the vehicle bodies, assuming a 2010 Volkswagen Golf 4 body. The EcoInvent Database is a commonly used depository for LCA data run by the Swiss Center for Life Cycle Inventories.[22] The Database compiles information from industrial sources, and continuously updates the data with new information. In addition to the Golf 4 body, the authors added appropriately sized batteries to the HEV and BEVs in order to arrive at a complete manufacturing and disposal LCA. The data was reported on a per-vehicle basis, so the raw numbers were divided by 150,000 to arrive at a per mile number consistent with the other studies.

- Hawkins et al. published an extremely detailed LCA based on a Mercedes A Class for the ICE vehicle, and a Nissan Leaf for both BEVs and HEVs.[23] The authors started with GREET 2.0 data for the car bodies, but then adjusted it based on data provided by the manufacturers in order to make it more specific to the vehicles studied. Data concerning the battery was referenced from an earlier paper.[24] Overall, this paper provides a comprehensive LCA, which can be examined component-by-component in the supplementary section. Data was reported in units of g-CO2e/km, and the vehicles were assumed to have a lifetime of 150,000 km. The raw data was converted from a per km to a per mile basis, and then adjusted to the 150,000 mile total life assumed in this study.

- Baptista et al. published a paper examining vehicle life cycle GHG emissions in Portugal.[25] Manufacturing data was sourced from GREET 2.0. The models of vehicles were not specified, but the mileage and battery characteristics were consistent with the other papers examined. As with the example above, data was reported in units of g-CO2e/km, and was then converted to be consistent with the other studies.

Results

Figure 4 shows the GHG emissions from the well-to-wheel phase of each vehicle. For comparison's sake, the GHG emissions from each vehicle in the standard, non-adjusted GREET model are also displayed (Figure 5). Most of the AFVs produce fewer GHG emissions than ICE vehicles. Since EVs have no tailpipe emissions, it is unsurprising that they produce the fewest emissions during the use and production stages of the fuel. Additionally, because electricity consumed in New York is less GHG intensive than that of the US on average, BEVs were found to produce fewer GHG emissions when charged in New York.

GHG emissions attributable to the manufacturing and disposal stages of the LCA are shown in Figure 5. The height of each bar is the average emissions reported by the studies reviewed for each vehicle type. There was wide variation between the studies reviewed, although every study indicated that the manufacturing and disposal of BEVs and HEVs resulted in higher levels of GHG emissions relative to the ICE vehicle. This result is largely attributable to the battery. The whiskers on the chart show the maximum and minimum values reported across the four studies. Table 4 shows the GHG emissions reported by each individual study. It is important to note that the 150,000 mile vehicle life is at the higher end of the range assumed in the individual studies. Increasing vehicle mile-life serves to decrease GHG emissions per mile because; emissions from vehicle manufacturing and disposal are one-time emissions that are then spread out over a greater number of miles.

The combined LCA results are displayed in Figure 7.

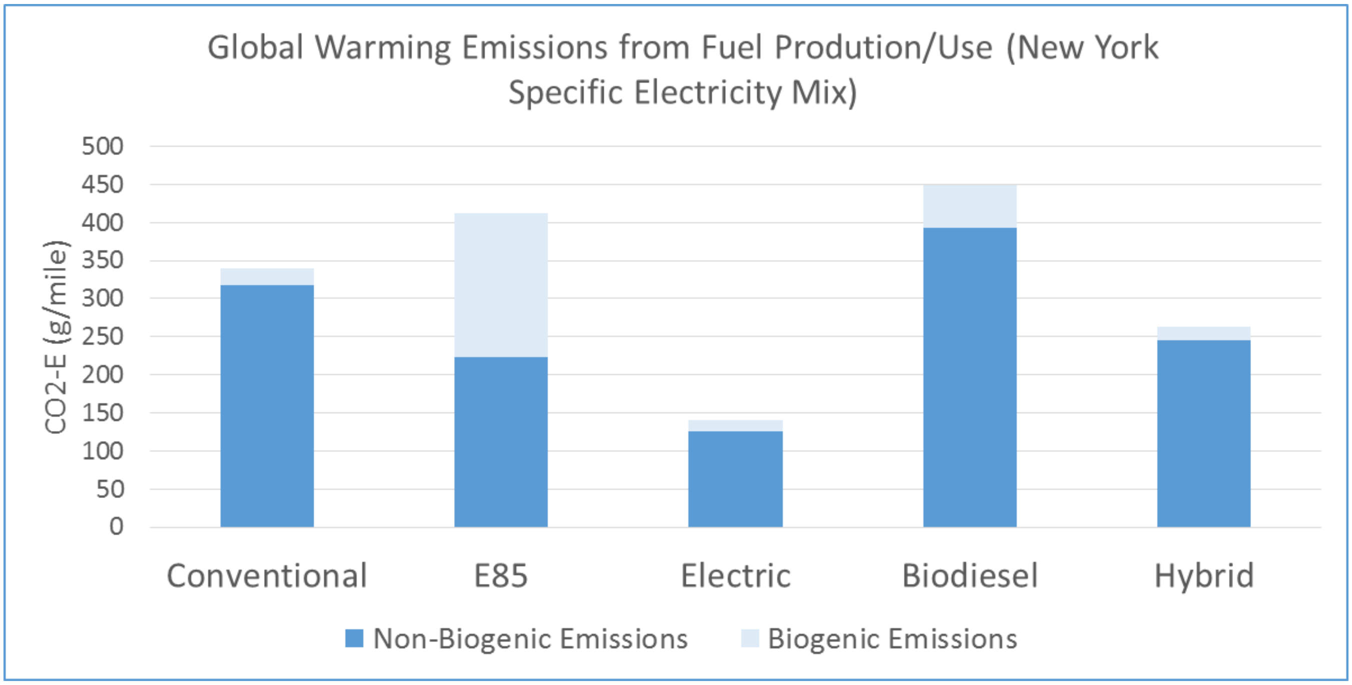
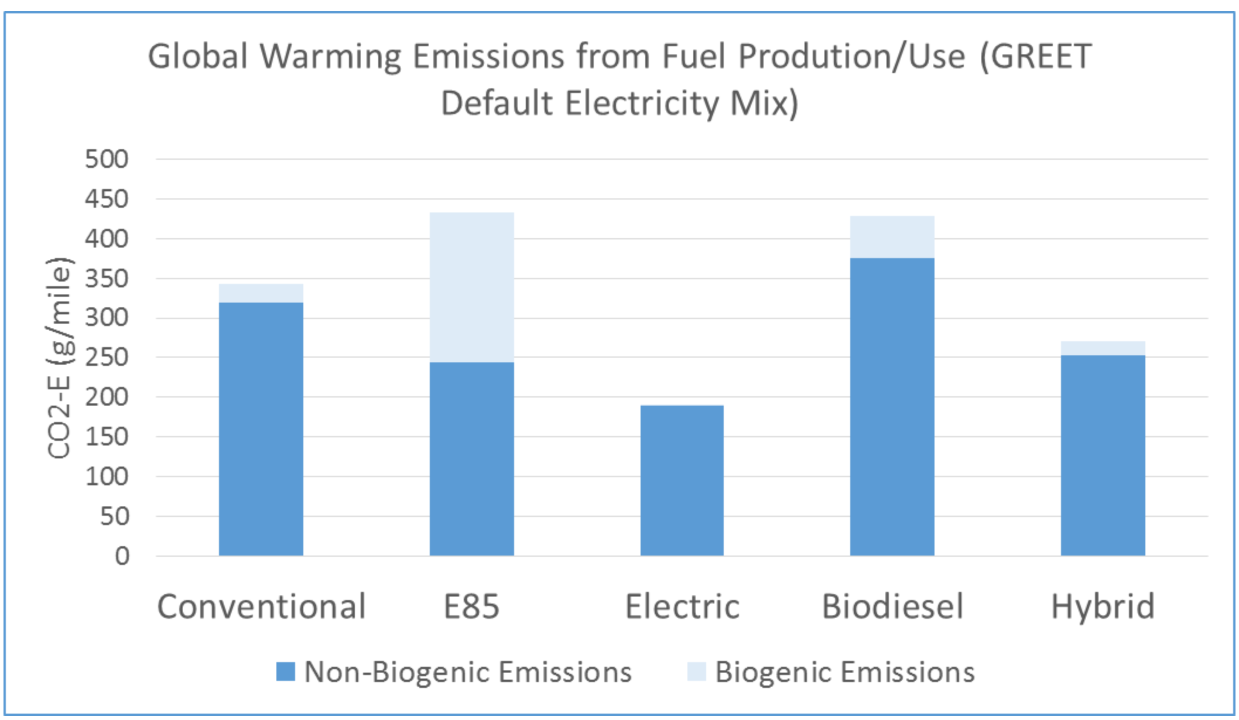


Figure 4 GHG Emissions from Fuel Production/Use (GREET Default)

BEV's have not actually accrued 150,000 miles in real driving. As these vehicles reach higher mileage their batteries may need to be replaced. This would represent a significant increase in GHG emissions. However, current LCA based research finds this assumption to be unfounded.

The BEV emits less than half of the total GHG emissions of the ICE vehicle in NYS, according to the parameters of this study. Both the E85 and biodiesel vehicles

Figure 5 GHG Emissions from Fuel Production / Use (NY State Specific)



In Figures 4 and 5, biogenic carbon emission are broken out as distinct from other sources of GHG emissions. Biogenic emissions are defined by the EPA as emissions related to the natural carbon cycle, or those relating to the combustion or processing of biologically based materials.[26] According to generally accepted GHG reporting protocols, biogenic emissions should be reported separately from fossil-fuel related GHG emissions. This is because the carbon emissions associated with biogenic emissions are reported through land-use changes required to produce the biogenic fuel. However, if wider adoption of ethanol or other fuel sources with high biogenic emissions were to occur, it is likely that significant amounts of land area would need to be devoted to the production of the fuel, thereby increasing the volume of GHG emissions due to land-use change. For the purposes of this report, biogenic GHG emissions are reported but broken out as distinct from fossil fuel GHG emissions. This has particular implications on ethanol-fueled vehicles, due to the high biogenic component of ethanol's GHG emissions profile. Biogenic emissions are present to a lesser degree in biodiesel, although the relatively low percentage of biodiesel in the B20 blend makes the biogenic portion less dominant overall. In general, ignoring the biogenic emissions would constitute a "best case scenario," and fully counting them would constitute a "worst case scenario." The true emissions attributable to the biofuels lies in between these extremes, which means that E85 vehicles likely produce fewer GHG emissions when compared to conventional vehicles.

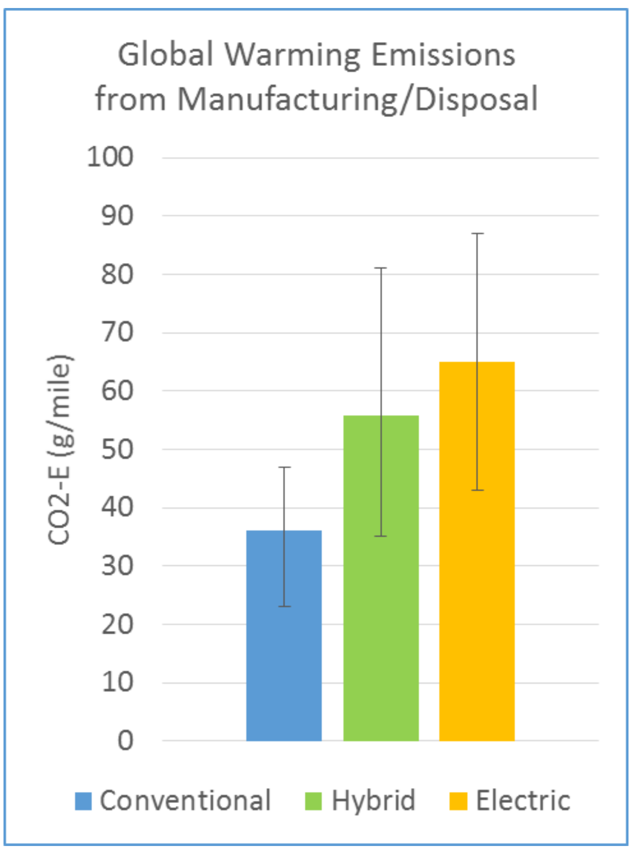


Figure 6 Global Warming Emissions Attributable to Vehicle / Battery Manufacturing and Disposal

were assumed to have the same vehicle manufacturing and disposal emissions as the ICE vehicle, as the drivetrains are essentially identical. As mentioned above, both the 150,000 mile assumed lifetime use and the relatively clean electricity that NYS utilizes contribute to the large difference in emissions between the ICE vehicles and BEVs.

Hybrid vehicles also produce fewer GHG emissions than ICE vehicles but more than BEVs, as would be expected. However, their increased range with respect to EVs could make them a good short-term option as BEV ranges improve.

E85 vehicles produce a higher amount of GHG emissions than

ICE vehicles only when all biogenic emissions are considered. This suggests that while E85 vehicles are likely slightly superior to ICE vehicles with respect to total GHG emissions, the difference between the vehicle classes is not very large. See

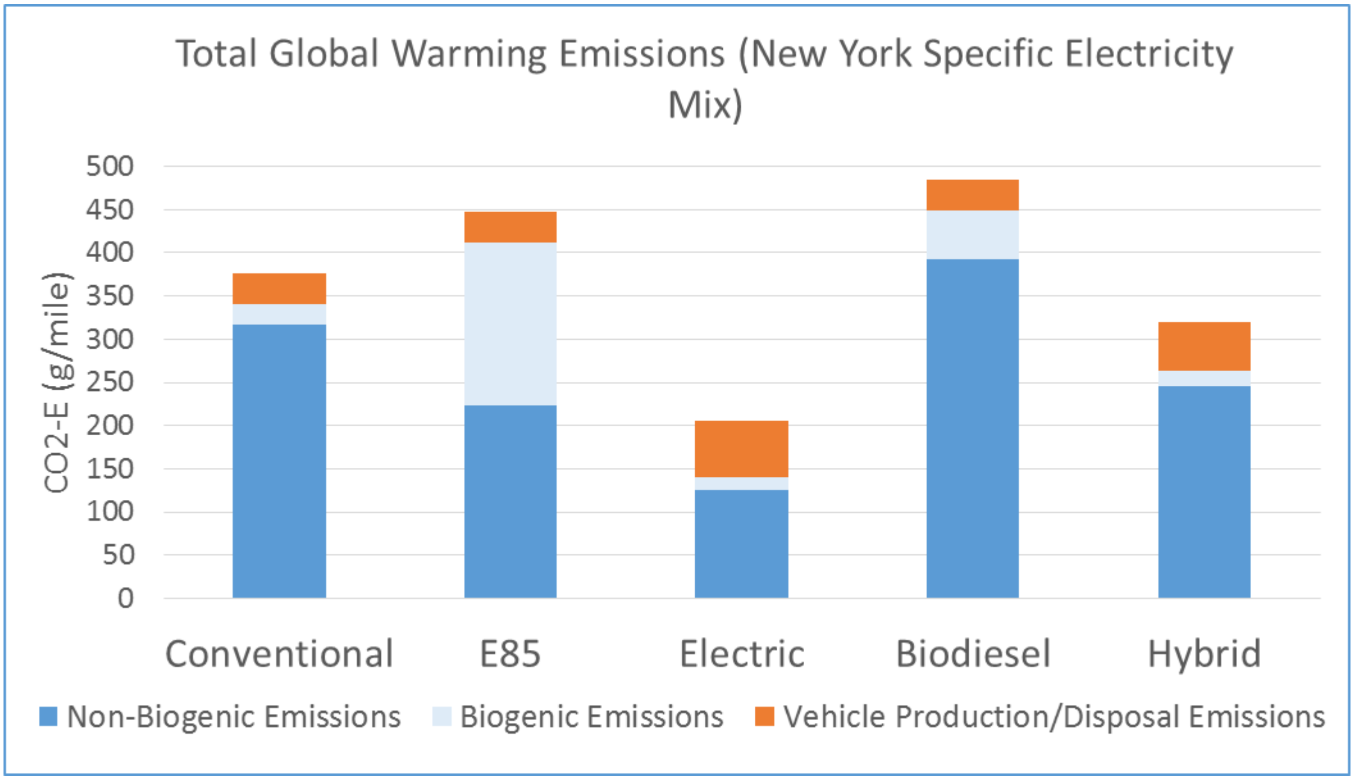


Figure 7 Complete Life Cycle Analysis Emissions

Talbe 4 Vehicle Production/Disposal Literature Review				
Author	Mileage Assumed	ICE g CO2e/mi	HEV g CO2e/mi	BEV g CO2e/mi
Gao et. al	160000	43	51	82
Helms et. al	N/A	23	35	43
Hawkings et. al	93206	47	81	87
Baptista et. al	93206	31	N/A	48

the sidebar for a more complete discussion on biogenic emissions.

