GEORGIA DOT RESEARCH PROJECT 20-21

FINAL REPORT

A FORECAST OF STATE MOTOR FUEL REVENUES: THE EFFECT OF NEW TECHNOLOGIES AND THE STATE VEHICLE FLEET MIX ON GEORGIA MOTOR FUEL RECEIPTS

OFFICE OF PERFORMANCE-BASED MANAGEMENT AND RESEARCH

600 WEST PEACHTREE STREET NW
ATLANTA, GA 30308

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-GA-22-2021	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle A Forecast of State Motor Fuel Revenues: The Effect of New Technologies and the State Vehicle Fleet Mix on Georgia Motor Fuel Receipts		**5. Report Date** March 2022 **6. Performing Organization Code** N/A
7. Author(s) Laura Wheeler, Ph.D. Meera Omar Jonatas Teixeira Prates		**8. Performing Organization Report No.** 20-21
9. Performing Organization Name and Address Georgia State University Research Foundation, Inc. 58 Edgewood Ave., Third Floor, Atlanta GA 30303 Phone: (404) 413-3500 Email: research@gsu.edu		**10. Work Unit No.** N/A **11. Contract or Grant No.** PI# 0017439
12. Sponsoring Agency Name and Address Georgia Department of Transportation Office of Performance-based Management and Research 600 West Peachtree St. NW Atlanta, GA 30308		**13. Type of Report and Period Covered** Final Report (September 2020–March 2022) **14. Sponsoring Agency Code** N/A
15. Supplementary Notes Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.		

16. Abstract

This research focuses on the impact of greater rates of adoption of higher fuel-economy vehicles and electric vehicles (EVs) on anticipated motor fuel receipts from 2022 through 2050. We find that motor fuel consumption has increased in Georgia over the 2000–2019 period, but it has fallen on a per capita basis. Also, during this time, the trend in EV adoption is increasing. Motor fuel receipts are increasing but only due to the indexing of the state motor fuel rate. Close examination of motor fuel consumption in the state reveals that increases in the miles per gallon (MPG) of conventional internal combustion engine (ICE) vehicles are currently having a greater negative effect on motor fuel consumption than the adoption of electric vehicles. Two forecasts are produced for this research. The first is an econometric forecast based on historical data of motor fuel consumption and important determinants of motor fuel consumption. The second model is more conservative and is constructed from the detailed tables available from the Annual Energy Outlook (AEO). The optimistic forecast model projects a slightly increasing trend in motor fuel consumption of 0.3 percent annually over the 2022–2050 period for Georgia. Under this forecast, motor fuel receipts are forecast to increase at an average annual rate of 0.6 percent over the forecast window of 2022-2050. The conservative forecast projects a slightly declining average annual growth rate of motor fuel consumption of −0.1 percent. Receipts under this forecast are expected to increase 0.2 percent on average annually over the 2022-2050 period.

17. Key Words Motor fuel revenues, electric vehicles, alternative transportation funding, BEVs, PHEVs, AFVs		**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 86	**22. Price** Free

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

GDOT Research Project No. 20-21

Final Report

A FORECAST OF STATE MOTOR FUEL REVENUES: THE EFFECT OF NEW TECHNOLOGIES AND THE STATE VEHICLE FLEET MIX ON GEORGIA MOTOR FUEL RECEIPTS

By

Laura Wheeler, Ph.D.
Senior Research Associate

Meera Omar
Graduate Research Assistant

Jonatas Teixeira Prates
Graduate Research Assistant

Georgia State University

Contract with
Georgia Department of Transportation

In cooperation with
U.S. Department of Transportation Federal Highway Administration

February 2022

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The purpose of this research is to develop a long-run forecast of motor fuel receipts that incorporates the changes that are occurring with respect to fuel consumption. Specifically, this research focuses on the impact of greater rates of adoption of higher fuel-economy vehicles and electric vehicles (EVs) on anticipated motor fuel receipts from 2022 through 2050.

We find that motor fuel consumption has increased in Georgia over the 2000–2019 period, but it has fallen on a per capita basis. At the same time, the trend in EV adoption is increasing. Motor fuel receipts are increasing but only due to the indexing of the state motor fuel rate.

The research provides a framework by which policy makers can organize the various factors affecting motor fuel receipts over time. Based on the calculation of motor fuel consumption for a single vehicle per year, we (the research team) present the main determinants of motor fuel receipts, including number of vehicles in operation, vehicle miles traveled per vehicle, fuel economy and the motor fuel tax rate. We further explore the impact of these main factors on motor fuel receipts. Our findings suggest that the increasing fuel economy of ICE vehicles is a more important factor in the decline of motor fuel consumption in the short run than the adoption of electric vehicles.

Two forecasts are produced for this research. The first is an econometric forecast based on historical data of motor fuel consumption and important determinants of motor fuel consumption. The second model is more conservative and is constructed from the detailed tables available from the Annual Energy Outlook (AEO). These tables provide information on a national level that is modified to represent Georgia. This forecast specifically incorporates the adoption of alternative fuel vehicles. Furthermore, this forecast may be updated annually which will provide GDOT officials a tool by which to monitor the status of motor fuel receipts over time.

Under the optimistic forecast, total motor fuel revenues are forecast to increase at an average rate of 0.6 percent annually over the 2022–2050 period, from $2.0 billion in 2022 to $2.3 billion in 2050. The annual increase in receipts is due to the annual increase in the tax rate and the increase in the use of diesel fuel. Over the 2022–2050 period, revenues from gasoline are forecast to decline on average 0.1 percent annually, while revenues from diesel are forecast to increase 2.2 percent annually. Under the conservative forecast, total motor fuel revenue is projected to rise by an average of 0.2 percent annually, from $2.1 billion in 2022 to $2.2 billion in 2050. Based on the assumptions reflected in the NEMS reference model, the share of light-duty BEVs and PHEVs in Georgia is forecasted to increase from 1.6 percent in 2022 to 11.7 percent of all new vehicles sold in Georgia.

Lastly, this research provides 5 options for supplementing motor fuel receipts:

- Option #1 recommends that the state apply the AFV registration fee to PHEVs and other alternative fuel vehicles, such as natural gas and hydrogen possibly at a reduced rate.
- Option #2 recommends that the state not eliminate the annual CPI adjustment and extend the indexing to the AFV fee.
- Option #3 recommends that as an alternative to indexing to the CPI, the state consider indexing both the motor fuel tax rate and the AFV fee to the National Highway Construction Cost Index.

- Option #4 recommends that the state consider implementing a new fee or modifying the existing registration fee structure to impose a higher tax by vehicle weight.

- Option #5 recommends that the Georgia DOR maintain a database of motor vehicle registrations, including information on the make, model, model year, fuel-type, body-style, trim-level, number of cyclinders, gross weight, and county and date of registration for each vehicle registered in the state. This database should be updated at least annually and made available to GDOT for analysis. Furthermore, DOR should maintain these annual databases over a number of years so that time-series analysis may be conducted to understand trends and changes in vehicle ownership and adoption over time.

CHAPTER 1. INTRODUCTION

Motor fuel receipts represent the largest single source of state transportation funding. Accurate forecasts of these receipts are crucial for successful planning and completion of transportation projects. These forecasts are particularly challenging because of the significant number of years involved in moving a transportation project from the planning stage to completion. On top of this, changes in technology have altered the historical trajectory of motor fuel receipts, adding more uncertainty to existing forecasts of long-run receipts. This research addresses the challenge of forecasting long-run motor fuel receipts in this complex environment.

The purpose of this research is to develop a long-run forecast of motor fuel receipts that incorporates the changes that are occurring with respect to fuel consumption. Specifically, this research focuses on the impact of greater rates of adoption of higher fuel-economy vehicles and electric vehicles (EVs) on anticipated motor fuel receipts from 2022 through 2050.

We find that motor fuel consumption has increased in Georgia over the 2000–2019 period, but it has fallen on a per capita basis. Specifically, the volume of motor fuel gallons consumed rose between 2000 and 2005, fell between 2005 and 2012, and rose again over the 2012-2019 period but have not yet returned to its peak reached in 2005. At the same time, the trend in EV adoption is increasing. Motor fuel receipts are increasing but only due to the indexing of the state motor fuel rate. Close examination of motor fuel consumption in the state reveals that increases in the miles per gallon (MPG) of conventional internal combustion engine (ICE) vehicles are currently having a greater negative effect on motor fuel consumption than the adoption of electric vehicles. Two forecasts are produced for this research. The first is an econometric forecast based on historical data of motor fuel consumption and important determinants of motor fuel consumption. The second model is more conservative and is constructed from the detailed tables available from the Annual Energy Outlook (AEO). These tables provide information on a national level that is modified to represent Georgia. This forecast specifically incorporates the adoption of alternative fuel vehicles. Furthermore, this forecast may be updated annually which will provide GDOT officials a tool by which to monitor the status of motor fuel receipts over time. The optimistic forecast model projects a slightly increasing trend in motor fuel consumption of 0.3 percent annually over the 2022–2050 period for Georgia. Under this forecast, motor fuel receipts are forecast to increase at an average annual rate of 0.6 percent over the forecast window of 2022-2050. The conservative forecast projects a slightly declining average annual growth rate of motor fuel consumption of −0.1 percent. Receipts under this forecast are expected to increase 0.2 percent on average annually over the 2022-2050 period.