5.4 Health Impacts

While increasing AFV use has the potential to reduce GHG emissions, it is important to consider the other potential health impacts that are associated with AFVs and could arise from increased AFV use. There are many alternatives to fossil fuels that still have varying degrees harmful emissions. Though not an in-depth analysis, the following section analyzes non-GHG well-to-wheel emissions that have potential negative health impacts in order to provide a broad overview of the possible implications of widespread AFV adoption for policymakers to consider.

PM2.5 & PM10

Particulate matter (PM) is comprised of a mixture of solid particles and liquid droplets. There are two types of PM that are monitored for health impacts. Fine particles that are less than 10 micrometers in diameter are classified as PM10 and fine particles that are less than 2.5 micrometers in diameter are classified as PM2.5. PM10 and PM2.5 include sulfate and nitrate particles, which account for the majority of PM in the atmosphere.[27]

SO_x, and NO_x

SOx refers to a group of gaseous sulfur oxides, including sulfur dioxide (SO2) and sulfur trioxide (SO3). The majority of SOx emissions is comprised of SO2, thus resulting in a higher concentration in the atmosphere compared to SO3.[28] NOx refers to a group of gaseous nitrous oxides, including nitric oxide (NO) and nitrogen dioxide (NO2).[29]

According to the EPA, several studies have been conducted, which have acknowledged that there is a strong correlation between higher exposure to sulfate and nitrate particles and increased incidences of illness and premature deaths in elderly who previously suffered from heart or lung disease. Sulfate and nitrate particulate matter has also been shown to exacerbate respiratory problems and illnesses in children who suffer from heart or lung disease. The higher concentration of these pollutants near major roadways presents an increased concern for population most susceptible to the negative health impacts.[27]

CO & VOCs

Exposure to carbon monoxide (CO) can reduce the ability of blood to absorb oxygen for transport to organs.[30] The health effects from CO range in conjunction to different levels of exposure, from cardiovascular and neurobiological effects to death. [31] Another major source of emissions are Volatile organic compounds (VOCs). Exposure to VOCs may also cause birth defects, serious developmental delays in children, and reduced activity of the immune system, leading to a number of diseases. The ability of organic chemicals to cause health effects varies greatly based on the particular VOC type.

Comparison

As Figure 7 demonstrates, overall, the well-to-wheel emissions from AFVs for NYS illustrates that E85 vehicles emit greater quantities of non-GHG pollutants in almost all emissions categories analyzed, relative to ICE vehicles. BEVs have a lower concentration of emissions in most categories in comparison to not only ICE vehicles, but the other AFVs as well, though SOx emissions are higher due to the use of coal for electricity generation.

While an overall comparison of emissions on a per vehicle basis does reveal some potential concerns, the analysis does not reveal if the differences in emissions between the vehicle types are significant enough to cause changes in ambient concentrations of the pollutants. To determine how overall concentrations of the pollutants might change and therefore how human health might be affected, the per vehicle emissions identified here would need to be multiplied by the number of vehicles of each type on the road to yield the total emissions from a particular vehicle type. As neither the current number of AFVs on NY roads nor projections for these vehicles are available, determining how human health might be impacted by these vehicles is not currently possible.

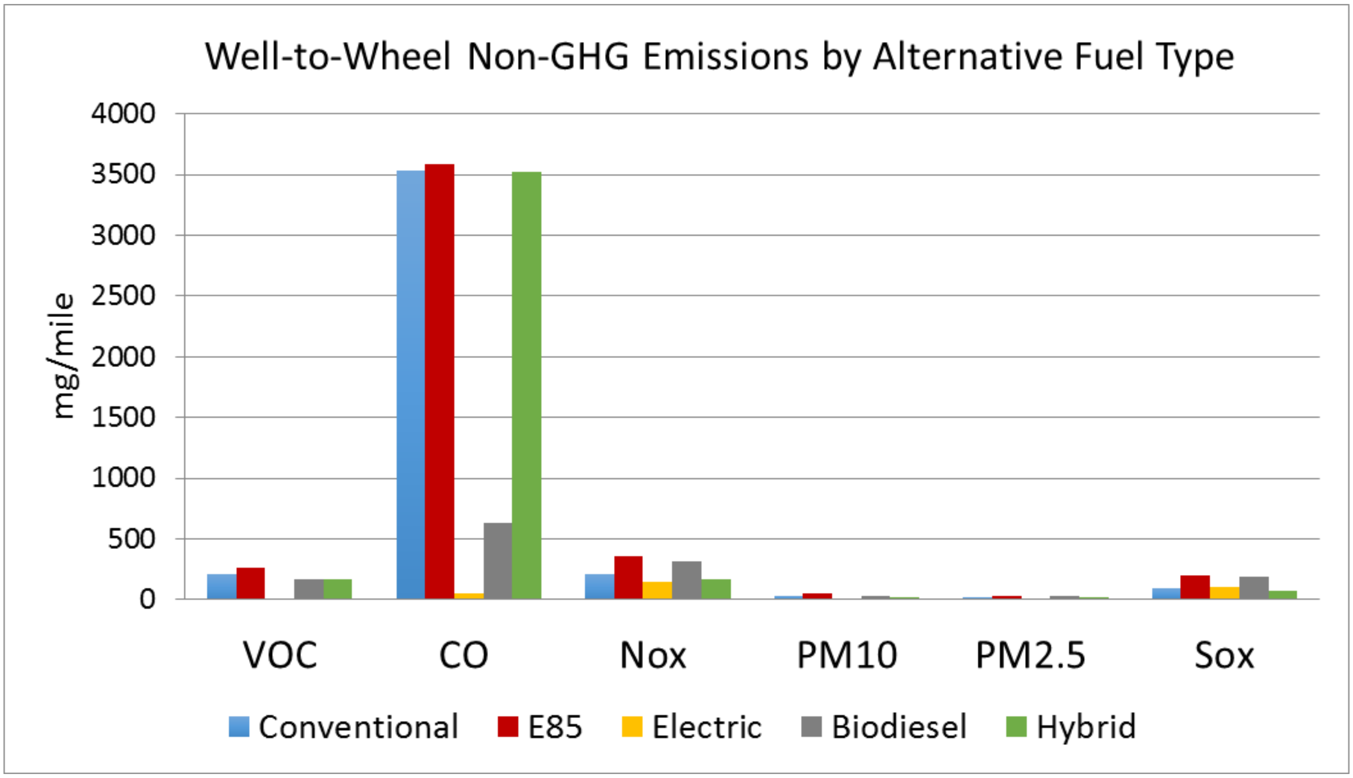


Figure 8 Non-GHG Emissions by Vehicle Type

Hazardous Materials Contained in Alternative Fuels

While AFVs produce fewer GHG emissions, the so called "clean fuels" that power these vehicles often contain unique and hazardous materials.

Biodiesel

The production of biodiesel requires the use of chemicals, which can be harmful to human and ecological wellbeing if handled and disposed of improperly. For example, glycerol, a byproduct of biodiesel production is particularly harmful to aquatic life if introduced to waterways. [32]

EV Batteries

Lithium-ion batteries are the primary battery type used in hybrids and BEVs. These batteries typically have nominal environmental impacts during their use phase, but upon the end of their usable life, disposal may present unique challenges. The cells contain lithium carbonate and hydrofluoric acid which are both potent toxic pollutants.[33] Similarly, nickel-metal-hydrate (NiMH) batteries, which are used in the Toyota Prius, contain various hazardous chemicals and known carcinogens. Disposal of both these battery types are difficult and costly, and for that reason, battery manufacturers often offer incentives to encourage users to return their old batteries so that they can be recycled and reused.

Ethanol

Ethanol, specifically E85, has been found to release "peroxyacetyl nitrate, formaldehyde, and acetaldehyde into the air.[34]" The symptoms of exposure to these vapors in high concentrations include immediate negative health impacts or even death. (Clean Air Trust, 2008)[35].

Cost Analysis

Methodology

The purpose of this model is to estimate the total cost of owning the selected representative cars over the lifetime of the car. Estimated costs are provided in annual terms, and the aggregate of the 10 years of annual costs plus the initial cost less the scrap value equal the lifetime cost. Scenario analyses have also been included in this model to enhance its adaptability and examine how fluctuations in fuel prices affect the relative costs of ownership.

Assumptions

As previously stated in Table 1, five specific vehicles were used to represent costs associated with each vehicle type. Calculation assumptions are listed below:

- Prices: The costs in this analysis are based on 2015 dollars
- Scrap Value: As the vehicle would retire after 10 years of service, its value would be the initial cost less depreciation. According to Money-Zine,[36] the average depreciation for 10 years would roughly equal 82% of the initial value of the vehicle with the remaining 18% of the initial price representing the scrap value. An exception would be the electric vehicles, which their scrap value would be significant less (set as 10%) due to battery depreciation and outdated technology.
- Inflation Escalator: Vehicle Prices are expected to rise in tandem with the historical Consumer Price Index (CPI), which is 3% per annum.
- Highway to City Driving Ratio: The highway-to-city driving ratio is currently set as 80/20. However, since it is highly behavioral, it is adjustable and is included as an adjustable variable in the interactive calculator.
- Fuel Price: Fuel prices are set at the average fuel price during the first quarter of 2015. Electricity prices are set to a slow increase of 2 – 3% per year unless otherwise stated.
- Policies: Subsidies and other governmental incentives for vehicle ownership are set as of the first quarter of 2015.
- Miles Driven Per Year: 15,000 miles per Department of Transportation request.
- Number of Years Vehicles are in Service: 10 years

Calculations

There are two distinct periods within the ownership timeline: the first is the time of purchase and the second is the subsequent 10 year period of ownership. At the time of purchase, the upfront cost of the vehicle would be reduced by any applicable incentives, resulting in the net initial cost. Thereafter, from Year 1 through Year 10, the annual cost of ownership is comprised of four cost components: insurance, maintenance, repairs, and fuel. Of the four variables, fuel cost is the most volatile factor and would significantly influence the lifetime cost of ownership of the vehicle. Various fuel price scenarios are addressed in the analysis to account for these fluctuations. At Year 10, the vehicle is assumed to be sold and the estimated scrap value would become a source of income, reducing the costs in year 10.

Scenario Analysis and Results

The major driver in the scenario analysis is the state gasoline price, as it directly impacts the variable cost of conventional cars as well as hybrid electric vehicles. It would also influence the cost of ethanol and biodiesel vehicle to a certain extent, as gasoline is mixed with these alternative fuel types. The price correlation to gas price would be higher for biodiesel than ethanol as the former has a higher gas mix in the fuel (80% versus only 15% for E85). Oil prices have plunged over 50% since July 2014, and accordingly motor gasoline has become significantly less expensive. This development impacts the relative affordability of the different vehicle types, making traditional gasoline fueled vehicles more affordable relative to many AFVs. To project the true intrinsic cost, three gasoline price scenarios have been modeled: stagnant, mean-reversion, and increasing. The time period of estimation is set as 3 years, which is considered as a mid-term forecast. A mid-term forecast was used instead of a long-term one because macroeconomic factors and political uncertainties are more unpredictable in the long term, which significantly undermines the accuracy of the forecast. At the other end of the spectrum, immediate short-term predictions are equally difficult to make, as information costs and market imperfections prevent prices from reflecting their true intrinsic value within a short period of time.

Scenario 1: Stagnant Prices

The Stagnant Prices scenario projects cost of ownership for each vehicle type while gas prices remain stagnant and inflation (CPI) rises. The inputs for this analysis are examined in Table 5, with the results displayed in Table 6 and Figure 9.

In this scenario, gas prices are assumed to remain at the current low level and would only rise by the nominal inflation rate. The flat gas price curve would benefit conventional and hybrid vehicles because of the low cost of fuel. However, it should be noted that the conventional vehicle still has a higher cost in comparison to most of the AFVs. This difference is largely due to government incentives offered to purchasers of AFVs, which substantially lower their initial costs, especially for the electric and hybrid vehicles. However, even if you do not account for the $7,500 federal tax rebate for purchasing an electric vehicle, EVs still emerge as the cheapest lifetime option at $54,801, though the gap between the other vehicles would be significantly reduced. Biodiesel has the highest 10-year cost because of its minimal subsidy and

Table 5 Parameters for Stagnant Prices Scenario

Scenario 1: Gas Prices Rise w/ CPI			
CPI	3.00%		
Projected Gasoline Price	$2.50		
Years to Reach Projected Gasoline Price	N/A		
Yearly growth rate	0.00%		

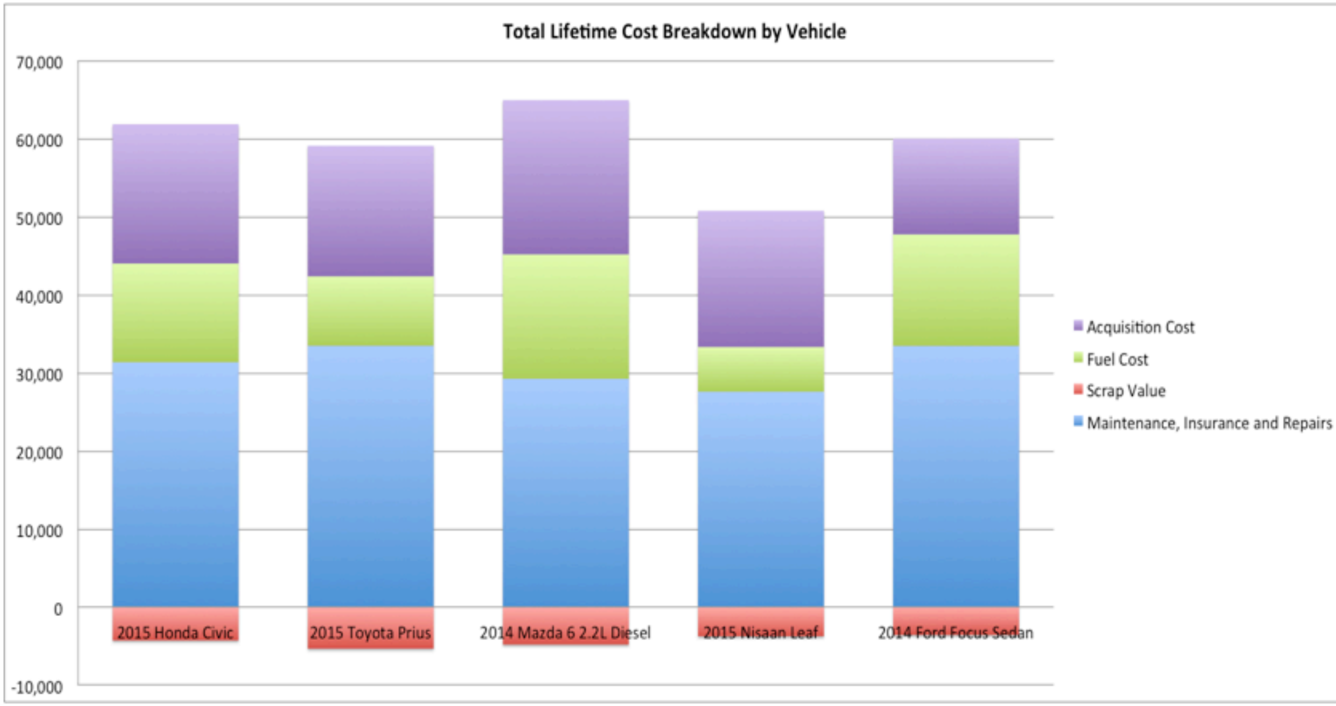


Figure 9 Total Costs of Ownership in Stagnant Prices Scenario

Table 6 Ranking of Costs of Ownership in Stagnant Prices Scenario			
Fuel Type	Sample Vehicle	Total Cost (USD)	Ranking (1=Cheapest)
Electric	2015 Nissan Leaf	$44,374	1
Hybrid	2015 Toyota Prius	$53,673	2
Ethanol	2014 Ford Focus Sedan	$55,561	3
Conventional	2015 Honda Civic	$56,905	4
Biodiesel	2014 Mazda 6 2.2L Diesel	$59,039	5

greater annual fuel costs due in part to lower fuel efficiency.