In this report, chapter 2 reviews the structure of the motor fuel tax in Georgia and provides a discussion of the recent trends in motor fuel receipts. Chapter 3 focuses on the recent trends in motor fuel consumption, while chapter 4 focuses on the trends in EV[1] adoption nationally and in Georgia. Chapter 5 considers the underlying trends in fuel economy and vehicle miles traveled (VMT) that influence the overall level of motor fuel consumption and provides a framework for understanding the underlying influences on motor fuel consumption. Chapter 6 provides results of several analyses relating to gasoline consumption, MPG, and VMT at the state level. Chapter 7 provides the analysis of the forecast of the motor fuel tax rate. Chapter 8 provides the results of the long-run econometric forecast of motor fuel receipts for Georgia, while chapter 9

[1] For the purposes of this report, the term EV includes battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs). This report uses the term alternative fuel vehicle (AFV) interchangeably with EV. Technically, AFV also includes natural gas, propane, and hydrogen vehicles, but adoption of these types of vehicles is negligible over the study period of this report.

provides the results of an alternative long-run forecast generated from the National Energy Modeling System (NEMS) adapted for Georgia. Chapter 10 provides the results of several forecasts based on alternative assumptions regarding national fuel economy standards and rates of EV adoption in Georgia. Chapter 11 provides a discussion of various modifications to the existing transportation funding arrangement in the state, and the report concludes with chapter 12.

CHAPTER 2. MOTOR FUEL TAXES

MOTOR FUEL TAXES IN GEORGIA

The motor fuel tax is a state excise tax, as described in the Official Code of Georgia Annotated (O.C.G.A.) § 48-9-3[2], levied on gasoline, compressed petroleum gas, fuel oils, and special fuels. The rate varies by the type of fuel and is applied per gallon. Table 1 shows the rate for each fuel type between 2016 and 2021.

Table 1. Georgia motor fuel excise tax rates, 2016–2021.

	Gasoline	Diesel	Aviation Gas	LPG[1]	Special Fuel[2]
1/1/2021	$0.287	$0.322	$0.010	$0.287	$0.287
1/1/2020	$0.279	$0.313	$0.010	$0.279	$0.279
1/1/2019	$0.275	$0.308	$0.010	$0.275	$0.275
1/1/2018	$0.268	$0.300	$0.010	$0.268	$0.268
1/1/2017	$0.263	$0.294	$0.010	$0.263	$0.263
1/1/2016	$0.260	$0.290	$0.010	$0.260	$0.260

[1] Liquefied petroleum gas.
[2] Including compressed natural gas (CNG).

Exemptions to the motor fuel tax exist for bulk sales of fuel to distributors, exports from Georgia to the U.S. government, sales of petroleum or special fuel that are not for highway use or reselling, and sales for heat. Aviation gasoline is exempted except for 1 cent per gallon when sold to licensed aviation gasoline dealers.

The motor fuel tax is paid by distributors of motor fuel in the state and is due by the 20th of each month. The tax revenues are allocated to the Georgia Department of Transportation (GDOT) for highway purposes by the state constitution. Table 2 shows the tax revenue for fiscal year (FY)

[2] http://www.lexisnexis.com/hottopics/gacode/default.asp

2016 through FY 2021 (SAO, n.d.). For FY 2021, approximately 97 percent of own-source transportation funding came from motor fuel receipts (Georgia SAO, 2021). This single source comprised 48 percent of the total funding for GDOT in FY2021 (OPB 2022). Transportation funding is also supported by Hotel/Motel tax receipts, and receipts from the Highway Impact Fee. As of July 1, 2022, and until June 30, 2032, all revenue from the state AFV Registration Fee will be deposited into the state Transportation Trust Fund (O.C.G.A. § 40-2-151.2).

Table 2. Motor fuel receipts, FY 2016–2021.

Fiscal Year	Motor Fuel Excise Tax Revenue
2016	$1,603,101,885
2017	$1,750,783,811
2018	$1,790,576,123
2019	$1,818,273,405
2020	$1,865,514,651
2021	$1,772,875,040

The motor fuel tax was modified significantly in 2015 with the passage of Georgia HB 170. Prior to the implementation of this legislation, motor fuels in Georgia were taxed at the distributor level through an excise tax and a prepaid motor fuel tax. The excise tax was a per-gallon tax of 7.5 cents. The prepaid motor fuel tax, also referred to as the second motor fuel tax, was also paid by fuel distributors but was based on the average retail sales price, which was converted to a cent-per-gallon rate.[3] The per-gallon rate for the prepaid tax was adjusted by the Georgia Department of Revenue (DOR) every six months.

Passage of HB 170 eliminated the prepaid component of the tax and increased the excise tax rate to $0.26 cents per gallon. Under the new law, the excise tax rate is adjusted annually to reflect

[3] In addition, there was a prepaid local tax. The discussion above is limited to the state tax.

changes in the consumer price index (CPI) and in the fuel efficiency of new model-year vehicles compared to the previous year.[4] The preliminary excise tax rate is calculated by multiplying the percentage increase (decrease) of average fuel efficiency of the new model-year vehicles registered in the state relative to the base year of 2014. The preliminary excise tax is then multiplied by the annual percentage increase (decrease) in the CPI to produce the final motor fuel excise tax rate. Through these adjustments, annual increases in fuel prices and the fuel efficiency of the stock of vehicles on the road are incorporated into the motor fuel excise tax rate. As a result, increases in overall prices of goods and services and/or fuel efficiency translate into higher motor fuel tax rates.

MOTOR FUEL TAXES IN OTHER STATES

Table 3 provides a snapshot of applicable motor fuel rates in the Southeastern states of the United States in effect as of January 2021 (FTA 2021). In comparison to the selected states, Georgia has the third-highest state rate per gallon for both gasoline and diesel, behind Florida and North Carolina.

[4] The use of CPI was originally set to sunset in July 2018 but was extended to July 1, 2025 (Georgia Code Title 48, § 48-9-3).

Table 3. Motor fuel rates by state and fuel type, January 2021.

STATE	State Excise Tax and Fee – Total		
	Gasoline	Diesel	Gasohol
Alabama	26.0	27.0	26.0
Florida	32.625	33.5	32.625
Georgia	28.7	32.2	28.7
Kentucky	26.0	23.0	26.0
Mississippi	18.4	18.4	18.4
N. Carolina	36.35	36.35	36.35
S. Carolina	24.75	24.75	24.75
Tennessee	27.4	28.4	27.4
Virginia	21.2	20.2	21.2
U.S.	18.4	24.4	18.4

Rates may not include all local taxes or fees. Federal rates are inclusive of the Leaking Underground Storage Tank (LUST) tax.

Table 4 provides the motor fuel revenue for 2018 on a per capita basis. The second and third columns of this table provide the percent of roads in poor repair and the percent of structurally deficient bridges, respectively, in the state as assessed by the American Society of Civil Engineers (ASCE) as of 2021.

Table 4. Motor fuel revenue per capita, 2018, and road and bridge conditions, 2021.

State	Per Capita Revenue[1]	Roads in Poor Conditions (%)	Bridges Structurally Deficient (%)[2]
Alabama	$133	11	4
Florida	$132	13	2.9
Georgia	$171	7	3
Kentucky	$158	10	7.2
Mississippi	$146	27	8.7
N. Carolina	$190	14	9.3
S. Carolina	$127	18	8.4
Tennessee	$160	5	4.4
Virginia	$121	14	4.4
U.S.	$148	20	7.5

[1]U.S. Census Bureau (2021).
[2]ASCE (2021).

CHAPTER 3. TRENDS IN FUEL CONSUMPTION

Although the majority of fuel purchased is gasoline, Georgia and most states levy different rates by fuel type. Special fuels consist of diesel, aviation fuel, and compressed natural gas.[5] Over time, the share of gasoline usage has remained fairly constant at about 79 percent in both the U.S. and Georgia, as shown in table 5 (FHWA n.d.-a). Furthermore, of the special fuels, diesel made up about 97 percent in 2019 and has remained a constant share since 2013.

Table 5. Motor fuel usage by type of fuel.