Scenario 2: Mean Reversion

The second case is based on the theory of “mean reversion,” a theory suggesting that prices would eventually return to the historical average over time.[37] This is based on the assumption that the market has the same prospect as it had in the past. Though the current gasoline price is at its lowest point in the past five years, there is a certain probability that the gas price will return to the five-year average of $3.40 in the mid-term future. For this analysis, the gas price was assumed to take 3 years to recover to that level, which is equivalent to a yearly growth rate of 10.79% for 3 consecutive

Table 7 Parameters for Mean Reversion Scenario			
Scenario 2: Gas price rebounds to the 5-year average (~$3.4) over 3 years and rises with CPI			
CPI	3.00%		
Projected Gasoline Price	$3.40		
Years to reach the Projected Gasoline Price	3		
Yearly growth rate	10.79%		
Table 8 Ranking of Costs of Ownership in Mean Reversion Scenario			
Fuel Type	Sample Vehicle	Total Cost (USD)	Ranking (1=Cheapest)
Electric	2015 Nissan Leaf	$44,374	1
Ethanol	2014 Ford Focus Sedan	$56,217	2
Hybrid	2015 Toyota Prius	$56,538	3
Conventional	2015 Honda Civic	$60,808	4
Biodiesel	2014 Mazda 6 2.2L Diesel	$61,459	5

years. The gas price would then grow at the inflation rate thereafter. Given the increase in fuel cost, the annual operating expense for conventional and hybrid vehicles rises, making their cost of ownership second and third highest, respectively. The inputs for the mean reversion scenario analysis are examined in Table 7, with the results displayed in Table 8 and Figure 10.

Figure 10 Total Costs of Ownership in Mean Reversion Scenario

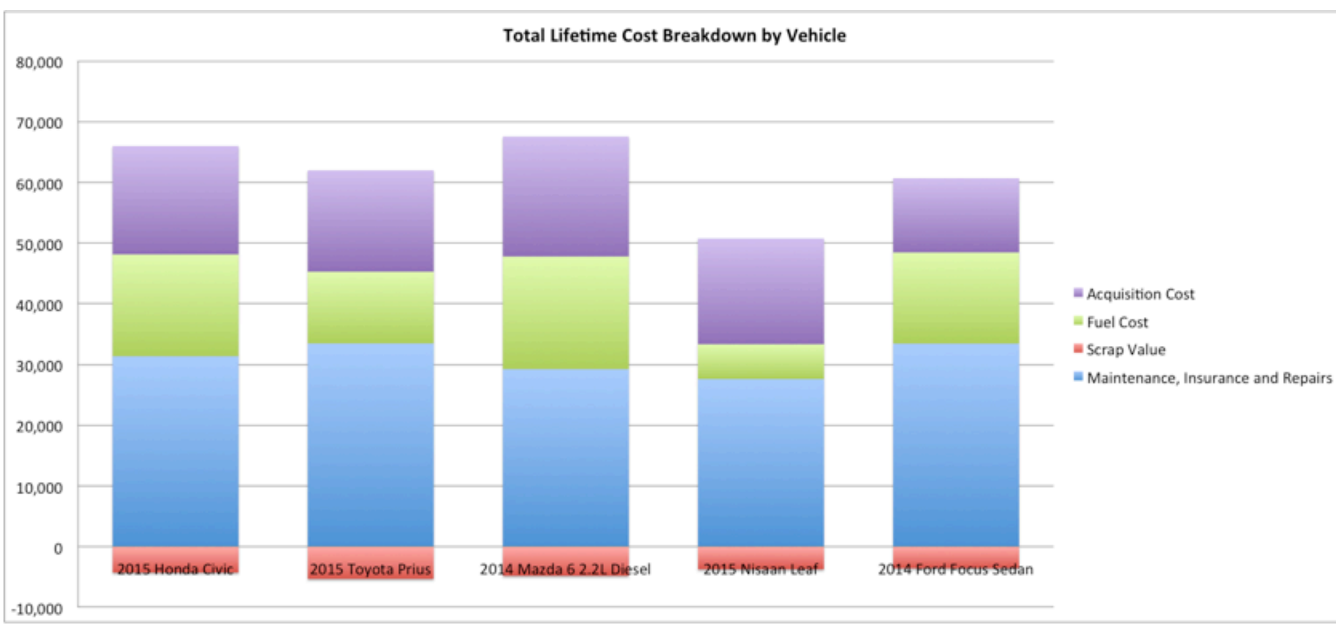


Table 9 Parameters for High Prices Scenario Scenario 3: Gas price rebounds to $4.50 over 3 years and then rises with CPI			
CPI	3.00%		
Projected Gasoline Price	$4.50		
Years to reach the Projected Gasoline Price	3		
Yearly growth rate	21.64%		
Table 10 Ranking of Costs of Ownership in High Prices Scenario			
Fuel Type	Sample Vehicle	Total Cost (USD)	Ranking (1=Cheapest)
Electric	2015 Nissan Leaf	$44,374	1
Ethanol	2014 Ford Focus Sedan	$57,010	2
Hybrid	2015 Toyota Prius	$60,002	3
Biodiesel	2014 Mazda 6 2.2L Diesel	$64,385	4
Conventional	2015 Honda Civic	$65,525	5

Scenario 3: Increasing Prices

The final scenario assumes gasoline prices will rise to an unprecedented level in 3 years. The scenario would happen if oil demand rises or if supply decrease significantly. Relevant events would include but are not limited to increasing global population, improving living standard, increasing drilling cost and fewer available oil fields. For this scenario, the 3 year target gas price is set at $4.50, which is 20% greater than the 10-year high. The annual growth rate

Figure 11 Total Costs of Ownership in Increasing Prices Scenario

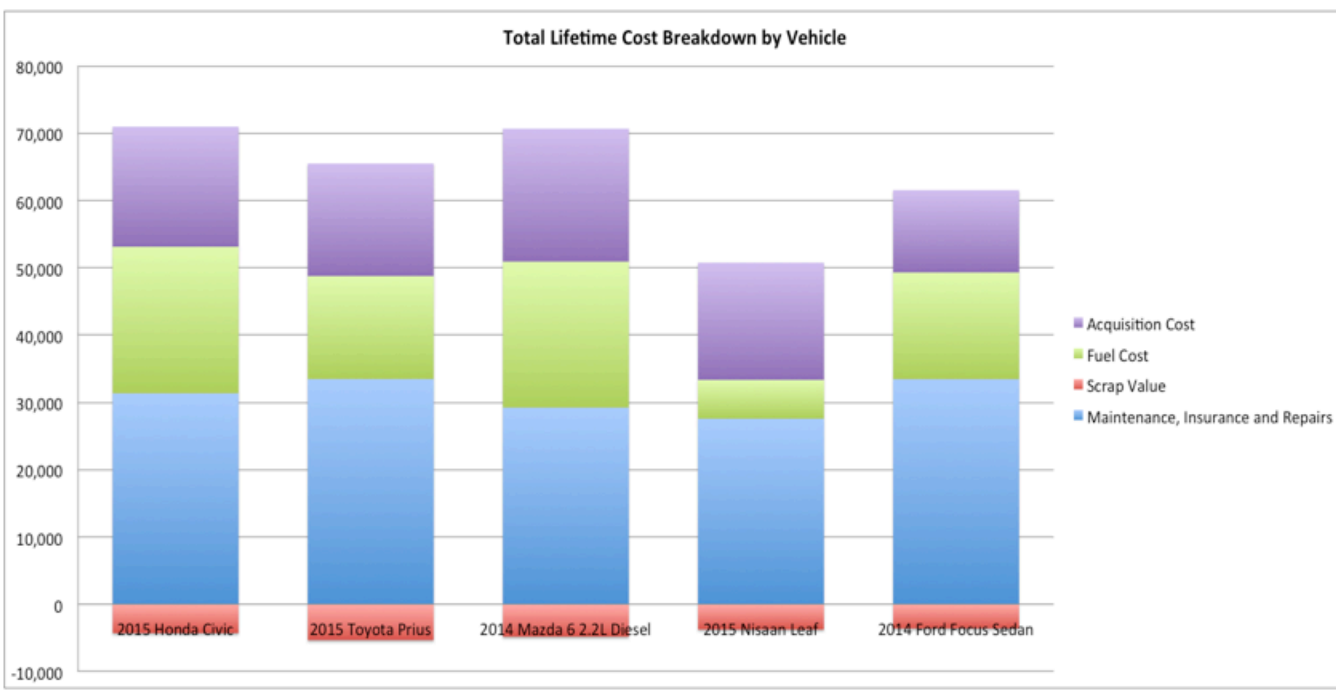


Table 11 Weighting of Scenarios				
	Stagnant Gas Price	Mean-Reversion	High Gas Price	
Current Price	$2.50	$2.50	$2.50	
Projected Gasoline Price	$2.50	$3.40	$4.50	
Years to reach the Projected Gasoline Price	N/A	3	3	
Yearly growth rate	0%	11%	22%	
Weight	10%	60%	30%	100%
Weighted-Average Growth Rate				13%
Relative 5-year yearly SD				0.57907

would thus be 21.64% for the first three years. Under such a scenario, conventional vehicles would be roughly 50% more expensive to own, compared to an electric vehicle over the same 10 year time horizon. The inputs for this analysis are examined in Table 9, with the results displayed in Table 10 and Figure 11.

Simulation

To provide a single estimate of the cost of ownership among the conventional and AFVs, the three aforementioned scenarios are weighted and combined into a simulated scenario. Based on strong global population growth, energy scarcity, and limited impact from renewable energy, it is believed that low oil and gas price would not persist for a long period of time, thus a weight of only 10% is assigned to the stagnant gas price scenario. Even though oil and gas is anticipated to rise over time, it would be more conservative to assume that the gas price returns to its historical value rather than the price rice rising to an unprecedented level. As a result, a 2:1 ratio is allocated to the remaining 90%, with a 60% weight assigned to mean-reversion and 30% to the increasing gas price scenario.

The net present value (NPV) metric was not applied to this analysis, as it is a technical term in corporate finance and might not be user-friendly to the general public. However, if NPV were considered, the difference in annual cost saving between AFVs and conventional vehicles would be reduced by the time value of money (inflation rate) over the 10-year period.

The result is exhibited in Table 11.

Given the expected growth (mean) and volatility (standard deviation) of gasoline prices, we performed a Monte Carlo Simulation to estimate change in gas prices in the mid-term, which is defined as the next 3 years. Each year consists of a sample size of 1,000 random variables bounded by the annualized 5-year historical standard deviation. The average number of the 1,000 random variables would then become the projected annual change. This process is then be repeated for 3 years to generate the gasoline price curve.

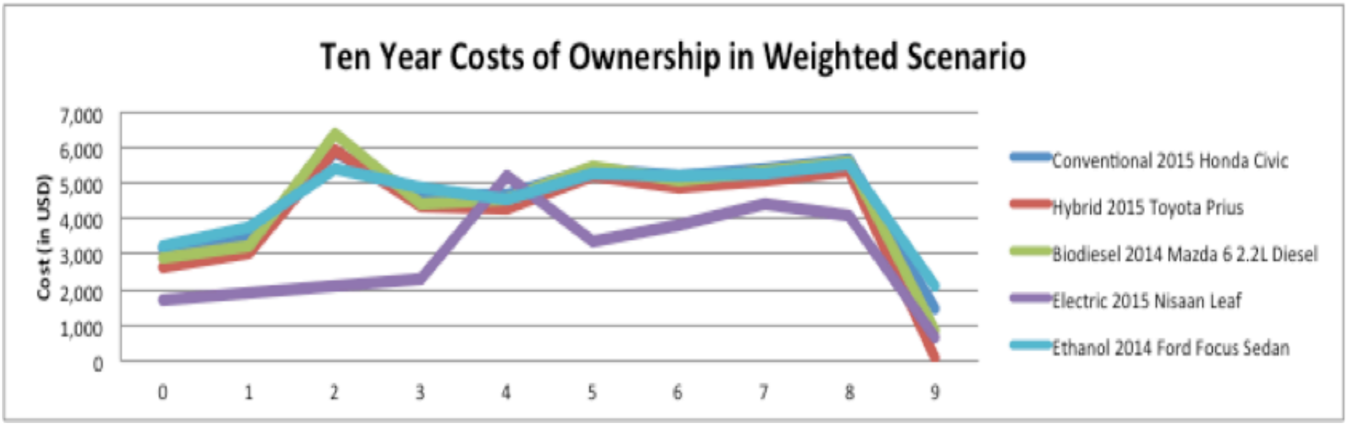
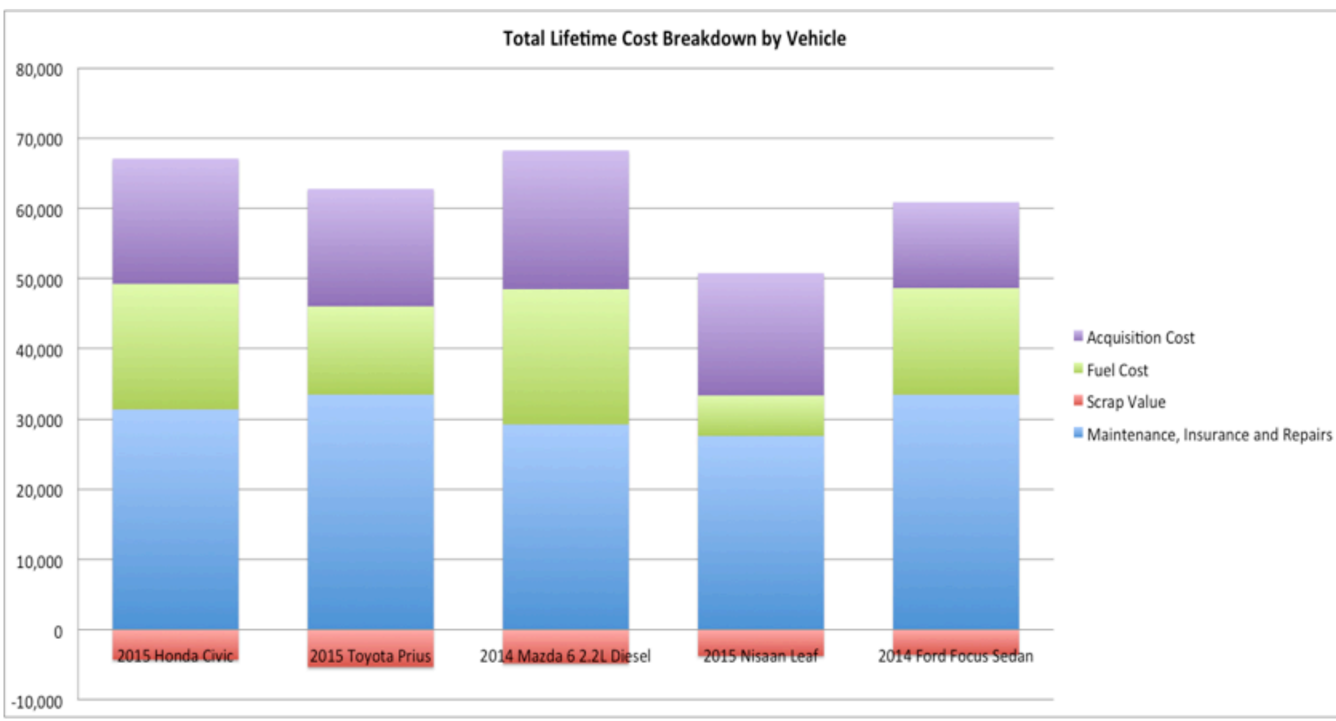


Figure 12 Annual Cost of Ownership by Vehicle Type

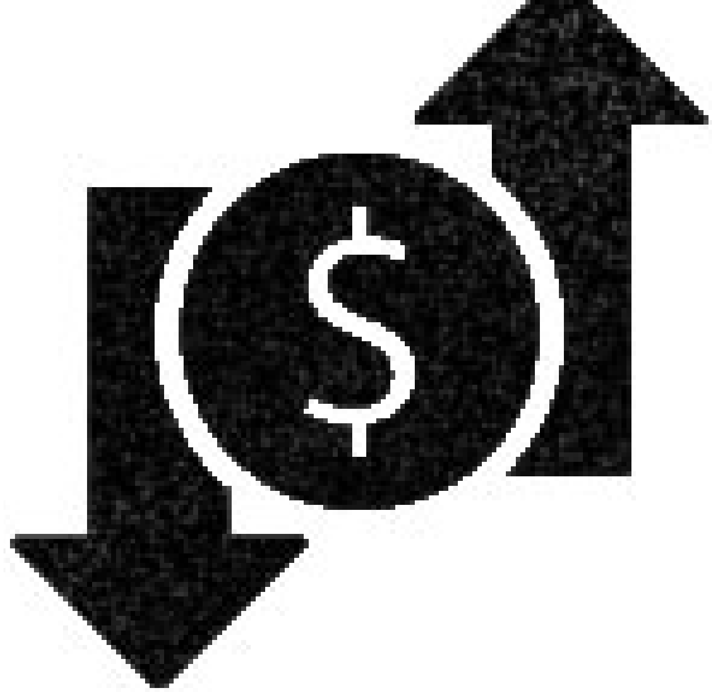
Table 12 Ranking of Costs of Ownership in Weighted Scenario			
Fuel Type	Sample Vehicle	Total Cost (2015 USD)	Ranking (1=Cheapest)
Electric	2015 Nissan Leaf	$44,374	1
Ethanol	2014 Ford Focus Sedan	$56,351	2
Hybrid	2015 Toyota Prius	$57,122	3
Biodiesel	2014 Mazda 6 2.2L Diesel	$60,992	4
Conventional	2015 Honda Civic	$61,602	5

Figure 13 Total Cost of Ownership in Weighted Scenario



Results:

Given the weighted-average growth rate of 13% and an annual volatility of 0.579, the simulation result was largely the same as the mean reversion scenario, which is intuitive because that scenario was assigned the most weight. The annual costs of ownership in this weighted scenario can be found in Figure 12. The total costs of ownership and the rankings of those costs can be found in Figure 13 and Table 12 respectively.



Interactive Calculator

To help individual consumers determine what their personal cost of ownership would be for each vehicle type, an interactive calculator was designed. Users can adjust a number of variables, including the highway to city mileage ratio, target gasoline price and the number of years to reach that price in order to create a tail-made scenario that reflects their personal driving habits. A screenshot of this calculator has been attached as Appendix 2.

BARRIERS TO ADOPTION

While alternative fuel vehicles are commercially available, they have not been widely adopted due to a number of key barriers.

First and foremost among the barriers is the higher upfront cost associated with the purchase of many of these vehicles. Though the total cost of ownership for many alternative fuel vehicles in NY is actually less than for conventional cars, these savings are typically realized slowly over time from lower annual fuel and maintenance costs, with the upfront costs still being greater for AFVs. As a result, many consumers choose not to purchase an AFV because there are unable to afford the greater initial cost or because they perceive the vehicles as more expensive because they are not aware of the long-term savings.[38]

Many consumers are also concerned about the resale value. The tax rebates and other incentives for purchasing a new electric vehicle are depressing the resale values, as prospective buyers can purchase a new PEV for roughly the same cost as a used one. [39] Therefore, consumers who are afraid that their PEV might not be worth as much in the future when compared to a conventional vehicle might be less likely to purchase one. Manufacturers have begun to address this so-called “resale anxiety” by offering resale value guarantees that allow owners to sell their PEVs at rates comparable to conventional cars.[40]

A close second barrier to cost concerns is “range anxiety,” which is the fear that a driver will not be able to reach all their desired destinations due to limited onboard fuel storage or the inability to conveniently refuel. Range anxiety typically applies to BEVs, as it stems from two main concerns: a lack of fueling stations along well-traveled corridors and the length time that fueling requires.[41] For example, while electrical outlets are widespread, it can take up to 20 hours to fully charge an electric vehicle using a Level 1 charging station. There are charging stations that can decrease charging time down to about 20 minutes, but these stations are expensive to install in homes and are not readily available publically.[42] Together, these concerns serve to compel consumers to opt for conventional vehicles that they are confident can be refueled in a few minutes anywhere they are driving.

Another significant barrier to adoption is the lack of awareness among consumers about the variety of alternatives available to them. Not to mention the benefits those alternatives might provide over conventional gasoline vehicles. Even visiting dealerships while shopping for a new car might not inform the consumer about all the options. Many times alternative fuel vehicles are not displayed on car lots because they must be special ordered. [43]

Finally, there are also psychological barriers to adoption that relate to the perceived image, safety, and performance of AFVs. Being a relatively new technology, AFVs can seem risky and unproven from a safety and reliability perspective.[44] Additionally, when problems occur, there is a perception that the costs of repairs will be significant and that there are few qualified mechanics able to work on the vehicles.[45] This concern exists despite the fact that lifetime maintenance costs are estimated to be lower for certain types of AFVs.[46] Finally, there is also a perception about BEVs in particular that they are for a certain type of environmentally-minded consumer rather than for the masses. This is in part fueled by the fact that the EVs that are available tend to be small, four-door sedans with few minivans, SUVs, pickup trucks, or 4-wheel drive options available.[47]

Of these challenges, the higher upfront costs, range anxiety and lack of awareness are the three key barriers that can be readily addressed by the NYS DOT through policy changes and infrastructure investments.

Gap Analysis

Introduction to Gap Analysis

Gaps in the alternative fueling infrastructure can be a cause of range anxiety, so addressing these gaps is critical in promoting the adoption of AFVs in NYS. The purpose of this section is to conduct a gap analysis using Geographic Information Systems (GIS) tools to map and analyze the current fueling infrastructure. The results of the analysis reveal general gaps in the infrastructure along New York's major highways where range anxiety might be felt.

This gap analysis leverages data from a number of different georeferenced sources to produce maps. Locations of AFV fueling stations were sourced from The Department of Energy's Alternative Fuels Data Center[48]. A dataset of highways throughout the state was sourced from the NYS GIS Clearinghouse.[49] A base map of NYS counties was assembled from the NYS GIS Clearinghouse. Finally, the base map of NYS counties[50] was joined with census data from the New York State Open Data initiative to attribute population-based nuances to each county.[51]

As the analysis cannot presuppose where a driver enters the NYS highway system or their fuel levels when they do enter, this gap analysis is based on departures from major hubs, including New York City, Albany,

Table 2 Electric Vehicle Chargers

	Operative Voltage	Charging Time (Full to Empty)	Characteristics and Feature
Level 1	120V	20 Hours	Household Electric Plug
Level 2	240V	4 Hours	Variable Charging Speeds
Level 3	480V	20 Minutes	Fast Charging Capabilities

Rochester, Syracuse, Buffalo, and the Canadian border. The four routes analyzed were: (1) Interstate Highway-87 between New York City, Albany, and Canada; (2) Interstate highway I-90 between Albany, Syracuse, Buffalo, and Rochester; (3) Route 17 between New York City and Syracuse; and (4) Interstate highway I-81 between major centers in Pennsylvania, New Jersey and Canada.

Existing AFV Fueling Infrastructure

There are 22,000 AFV fueling stations across the United States[52]. Together they service vehicles fueled by ethanol, biodiesel, electricity, hydrogen, compressed natural gas, liquefied petroleum gas, and propane. Some stations service private fleet vehicles for government agencies, municipalities, and commercial fleets while the remainder are available for public fueling. 80% of AFV fueling stations across the country are for public use. [53]

To date, New York State hosts 669 publicly available AFV fueling stations, with plans to build an additional 29 in the near future.[50] New York follows a similar trend as the national average, as 65% of the country's publicly available AFV stations service PEVs with the next largest set of publicly available fueling stations for AFV's fuel liquefied petroleum gas based vehicles.[52]

The number of charging units varies between PEV charging stations. The average PEV station hosts one Level 1 pump, two Level 2 pumps, and no Level 3 pumps. Some stations host as many as thirty Level 2 pumps at their fueling stations. [52]

At 150 miles, the quarter tank range of hybrid vehicles is higher than the 100 mile quarter tank range of conventional vehicles. As hybrids have both an internal combustion engine and an electric motor, they have two methods of propulsion, which allows for the higher overall range. Subsequently, these vehicles were not mapped in this analysis. They can fill up at any gas station, of which there are 4,658 in New York State alone.[56]

Gap analysis based on fuel type fueling stations utilizing geographic information systems

Outline of Methodology

The following gap analysis is based on the methodology used by the West Coast Electric Highway (WCEH) initiative. Although the WCEH initiative only addressed PEV charging infrastructure, this gap analysis analyzes electric, E85 and biodiesel fueling infrastructure.

Like the WCEH initiative, this gap analysis only considers publicly available AFV fueling stations that are within a half mile of the selected NYS highways. A buffer that represents a quarter of the maximum range for each vehicle type was sourced from each of the respective fueling stations to indicate range. The rationale for this measure is that any AFV within that buffer range can easily reach a fueling station with only a quarter tank or charge. Conversely, sections of the highways that lie outside of these buffer zones represent areas where it would be unwise for an AFV owner to drive with less than a quarter tank or charge. For BEVs, the buffer range is 25 miles while it is 75 miles for flex-fuel E85 vehicles and

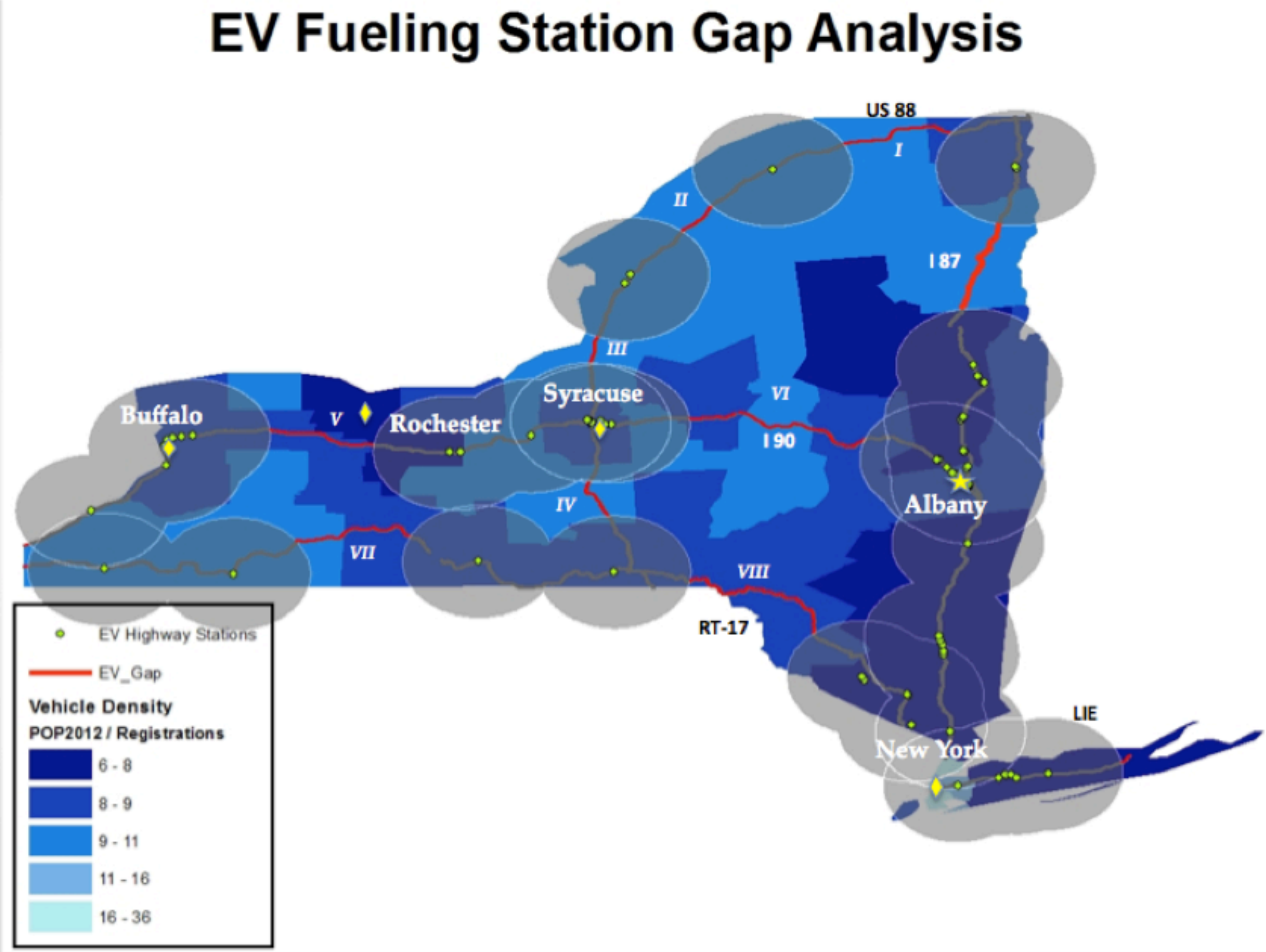


Figure 14 Electric Vehicle Charging Infrastructure in New York

130 miles for biodiesel vehicles.[55] These infrastructure maps were then placed over a geographically referenced projection map of New York State's counties, which were colored to indicate vehicle density in order to help prioritize station placement, as future AFV stations should first be placed to fill infrastructure gaps in counties with high numbers of vehicle registrations.

This analysis incorporates vehicle density per capita. Each county has been normalized to display the ratio of people to cars, with lower numbers indicating more vehicle-dependent counties. These vehicle dependent counties are a high priority for AFV fueling infrastructure placement, as they indicate areas where there are greater densities of vehicles. This is seen in the varying shades of blue filling NYS.

Results of Analyses

EV Gap Analysis

Overall, BEV fueling infrastructure in NYS is well developed. Most stations are clustered near metropolitan regions such as Syracuse, Albany, Buffalo, and New York City. However, there are ten notable gaps totaling 525 miles along the five highways surveyed. The gaps for each highway are listed in Table 14.

Each highway has at least one significant gap in excess of the 25 mile quarter charge range. The shades of blue on the map of NYS correspond to the number of registered vehicles per capita. Counties colored with darker shades of blue have a higher vehicle density than counties with a lighter shade. Below is a list of counties that contain BEV fueling gaps listed in order of registered vehicles per capita:

1. Clinton
2. Steuben
3. Livingston
4. Genesee
5. Sullivan
6. Delaware
7. Broome
8. Oneida
9. Montgomery
10. Allegany
11. Cortland
12. Essex
13. Franklin
14. Herkimer
15. Oswego
16. St. Lawrence

Table 14 Gaps in the Electric Vehicle Charging Infrastructure EV New York State Freeway Gaps (Miles)				
US88	I90	RT17	I87	LIE
66 (I)*	35 (V)*	71 (VII)*	57	41
15 (II)*	78 (VI)*	105 (VIII)*		
12 (III)*				
45 (IV)*				
	*Roman Numerals correspond to the Highway Gap segment specifying incomplete Infrastructure.			

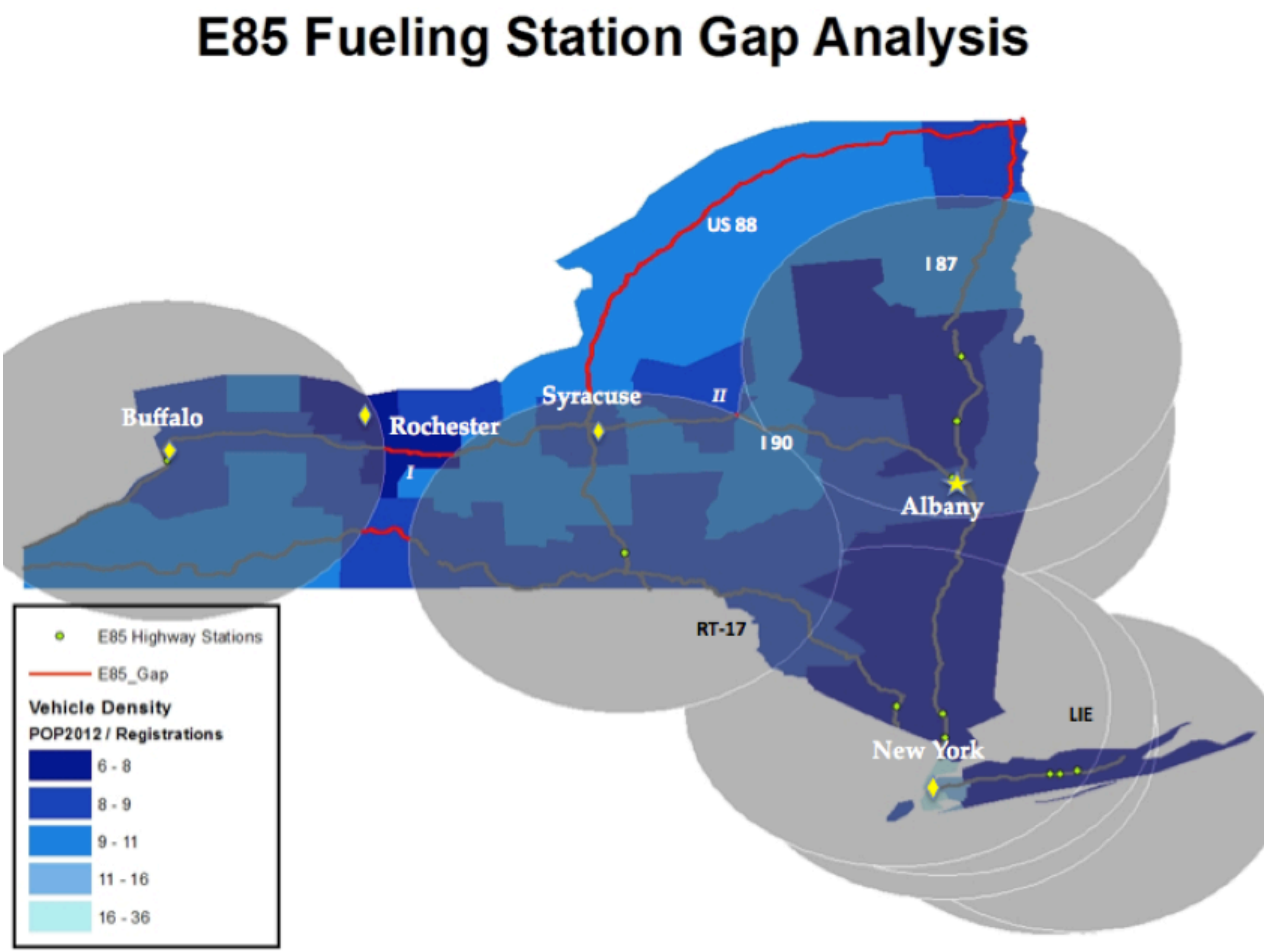


Figure 15 Ethanol Fueling Infrastructure in New York

E85 Gap Analysis

There are four notable gaps totaling 321 miles within the NYS E85 fueling infrastructure. As the range of E85 fueled vehicles is substantially greater than that of BEVs, the grey circles represent a 75-mile range quarter tank range. The gaps are broken down based on each highway and listed in Table 15.

There are a large number of gaps with New York State's current E85 fueling infrastructure. As this study addresses E85 passenger vehicles that are flex fuel capable, these vehicles are able to operate on multiple varieties of ethanol blends, including conventional gasoline. That being the case, the gaps identified above would not limit the ability of the driver of a flex fuel vehicle to travel long distances. However, these gaps would be of concern for drivers of vehicles that can only operate on high concentration ethanol blends.

Figure 14 can be used to assess the ability of a driver to purchase E85 fuel instead of conventional gasoline on trips across the routes examined. The results reveal that it is unlikely that the flex-fuel vehicle owner will be able to complete trips along the designated routes while fueling exclusively with E85. Therefore, gaps in the infrastructure also force owners of flex-fuel vehicles to resort to gas rather than E85, which means these drivers are not able to reap the full benefits of owning a flex fuel vehicle, such as a lower total cost of ownership.

Table 15 Gaps in the Ethanol Fueling Infrastructure

E85 New York State Freeway Gaps (Miles)				
US88	I90	RT17	I87	LIE
215	29 (I)*	37	38	None
	2 (II)*	105 (VIII)*		
	*Roman Numerals correspond to the Highway Gap segment specifying incomplete Infrastructure.			

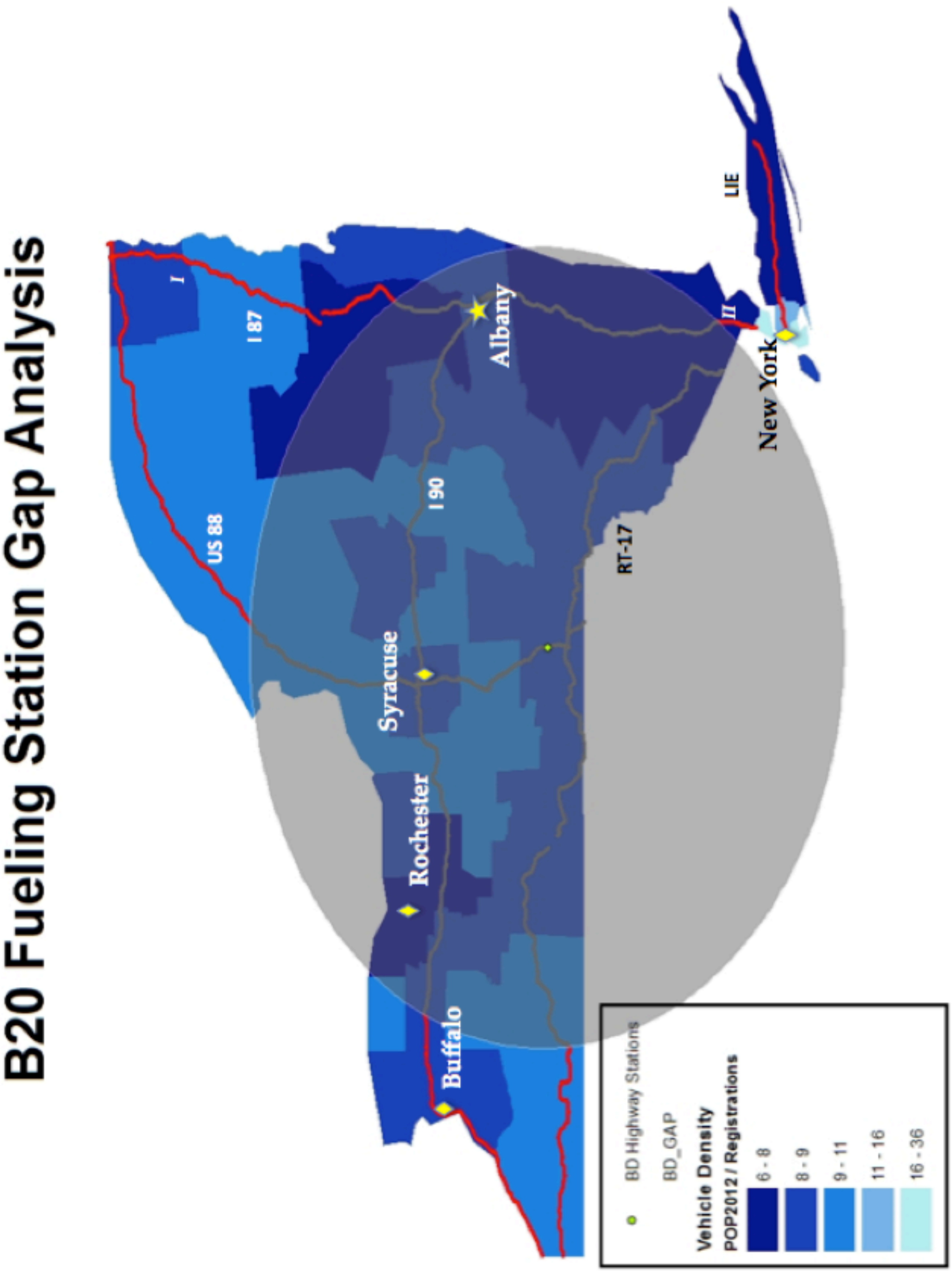


Figure 16 Biodiesel Fueling Infrastructure in New York

Biodiesel

There are four notable gaps within NYS's biodiesel fueling infrastructure totaling 576 miles across five highways. The largest gaps are listed in Table 16.

Among the alternative fueling infrastructures examined, the availability of publicly accessible biodiesel fueling infrastructure in close proximity to the highways studied is the most limited. Only one of four public biodiesel fueling stations across the state is along a highway. Even though biodiesel has a quarter tank range of 130 miles, it has the most significant gaps ranging from 79 to 149 miles. Much like flex-fuel vehicles, biodiesel vehicle drivers are not bound by range anxiety concerns as they can fuel their vehicles with readily available petroleum diesel fuel.

As with E85, Figure 15 can be used to determine the ability to procure biodiesel fuel instead of conventional diesel. The results indicate that NYS does not have a robust biodiesel fueling network that would allow drivers to consistently fill up with only biodiesel. As a result, drivers of diesel vehicles are not accruing the benefits associated with using solely biodiesel, which include lower long-term costs and fewer greenhouse gas emissions.

Table 16 Gaps in the Biodiesel Fueling Infrastructure

BD New York State Freeway Gaps (Miles)				
US88	I90	RT17	I87	LIE
149	106	79	140 (I)*	85
			17(II)*	
	*Roman Numerals correspond to the Highway Gap segment specifying incomplete Infrastructure.			

Suggestions on reducing gap issues

When looking at next steps on how to best support infrastructure growth for AFV vehicles, it is important to identify counties with high numbers of vehicles (AFV + conventional gasoline) but few to no AFV fueling stations. These counties should be given extra attention when determine where to develop new AFV fueling stations.

Table 17 reports New York State Counties that do not host alternative fuel charging/ fueling stations along major highways.

Note the counties of Clinton, Franklin, and St. Lawrence, all lack sufficient AFV stations to close the gaps necessary for extended trips. Similarly, Jefferson and Oswego counties each lack one type of AFV fueling station.

Table 17 NY Counties Lacking AFV Fueling Stations

Counties **Listed in alphabetical order**		
EV Gap	**E85 Gap**	**BD Gap**
Allegany	Clinton**	Bronx
Broome	Franklin**	Cattaraugus
Clinton**	Jefferson*	Chautauqua
Cortland	Ontario	Clinton**
Delaware	Oswego*	Erie
Essex	Steuben	Essex
Franklin**	St. Lawrence**	Franklin**
Genesee		Jefferson*
Herkimer		Nassau
Livingston		Saratoga
Montgomery		St. Lawrence**
Oneida		Suffolk
Oswego*		Queens
Sullivan		Warren
Steuben		Westchester
St. Lawrence**		

**Counties that share gaps with two fueling types*

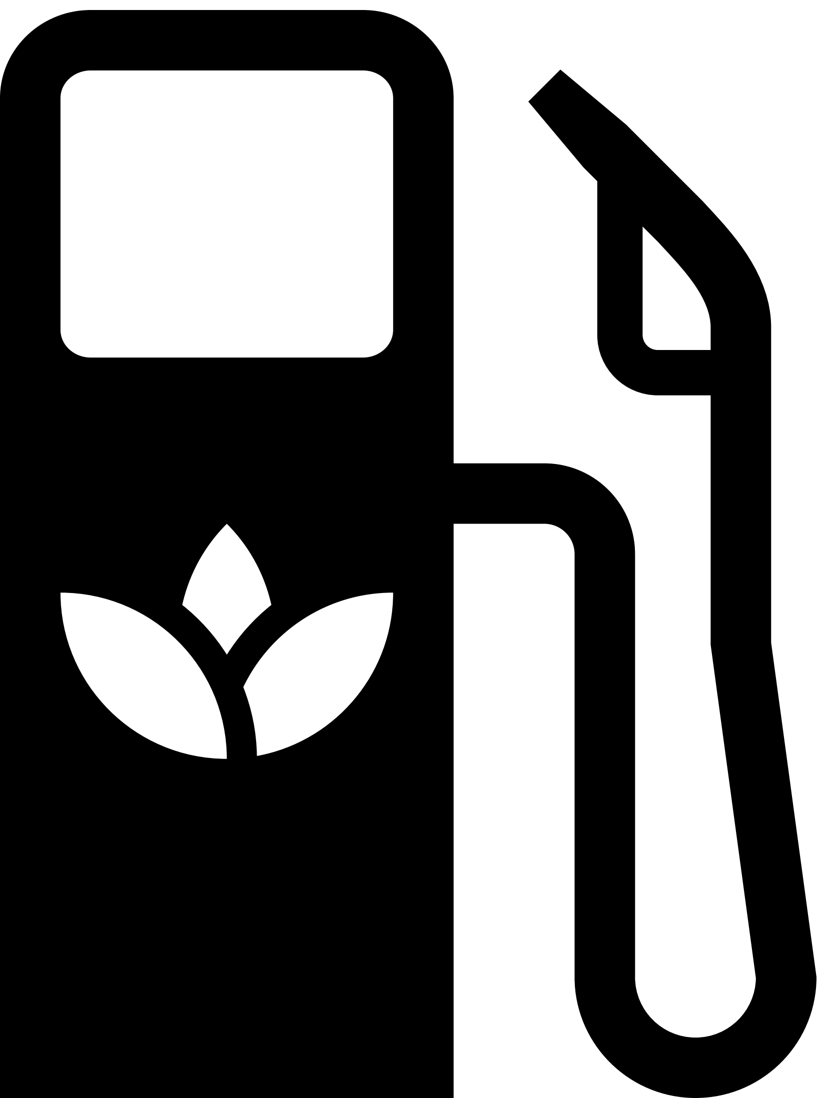
***Counties that share gaps with three fueling types*

How long would it take to drive across NY with your EV considering the time it takes to charge the EV to get back on the road? Table 18 maps out some of the most traveled routes in NY and how long a driver would have to spend waiting for their EV to charge, assuming their EV has a range of ~80 miles per charge.

Table 19 Charging Times Required for Long EV Journeys

Route	Distance (miles)	# of Charges	Minimum Time to Charge
NYC <> Albany	150 miles	2	6 hours
NYC <> Canada	300 miles	3-4	10 hours
NYC <> Syracuse	250 miles	3	9 hours
Albany <> Syracuse	150 miles	2	6 hours
Syracuse <> Buffalo	150 miles	2	6 hours

Of the 29 charging stations being constructed, a number of these stations will be DC fast charging. This will dramatically reduce minimum charge times.



Brownfield Sites Converted to Alternative Fuel Stations

The EPA's Repowering America Initiative partnered with the National Renewable Energy Laboratory in 2011 to produce a guide on how to convert decommissioned gas stations, now classified as brownfield sites, into alternative fuel stations. The first section of this guide reviews all of the selection criteria necessary to identify corridors and stations. The second step of this guide reviews measures and tools necessary to select potential alternative fuel types and prioritize stations. Lastly, the guide illustrates further action after specific sites have been chosen. It includes identifying specific charging or fueling equipment, the permitting process, and everything in between. Overall, the study reveals that there is significant potential for brownfield sites to be used to support AFV infrastructure.[57]

Reengaging decommissioned gas stations is a natural step toward increasing AFV infrastructure because these stations already have many of the characteristics necessary to service the public, as they are conveniently located to major roads and have the required storage and pumping facilities. As brownfields, these sites cannot easily be converted for other uses.[56]

The guide produces two case studies involving electric charging stations for the Seattle, Washington and Eugene, Oregon region. These case studies found 'land revitalization corridors', where the most traveled routes were highlighted to place AFS. "These are corridors where the EPA, in conjunction with state and local partners, is helping to facilitate efforts to get former gasoline stations into reuse while protecting human health and the environment."[56] The Seattle-Eugene region was chosen as one of these corridors since Interstate 5, which traverses the region, is one of the major corridors in the U.S. Vehicle density was also considered when selecting the region, as it is an important indicator of where the most AFV are located and is preferred over exact numbers in order to demonstrate the limited distances people are willing to drive to refuel. Similarly, existing infrastructure was also considered because it demonstrates where the demand for these fuels are in areas. Finally gasoline prices and available AFV incentives were also taken into account.

The study also revealed that multiple AFV fuel types, such as E85 and biodiesel could be placed in the same location. When equipment for ethanol and biodiesel is installed at the same time, it can decrease the installation costs for the owners of these stations. Currently, this co-location is not feasible for electric chargers, as electric stations require certain distances from most liquid and gaseous fuels in order to eliminate spark ignition. However, the appropriate buffer distance has yet to be determined by the EPA.[56]

The NREL study helped set the framework for the gap analysis detailed above. Many aspects of the gap analysis were created using this report, including the various factors needed to create buffer distances. The NREL report can further aid the DOT in choosing AFV station locations based on brownfield sites located across NYS.

Policy Environment

The federal government, NYS legislature and regulatory authorities have enacted numerous policies that incentivize the adoption of AFVs. The following sections outline these policies as they apply to different AFV types, compares the policies adopted in NYS to those in a selection of other states, and discusses potential next steps that NYS regulators may take to further encourage the introduction of AFVs.

Federal and State Policies by Fuel Type

Electric (EV) and Hybrid Vehicles (EV, HEV, PHEV)

In New York State, there are a number of incentives that promote the adoption of EVs, HEVs, and PHEVs. Table 20 contains all current EV and hybrid incentives available in NYS, including those offered by the federal government.[58] Currently, the most prominent ways to promote adoption of these vehicles are financial incentives including funding for basic research, grants to install charging infrastructure, and tax rebates and sales taxes exemptions to encourage consumers to purchase EVs and hybrids.

Biofuels (Ethanol and Biodiesel)

The EPA recognizes the potential hazards associated with the use of fossil fuels. As a result, the EPA established the Renewable Fuel Standard (RFS) to provide the impetus to start producing and selling renewable transportation fuels.[59] The RFS requires alternative fuels to be mixed with conventional fuels (gasoline and diesel) in increasing amounts each year.[60] Because of this requirement, 95% of the gasoline sold in the US actually contains 10% ethanol.[61]

To continue to meet the ever increasing requirements of the RFS, the federal government has established a number of funding programs for all parts of the biofuel value chain. First, the government encourages the development of new technologies that increase the production of biofuels through a series of grant programs. Once those technologies have been developed, there are a number of federally funded grant and loan programs that provide support to biofuel producers. Finally, once the biofuel has been produced, the government has created a number of regulations, grant programs, and partnerships to encourage the dissemination and consumption of these fuels. See Appendices 1, 2, and 3, for complete listings of the programs available.

On the state level, some policies are in place to encourage biofuel production, advance related technologies, and mitigate special considerations required to store, dispense, and handle high-fraction blends. Most of the incentives are financial, including tax credits for biofuel producers, grants, and loans for technology research, demonstration, and deployment. Additionally, some incentives are available to promote biofuel consumption such as the excise tax exemption. Table 21 summarizes the NYS and federal incentives for biofuel vehicles.

See Policy Appendix for further NYS and federal rebates and incentives.

Analysis of Incentives Available in New York

There are a number of incentives that promote the use of a variety of alternative fuel vehicle types in New York. However, these incentives do not always address all the potential avenues to increase adoption

ChargeNY seeks to make it easier to install charging stations by developing best practice guides for municipalities to help them better enact regulations that streamline the permitting process and also ensure that zoning rules and building codes do not impede installations.

Table 20 NYS & Federal Incentives for HEVs and BEVs

NY State	Federal
AFV Research & Development Funding NYSERDA provides funding for projects that enhance mobility, improve efficiency, reduce congestion[1]Error! Bookmark not defined.	**Advanced Research Projects Agency – Energy (ARPA-E)*** Provides grant funding for early-stage technologies that have the potential to reduce GHG emissions[2]
HOV Lane Exemption & Discount (Clean Pass Program) EV and hybrid drivers may use HOV lanes on the Long Island Expressway regardless of the number of occupants[3]	**Loan Guarantee Program** Provides loans to support early commercial use (i.e. beyond basic research) of technologies with the potential to reduce GHG emissions and air pollution[4]
Alternative Fueling Infrastructure Tax Credit Income tax credit 50% of the cost AF infrastructure, up to $5,000. Unused credits may be carried over into future tax years[5]	**Air Pollution Control Program** Provides up to 60% of the funding for government agencies to plan, develop, establish, and improve programs for prevention & control of air pollution[6]
Emissions Test Exemptions BEVs (not hybrids) are exempt from motor vehicle emissions inspections[7]	**Pollution Prevention (P2)** Provides grants for projects that avoid or reduce air pollution8
ChargeNY Funding from NYSERDA & NYPA to install EV charging stations in NY[9]	**Federal Tax Credit** $2,500-$7,500 depends on battery size; new car only; before phase out; only qualified vehicles[10]
E-ZPass Discounts 10% off the regular rate[11]	

Table 21 NYS & Federal Incentives of Ethanol and Biodiesel

NY State	Federal
AFV Research & Development Funding NYSERDA provides funding for projects that enhance mobility, improve efficiency, reduce congestionError! Bookmark not defined.	**Technology Research, Demonstration and Deployment Funding** Funding for basic research up to deployment-stage technologies that have the ability to increase biofuel production ; see Appendix 1 for complete list
Alternative Fuel Tax Exemption and Rate Reduction Counties and cities may reduce the sales tax charged on B20 to 80% of the regular diesel rate [1]	**Production Assistance** Grant and loan programs for biofuel producers; see Appendix 2 for complete list
Biofuel Production Tax Credit $0.15 per gallon of biodiesel or denatured ethanol made available for sale, 40,000 gallons of biofuel per year. Max. credit $2.5 million per taxpayer for no more than 4 consecutive taxable years per production facilityError! Bookmark not defined.	**Consumption Incentives** Grants, regulations, and other programs to encourage the consumption of biofuels; see Appendix 3 for complete list

rates of all AFV types. For example, NYS has several initiatives geared at reducing the cost of ownership for EV and hybrid drivers, however there are relatively some incentive mechanisms to install charging infrastructure and none to promote education, outreach and awareness about these vehicles, as Table 22 indicates.

Similarly, there are a number of federally available biofuel incentives aimed at increasing activity in all parts of the commercialization pipeline, from research to consumption. However, NY still only has six biodiesel stations and seventy-four E85 stations in the state. Other states, such as Minnesota, have over 250 biofuels stations, more than triple what is available in New York.[62] The difference in fueling infrastructure may be explained in New York's lack of policies focusing on expanding infrastructure. In addition, there is only one biofuel awareness program operated by the federal government, but there are no identifiable projects currently being undertake in NYS.

Therefore, while the state and federal governments have been able to provide significant funding for research and biofuel production, they have been less successful at growing the number of fueling stations and raising awareness about biofuel AFVs. As range anxiety and low awareness are two key barriers to adoption, New York will have to consider focusing its policies and programs toward these areas in order to grow the number of AFVs within the state.

Table 22 Federal and State Incentives Available in New York for AFVs

Comparative Policy Landscape

States across the country are taking action to support the deployment of alternative fuel vehicles. As signatories of the ZEV Action Plan, California and Oregon have already begun to make strides in driving adoption of ZEVs. Other states like Washington have focused not only zero emission vehicles but also on biodiesel and ethanol vehicles. As New York is interested in ZEVs as well as other alternative fuel vehicles, the following sections will investigate the policies that these three states (California, Oregon, and Washington) have implemented in order to assess relevant policies and programs

New York could emulate to address the key barriers to consumer adoption.

California

California is one of the first states in the country to widely promote, support, and adopt AFVs. Although California primarily focuses on EVs and HEVs, the state does support other fuel types, including biodiesel and ethanol.

Similar to the federal tax credit for EVs and HEVs, California has successfully implemented a number of rebate and tax credit programs. The California Clean Vehicle Rebate Project has been in place since 2010 and has issued close to 85,000 rebates since inception, translating into $175.6 million.[63] One likely reason this mechanism has been successful is the timing of the rebates, as cost savings are realized at the time of purchase instead of

Table 23 Policies and Programs to Supports AFVs in California				
Available Incentives - California				
Type	Incentive	B-20	Ethanol	Hybrid
Financial	Funding for AFV technology development and deployment (via ARFVTP)	✓	✓	✓
	Clean Vehicle Rebate Project	-	-	✓
	PEV Charging Rate Reduction	-	-	✓
	Electricity Tax Exemption for Transit Use	-	-	✓
	Free Charging	✓	✓	✓
	Free Parking Programs	✓	✓	✓
	Auto insurance Discounts	-	-	✓
	Funding for AFV technology development and deployment (via ARFVTP)	-	-	✓
	Clean Vehicle Rebate Project	-	-	✓
Awareness	Funding for Consumer Awareness Projects (via ARFVTP)	-	-	✓
	Plug-In Electric Vehicle (PEV) Infrastructure Information Resource	✓	✓	✓
	Drive the Dream	✓	✓	✓
	Alternative Fuel and Vehicle Policy Development	✓	✓	✓
Other	High Occupancy Vehicle (HOV) Lanes	-	-	✓

when tax returns are received. Additionally, if the consumer's tax obligation is not large enough, they might not be able to receive the full federal rebate even after filling out the obligatory tax rebate forms. Therefore, being able to reduce the initial upfront cost of the vehicle has been shown to persuade consumers to purchase AFVs. Though there are a number of state and federal incentives available in New York to reduce the cost of ownership, improving the speed and convenience of the upfront cost reductions could encourage consumer adoption of AFVs.

Another best practice California has established is to track the effectiveness of all its rebate programs by capturing statistics on program use by administering an Electric Vehicle Consumer Survey. The Survey has been instrumental in allowing the state to understand the demographics and motivations of ZEV purchasers. For example, in 2014, the Survey revealed that "saving money on fuel costs" was the primary factor in deciding to purchase an AFV.[84] Gathering this information can help policymakers understand what drives consumers to purchase AFVs and develop more effective policies and programs that target these factors.

Like many other states currently, California struggled with low overall awareness about AFVs. Car dealers and consumers alike were often unfamiliar with the applicable rebates and tax incentives. To increase consumer awareness, California's Drive Clean program provides an online Buying Guide for BEV and PHEVs, even allowing consumers to compare these vehicles based on their charging time, battery range, and emissions.[64] The program also offers a straightforward list of all the ZEVs

Available Incentives - California				
Type	Incentive	B-20	Ethanol	Hybrid
Infrastructure	Fueling Infrastructure Grants (via ARFVTP)	✓	✓	✓
	Mandatory Electric Vehicle Supply Equipment (EVSE) Building Standards	-	-	✓
	Residential Electric Vehicle Supply Equipment (EVSE) Financing Program	-	-	✓
	Electric Vehicle Supply Equipment (EVSE) Rebate	-	-	✓
	Advanced Transportation Tax Exclusion (for manufacturers)	-	-	✓
	Clean Technology and Renewable Energy Job Training, Career Technical Education, and Dropout Prevention Program	✓	✓	✓
	Drive the Dream	✓	✓	✓
	West Coast Electric Highway	✓	✓	✓
	Zero Emission Vehicle (ZEV) Promotion Plan	-	-	✓

commercially available, the starting price for each vehicle, and the rebates and other applicable incentives. There is also a function to search for additional incentives based on zip code.[65]

As many consumers are concerned they might not have the infrastructure needed to charge their EV at home, the California Energy Commission is working with the Public Utilities Commission to develop a user-friendly website that answers a wide range of questions regarding whether or not a specific residence requires any upgrades to accommodate a PEV as well as the utility rate options.[66]

California has not limited its awareness campaigns to state-led efforts aimed at consumers either. For example, through the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), California provides funding to non-profits and private organizations that want to undertake consumer awareness projects.[67] Other programs such as Drive the Dream, focus on consumer awareness about EVs as well as employer awareness in order to promote the installation of workplace charging infrastructure. At the Drive the Dream launch event, Governor Jerry Brown met with 40 CEOs of Fortune 500 companies to discuss public workplace charging initiatives. [84] The event hosted a public EV car show and spurred corporate participants to commit to installing 2,033 chargers and purchasing 1,509 EVs by September 2014.[68]

To help businesses install these chargers, California provides funding through the ARFVTP.[69] California also developed a ZEV promotion plan to set key goals, including streamlining the permitting process for infrastructure improvements to support 1 million ZEVs by 2020 in order to further enhance the charging infrastructure.[70] To help achieve this goal, the Property-Assessed Clean Energy (PACE) financing program provides loans to property owners who want to install EVSE.[71]

While providing charging infrastructure at offices and homes is certainly a benefit, many of these chargers are not publicly available nor are they fast charging, so they do not address the issue of range anxiety head on. Instead, improving public fast-charging infrastructure is critical to decreasing consumer concerns about driving ranges. Therefore, California joined with Oregon and Washington to build the West Coast Electric Highway, which consists of a network of DC fast charging stations located every 25-50 miles along the interstate corridor through the Pacific Northwest.[72] Moreover, California has invested more than $38million in over 9,300 DC fast chargers within and between metropolitan areas through the ARFVTP. [84]

Learning from California's success in supporting AFV deployment, a combination of easy to use incentive programs, evaluations of those programs, investments in fast charging infrastructure, and awareness activities could be beneficial in supporting the growth of an AFV market in NYS.

The summary of the main California incentives and rebates for consumers, infrastructure holders and fuel producers are found in Table 23.

Washington State

Like California, Washington State has

Available Incentives – Washington State				
Type	Incentives	B-20	Ethanol	Hybrid & Electric
Financial	Biofuel Tax Deduction	✓	✓	-
	AFV Tax Exemption	-	-	✓
Infrastructure	Biofuel Production Tax Exemption	✓	✓	-
	Biofuel Distribution Tax Exemption	✓	✓	-
	Biodiesel Feedstock Tax Exemption	✓	-	-
	Supply Equipment Rebate – Puget Sound Energy	-	-	✓
	Electric Infrastructure and battery Tax Exemptions	-	-	✓
	West Coast Electric Highway	-	-	✓
Other	AFV and HEV Emissions Inspection Exemption	✓	✓	✓

supported electric vehicles through such initiatives as the West Coast Electric Highway or exempting PEVs from sales tax.[73] Unlike California, Washington also provides significant incentives to support the biofuel industry, with particular focus on promoting the production of biofuel and the expansion of the fueling infrastructure. The driving force behind this trend is Washington's Renewable Fuel Standard (RFS), which requires 2% of all diesel sold in the state to be biodiesel as well as 2% of all gasoline sold to be ethanol. [74]

The purpose of the RFS is twofold: to make Washington's transportation system more sustainable and to promote the state's agricultural sector. As a result, the Washington State Department of Agriculture Department of Agriculture encourages biofuel crop production by ensuring the farmers are educated about which crops can be used to produce biofuel in order to demonstrate that biofuels can be a profitable business.[75]

While raising awareness among producers certainly lays the groundwork for increasing the supply of biofuels, Washington also offers monetary incentives to increase biofuel production and distribution. For example, the use and sale of "machinery, equipment, vehicles, and services related to biodiesel or E85 motor fuel" are tax exempt.[76] Additionally, any property used to manufacture ethanol or biodiesel fuels are exempt from excise and property taxes.[77],[78] The state even has provisions to encourage the distribution of the biofuels once they are produced, as the sale and distribution of biofuels are both tax exempt.[79] These measures have been successful at encouraging the consumption of biodiesel, as Washington in 2012 consumed 89.5 million barrels of ethanol compared to New York's 24.7 million barrels.[80]

Washington States policies to support AFVs can serve as a model for NYS, particularly in promoting the consumption of biofuels. Two specific measures that could benefit NYS are: (i) a renewable fuel standard for biodiesel and ethanol consumption; and (ii) a set of biofuel incentives that cover the entire supply chain from biofuel production to delivery to consumption, which serves as a strong example of an integrated practice for a specific type of alternative fuel.

The summary of the main Washington incentives and rebates for consumers, infrastructure holders and fuel producers can be found in Table 24

Table 24 Policies and Programs to Supports AFVs in Washington

Oregon State

According to an analysis done by the Oregon Department of Energy, among the energy use sectors, transportation is the largest contributor to Oregon's poor air quality. 70% of all miles driven each year come from single occupant vehicles. In response to this study, Oregon has encouraged the use of a variety of AFV types through a number of innovative financial tools.[81]

From the consumer side, Oregon has a number of initiatives to promote the adoption of AFVs. For one, the state has created a program that provides low-interest loans for AFV buyers. These loans are fixed six-year low to zero interest loans for up to $2,500, [82] which enables buyers to purchase a typically more expensive AFV for less upfront capital and without having to file and wait to receive a tax rebate.

Loans are not the only incentives available, as the Public Utility Commission requires publicly owned utilities to provide residents with EVs the option of either paying a flat electricity rate or special time of use rates. For the latter option, the utility customer would have a sub meter just for their EV.[83] Any electricity used to charge the EV would be provided at a rate different from the rate charged for electricity used by the resident for other purposes. Rates would also vary with time of day, with the lowest rates offered at night when there is low electricity demand.

These financial incentives are not only available to car buyers either, as there are also low-interest long-term loans available to finance alternative fuel infrastructure projects, including "fuel production facilities, dedicated feedstock production, fueling infrastructure, and fleet vehicles."[84], [85] Oregon offers tax rebates in the amount of 35% of the total cost of installation for business that install "facilities for mixing, storing, compressing, or dispensing fuels for vehicles operating on alternative fuels."[86], [87] Residents can also receive a tax

Available Incentives - Oregon					
Type	Incentives	B-20	Ethanol	Hybrid	Electric
Financial	AFV Loan Program	✓	✓	✓	✓
	Alternative fuel loans	✓	✓	✓	✓
	B20 State fuel excise tax exempt	✓	-	-	-
	Auto Insurance discounts	✓	✓	✓	✓
Infrastructure	Biofuel production is property tax exempt	✓	✓	-	-
	Alternative fueling infrastructure tax credit for residents	✓	✓	✓	✓
	Alternative fueling infrastructure tax credit for businesses	✓	✓	✓	✓
	West Coast Electric Highway	-	-	✓	✓
Other	State Renewable Fuels Mandate	✓	✓	-	-

rebate for similar projects, though only up to $750 or 25% of the installation costs for projects.[88]

The summary of the main incentives and programs Oregon offers can be found in Table 25.

Table 25 Policies and Programs to Supports AFVs in Washington

Policy Suggestions and Next Steps to Consider

To better encourage the adoption of AFVs, NYS should pursue change by targeting the key barriers to adoption, which include range anxiety, high upfront vehicle costs, infrastructure gaps, and lack of awareness of AFVs. Currently, New York relies upon the federal tax rebate for EVs to reduce the initial costs of purchasing an EV. While the rebate is certainly an incentive, it can only be claimed when the buyer pays their taxes. Instead, more can be done to decrease the costs at the point-of-sale, such as by exempting AFVs from sales taxes as Washington has done or offering low-interest loans as are offered in Oregon.

Even if AFVs are competitively priced, many consumers will not feel comfortable with purchasing one until a robust fueling infrastructure is in place to support their transportation needs. New York has begun to adopt some policies such as ChargeNY and the biofuels production credit that have served to enhance the fueling infrastructure. However, other states like California and Washington have been more successful in their establishment of more robust distributed fueling infrastructure. Through programs such as the ARFVTP's infrastructure grants, residential and business EVSE financing programs, and tax exemptions for the production, transport, and sale of biofuels, California, Washington, and Oregon have all been able to reduce the cost and complications of installing fueling stations, resulting in fewer infrastructure gaps. New York could augment its currently existing programs with components of California, Washington, and Oregon's programs that have yet to be adopted in New York.

While installing fueling infrastructure and purchasing an AFV may in fact be economical, awareness programs are needed to erase the public perception that AFVs are too expensive to own. Direct campaigns like California's Drive Clean program distribute information regarding available incentives not only to prospective buyers but also to salespeople who can influence consumer opinion. Funding for more innovative consumer awareness campaigns through programs like ARVFTP also has the potential to raise the profile of AFVs among consumers, while other programs such as Drive the Dream educate employers about the importance of providing charging infrastructure for employees who own or would like to own a PEV.

In conclusion, NYS can drive consumer adoption of AFVs in a variety of ways, but all methods must address the consumers concerns directly, identify which groups to work with in alleviating those concerns, and communicate the results to the consumer.

Conclusions and Next Steps

Ultimately, a variety of factors, including market, technology and policy drivers will determine which alternative fuel types will become more prominent in New York State. The most feasible alternative fuel vehicle types are electric vehicles, hybrids, E85 (flex fuel vehicles), and biodiesel vehicles. All of these vehicle types, with the possible exception of E85 vehicles, produce fewer greenhouse gases when compared to conventional cars, and they also all have lower costs of ownership. Therefore, any of them could be a potentially beneficial alternative to conventional vehicles. However, with only six biodiesel stations in the entire state, the DOT would have to invest significantly in biodiesel infrastructure. Though EV charging infrastructure is more prevalent, the shorter range of BEVs indicates that there will need to be significantly more fueling stations, particularly fast-charging ones, in order to fill all the infrastructure gaps.

There are a few additional considerations that should be taken into account before determining what vehicle mix might be best for NYS. For one, further health study is needed in order to determine if widespread adoption of AFVs might inadvertently increase concentrations of non-GHG emissions such as SOx and NOx to potentially harmful levels. The research revealed that certain AFVs do produce higher levels of some of the six criteria air pollutants that the EPA monitors, but whether or not these increases are significant enough to impact human health and property remains to be determined.

The DOT will also have to further investigate the fueling infrastructure in order to determine how much investment would be needed to fill the gaps identified in the GIS gap analysis. To accomplish this, the DOT will have to focus in on the general areas of gaps identified by the gap analysis to pinpoint specific locations for fueling stations, perhaps by first identifying brownfield sites along the major highways. A closer look at the charging infrastructure in particular is needed, as there are only six fast chargers in the state, which is likely not enough to alleviate feelings of range anxiety.

Using all of the information about emissions, costs of ownership, fueling infrastructure, and barriers to adoption, the DOT will then be able to identify which combination of fuel types are best for NY and begin solidifying a strategy for driving adoption of these vehicles. As part of that strategy, consumer-facing documents are recommended not only to raise awareness about alternative fuel vehicles in general but also to market the specific fuel types deemed most beneficial for the state.

Educational content for consumers has proven valuable for other states like California and Maryland, but it should not be the only effort New York undertakes to address the key barriers to adoption. The policy analysis revealed that consumers in NY have a number of incentives available to them for reducing the cost of ownership and increasing the convenience of electric and hybrid cars. However, incentives for biodiesel and E85 vehicles were fewer, as were policies and programs aimed at improving the fueling infrastructure and raising public awareness.

A study of how other states such as Oregon, California, and Washington have promoted adoption of AFVs provides New York with a number of innovative policies and programs that could be worth emulating. For example, the three states have joined together to form the West Coast Electric Highway, which is a network of fast chargers for electric vehicles. The states have not focused entirely on electric hybrid and electric vehicles, as Washington and Oregon both have policies to promote the production and sale of biofuels through tax credits and loan programs. California has also been able to successfully drive adoption of EVs in particular through awareness campaigns such as Drive the Dream. These campaigns not only target the consumer directly, but also inform car dealerships, politicians, and other influencers of consumer opinion. While these options have all been implemented in other states, the policymakers and DOT will have to determine if similar programs would be appropriate for New York.

Appendix A

Policy Appendix

Policy Appendix 1: Federal Grant and Loan Programs Supporting Ethanol and Biodiesel Technology Research and Deployment

- **Advanced Research Projects Agency – Energy (ARPA-E)*:** "mission to fund projects that will develop transformational technologies that reduce the nation's dependence on foreign energy imports; reduce U.S. energy related emissions, including greenhouse gases; improve energy efficiency across all sectors of the economy; and ensure that the United States maintains its leadership in developing and deploying advanced energy technologies."[89]

- **Biomass Research and Development Initiative:** "The U.S. Department of Agriculture's National Institute of Food and Agriculture, in conjunction with U.S. Department of Energy's Office of Biomass Programs, provides grant funding for projects addressing research, development, and demonstration of biofuels and bio-based products and the methods, practices, and technologies for their production, under the Biomass Research and Development Initiative." [90]

- **Surface Transportation Research, Development, and Deployment (STRDD) Program:** "funds activities that promote innovation in transportation infrastructure, services, and operations. A portion of the funding made available to STRDD is set aside for the Biobased Transportation Research program to carry out biobased research of national importance at research centers and through the National Biodiesel Board." [91]

*Program also applies to electric vehicles and hybrids

Policy Appendix 2: Federal Grant and Loan Programs Supporting Ethanol and Biodiesel Production

- **Bioenergy Program for Advanced Biofuels:** "*eligible producers of advanced biofuels, or fuels derived from renewable biomass other than corn kernel starch, may receive payments to support expanded production of advanced biofuels.*"[92]

- **Biomass Crop Assistance Program** "*provides financial assistance (reimbursement of up to 50%) to landowners and operators that establish, produce, and deliver biomass feedstock crops for advanced biofuel production facilities."*[93]

- **Biorefinery Assistance Program: "***provides loan guarantees for the development, construction, and retrofitting of commercial-scale biorefineries that produce advanced biofuels."* [94]

- **Department of Energy's Loan Guarantee Program***: "*provides loan guarantees…to eligible projects that reduce air pollution and greenhouse gases, and support early commercial use of advanced technologies, including biofuels and alternative fuel vehicles*." [95]

*Program also applies to electric vehicles and hybrids

Policy Appendix 3: Federal Grant and Loan Programs Encouraging Ethanol and Biodiesel Consumption

- **Air Pollution Control Program*:** *"assists state, local, and tribal agencies in planning, developing, establishing, improving, and maintaining adequate programs for prevention and control of air pollution or implementation of national air quality standards. Plans may emphasize alternative fuels, vehicle maintenance, and transportation choices to reduce vehicle miles traveled."* ***Error! Bookmark not defined.***

- **Biodiesel Fuel Education Program:** goal is to "*educate governmental and private entities that operate vehicle fleets, the public, and other interested entities about the benefits of biodiesel use*."[96]

- **National Clean Diesel Campaign (NCDC):** mission is to "*reduce pollution emitted from diesel engines through the implementation of varied control strategies and the involvement of national, state, and local partners. The NCDC includes programs for existing diesel fleets, regulations for clean diesel engines and fuels, and regional collaborations and partnerships*."[97]

- **Renewable Fuel Standard (RFS):** "*requires renewable fuel to be blended into transportation fuel in increasing amounts each year, escalating to 36 billion gallons by 2022. Each renewable fuel category in the RFS program must emit lower levels of greenhouse gases (GHGs) relative to the petroleum fuel it replaces*."[60]

- **Pollution Prevention (P2)*:** "*supports grants and/or cooperative agreements that provide pollution prevention technical assistance services or training to businesses*."**Error! Bookmark not defined.**

*Program also applies to electric vehicles and hybrids

Appendix B

Consumer Companion Document [A memorandum was created to provide the DOT with suggested content for future consumer communications with a focus on alternative fuel vehicle (AFV) benefits, financial incentives, AFV cost-of-ownership comparisons, fueling infrastructure, and effective marketing approach.]

MEMORANDUM

From: Last Chance Gas Capstone Consulting Team, the Earth Institute at Columbia University
To: Colleen Smith-Lemmon & Elisabeth Lennon, NYS Department of Transportation
Subject: Recommendations for ZEV Action Plan Consumer Awareness Communications
Date: May 8, 2015

Recommended Actions

Our analyses of NYS's potential to meet ZEV Action Plan targets by 2025 indicate a need for DOT to increase consumer awareness and education. Focusing on alternative fuel vehicle (AFV) benefits, financial incentives, AFV cost-of-ownership comparisons, fueling infrastructure, and effective marketing approach will provide consumers with knowledge to make informed decisions to purchase an AFV.

Supporting Guidelines

1. Clean Cities 2015 Vehicle Buyer's Guide

Often, consumers do not know enough about AFV options and potential. Providing a link to The Clean Cities 2015 Vehicle Buyer's Guide will offer consumers access to a comprehensive publication about all EPA-certified light-duty AFVs for the model year 2015. The information for each AFV model includes vehicle type, battery size, starting MSRP, energy impact score, driving range, GHG score, and fuel economy. This guide will deepen consumers' understanding of the vast benefits from purchasing AFVs.

Link: http://goo.gl/riYHaq

2. Alternative Fuel Vehicles Incentives

Include all monetary incentives that are available to the customers upon purchase or lease of an AFV in awareness communications. This practice has been implemented in other states, including MD, CA, and OR. Components to include in this section are: (1) the names of incentives and dollar value; (2) direct information on how to obtain credit (e.g. necessary forms); and (3) a QR code and link that leads to the incentive(s) online. Refer to Appendix 1. for an example of a flyer Maryland for electric vehicle incentives.

Link: http://goo.gl/sl4soi

3. Interactive Cost-of-Ownership Calculator

Currently, one of the main barriers for AFV adoption is the cost-of-ownership and a strong consumer belief that the AFV ticket price and maintenance costs are very high. Integrating the Cost-of-Ownership Calculator on the DOT website will alleviate this barrier. This tool will allow consumers to estimate the projected cost of ownership based on vehicle of interest and driving habits. The consumer document should provide a QR code and link that leads directly to the calculator. Refer to Appendix 2. For an Excel based sample of the cost-of-ownership tool.

4. AFDC Alternative Fueling Station Locator (Charging Stations Map Link)

Range anxiety is an additional barrier for AFV adoption. The lack of charging infrastructure and awareness of existing infrastructure locations can discourage consumers from purchasing an AFV. The DOT can create its own online database for consumers to locate charging stations in NYS or provide a link that directs consumers to the "AFDC Alternative Fueling Station Locator". This tool provides a map of existing alternative fueling stations by selecting fuel type, an address, or a zip code. In addition, there are mobile and iPhone applications available to locate these stations.

Link: http://goo.gl/he3VoZ

5. Marketing Approaches

The consumer document should promote the idea of "Being a Good Citizen". Consumer communications can include promotional lines about how "driving green is doing good" for the environment. Sample Statements/Slogans include: *(1)* In New York, alternative fuel vehicles like EV have an environmental performance as efficient as an 80 mpg vehicle (compared to an average new compact gasoline vehicle's 27 mpg)[98]; (2) "ZEV ME" – Be a good citizen, where "ME" stands for Meeting Expectations of the ZEV MOU; and (3) Be green, be good, be an early adopter. Refer to Appendix.3 for examples of educational awareness.

Social Media plays an important role in consumer communications. This includes Facebook, Twitter, YouTube, and Instagram. NYS DOT and NYSERDA can integrate this through various ways including:

1. AFV related photo competition through social media. Submitted photos can be posted on DOT social media channels and prizes may be offered during certain campaigns.
2. Creative, memorable, and original social media hashtags (#), such as #NYSAFV. Trending AFV and transportation sustainability themes should be leveraged using hashtags. Trends may be monitored through implementation of social media management software or websites such as tagboard.com.
3. Produce an interesting and educational video content for a YouTube channel. Videos may prompt short quizzes or personality surveys that allows consumers to explore AFVs that best suits their lifestyle.
4. Posts should strategically utilize "call to action" links to engage consumers and drive traffic to AFV awareness content.

Implementation

The DOT Outreach Team can prioritize how they would like to increase consumer education and awareness of AFV. The team can create a consumer document (e.g. flyer or brochure), which provides a brief overview of AFV benefits, incentives, cost-of-ownership calculator, and alternative fueling infrastructure locator. Moreover, they can consider an effective way to use the QR code in the consumer document. The team could also focus on the market approach through social media accounts.

Consumer Appendix 1: Examples of Educational Awareness

1. ChargeNY Website Launch

The ChargeNY initiative aims to boost the number of Plug-in Electric Vehicles through building charging stations. The program target is to build 3,000 charging stations in NYS by the end of 2018.[111] The launch of ChargeNY website provides the following information for Plug-in Electric Vehicle consumers (and prospective ones):

- Current news regarding charging stations and technology updates
- Models, specifications, and prices of the available electric vehicles
- National map of charging station locations
- Interactive platforms including forums, blogs, and online chat-room. [99]

2. Connecticut Revolutionary Dealer Award

The Connecticut Department of Energy and Environmental Protection in a partnership with Connecticut Automotive Retailers Association launched a “Connecticut Revolutionary Dealer Award” to recognize state automotive dealers who sell or lease the highest number of EVs during 2014.[100] This is one of many creative ways to convince car buyers that electric is the way to go in Connecticut.

3. Vermont ZEV Action Plan Initiatives

Vermont ZEV Action Plan lists 11 state-specific actions and invites participation from private and public entities, nonprofits, academic organizations, and interested stakeholders. In particular, automakers and dealers were involved to explore financial feasibilities for reducing AFV purchase price and how to organize AFV awareness raising events for consumers.

Source: http://www.anr.state.vt.us/anr/climatechange/documents/FinalVTZEVAction-Plan_080114.pdf

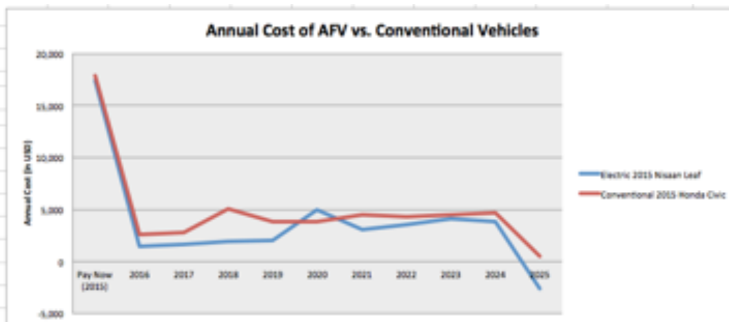
Consumer Appendix 2. Cost-of-Ownership Calculator

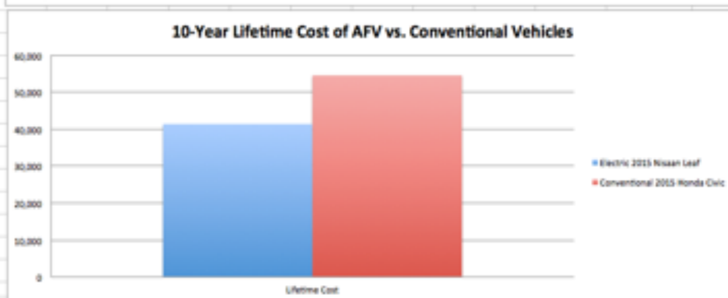
How to use the calculator (for a consumer):

1. Select desired AFV type, and default car models would be suggested respectively.
2. Input the estimated percentage of miles driven on highways and and total annual mileage.
3. Upfront cost and cash flow over 10 years would be generated for reference.

The outcome results for the consumer after using the calculator are presented below:

SUMA K4200 Integrated Capstone Workshop	
Cost of Ownership Financial Analysis	
Consumer Calculator (Simplified Version)	
Please input the 3 Cells highlighted in Orange	
Vehicle Type	**Electric**
Model	2015 Nisaan Leaf
Highway Usage (in %)	**50%**
City Usage (in %)	50%
Miles Driven per year	**8,000**
Years	10
Results	
Annual Cost by Year (in USD)	
Pay Now (2015)	17,418
2016	1,464
2017	1,659
2018	1,884
2019	2,053
2020	4,923
2021	3,102
2022	3,554
2023	4,110
2024	3,798
2025	-2,611
Lifetime Cost	**41,354**

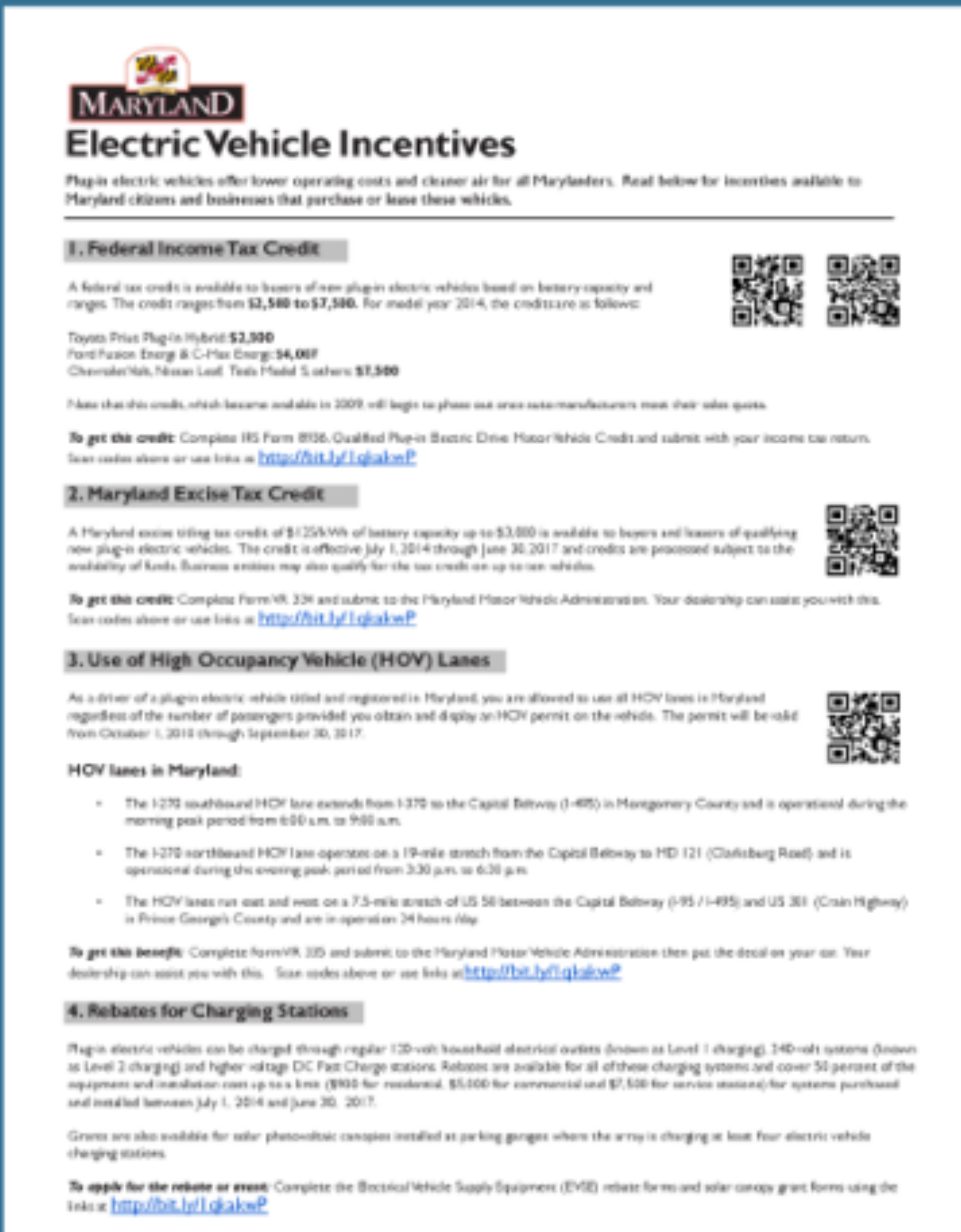




Appendix 3. Maryland Flyer: Electric Vehicle Incentives[101]

Followed by the QR Code is the 'Application for Plug-In Vehicle HOV Permit'

APPENDIX - CALCULATOR



MARYLAND

Electric Vehicle Incentives

Plug-in electric vehicles offer lower operating costs and cleaner air for all Marylanders. Read below for incentives available to Maryland citizens and businesses that purchase or lease these vehicles.

1. Federal Income Tax Credit

A federal tax credit is available to buyers of new plug-in electric vehicles based on battery capacity and ranges. The credit ranges from **$2,500 to $7,500.** For model year 2014, the credits are as follows:

Toyota Prius Plug-In Hybrid: **$2,500**
Ford Fusion Energi & C-Max Energi: **$4,007**
Chevrolet Volt, Nissan Leaf, Tesla Model S, others: **$7,500**

Note that this credit, which became available in 2009, will begin to phase out once auto manufacturers meet their sales quota.

To get this credit: Complete IRS Form 8936, Qualified Plug-in Electric Drive Motor Vehicle Credit and submit with your income tax return. Scan codes above or use links at http://bit.ly/1qkakwP

2. Maryland Excise Tax Credit

A Maryland excise titling tax credit of $125/kWh of battery capacity up to $3,000 is available to buyers and leasers of qualifying new plug-in electric vehicles. The credit is effective July 1, 2014 through June 30, 2017 and credits are processed subject to the availability of funds. Business entities may also qualify for the tax credit on up to ten vehicles.

To get this credit: Complete Form VR 334 and submit to the Maryland Motor Vehicle Administration. Your dealership can assist you with this. Scan codes above or use links at http://bit.ly/1qkakwP

3. Use of High Occupancy Vehicle (HOV) Lanes

As a driver of a plug-in electric vehicle titled and registered in Maryland, you are allowed to use all HOV lanes in Maryland regardless of the number of passengers provided you obtain and display an HOV permit on the vehicle. The permit will be valid from October 1, 2014 through September 30, 2017.

HOV lanes in Maryland:

- The I-270 southbound HOV lane extends from I-370 to the Capital Beltway (I-495) in Montgomery County and is operational during the morning peak period from 6:00 a.m. to 9:00 a.m.
- The I-270 northbound HOV lane operates on a 19-mile stretch from the Capital Beltway to MD 121 (Clarksburg Road) and is operational during the evening peak period from 3:30 p.m. to 6:30 p.m.
- The HOV lanes run east and west on a 7.5-mile stretch of US 50 between the Capital Beltway (I-95 / I-495) and US 301 (Crain Highway) in Prince George's County and are in operation 24 hours /day.

To get this benefit: Complete form VR 335 and submit to the Maryland Motor Vehicle Administration then put the decal on your car. Your dealership can assist you with this. Scan codes above or use links at http://bit.ly/1qkakwP

4. Rebates for Charging Stations

Plug-in electric vehicles can be charged through regular 120-volt household electrical outlets (known as Level 1 charging), 240-volt systems (known as Level 2 charging) and higher voltage DC Fast Charge stations. Rebates are available for all of these charging systems and cover 50 percent of the equipment and installation cost up to a limit ($900 for residential, $5,000 for commercial and $7,500 for service stations) for systems purchased and installed between July 1, 2014 and June 30, 2017.

Grants are also available for solar photovoltaic canopies installed at parking garages where the array is charging at least four electric vehicle charging stations.

To apply for the rebate or grant: Complete the Electrical Vehicle Supply Equipment (EVSE) rebate forms and solar canopy grant forms using the links at http://bit.ly/1qkakwP

The above electric vehicle flyer, which highlights incentives and rebates, is distributed by the State of Maryland.

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