	Georgia		U.S.	
	Gasoline (%)	**Special Fuels (%)**	**Gasoline (%)**	**Special Fuels (%)**
2000	77.3	22.7	79.9	20.1
2010	79.4	20.6	79.0	21.0
2019	78.9	21.1	76.9	23.1

FUEL CONSUMPTION TRENDS

Over the past 20 years, total fuel consumption in Georgia and across the United States has increased along with growth in population and number of vehicles. Total population of the U.S. grew at a compound average annual growth rate of 0.80 percent between 2000 and 2019, while number of vehicle registrations has grown at a rate of 1.07 percent. Population in Georgia has grown at a higher rate than the national average at 1.4 percent, while number of vehicle registrations has grown at a lower rate of 0.90 percent.

Fuel consumption trends reveal that total fuel consumption for Georgia has grown at a rate of 0.20 percent over the 2000–2019 period, which is significantly lower than the national average of

[5] For the remainder of this report, special fuels are defined to include all fuels not classified as gasoline. Georgia DOR has a more limited definition of special fuels as referenced in table 1.

0.70 percent. Figure 1 presents total fuel consumption for Georgia and the U.S. between 2000 and 2019 (FHWA n.d.-a). While the trends are similar for the state and the country overall, Georgia experienced a larger relative decline in consumption in 2010 and has since shown less growth relative to the country overall after having grown at higher rates prior to 2007.

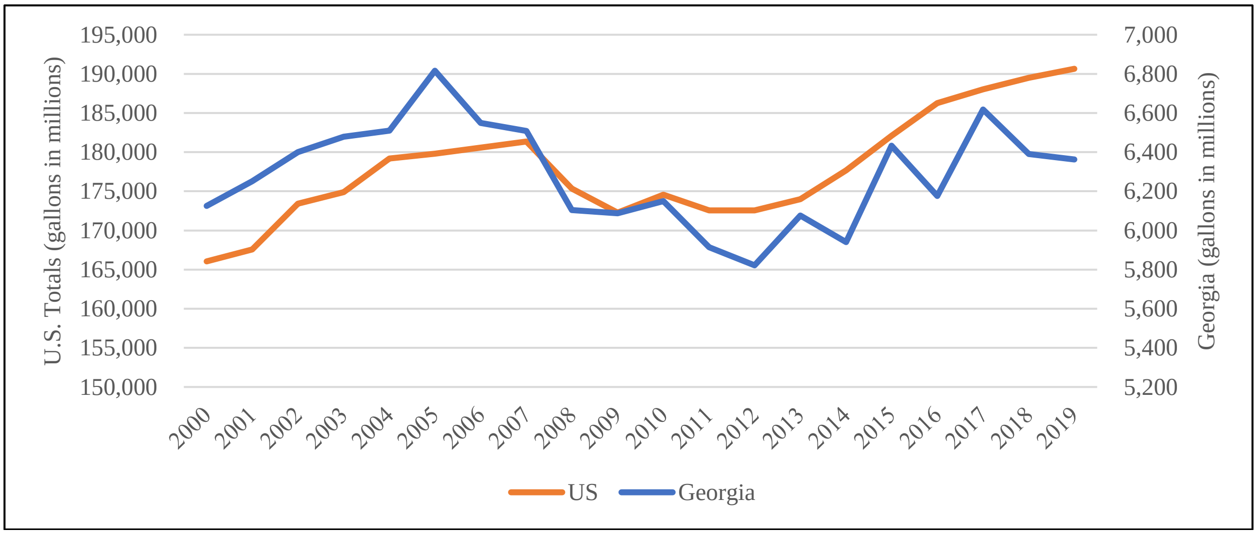

Figure 1. Line graph. U.S. and Georgia – Total fuel consumption, 2000–2019.

IMPACT OF COVID-19 PANDEMIC ON MOTOR FUEL USAGE

The COVID-19 pandemic initially had a profound impact on passenger travel and motor fuel receipts. Consumption in early 2020 tracked closely with that for the same period in 2019. During the spring lockdown period, however, motor fuel consumption fell to a low of about 48 percent from its pre-COVID level. This sharp decline lasted only a few weeks, and then motor fuel consumption began to recover throughout the year, as shown in figure 2 (FHWA 2021).

On a weekly basis, motor fuel consumption has returned to its pre-pandemic levels and tracks very closely to the FY 2019 levels for about the last two quarters of FY 2021. On a cumulative basis, motor fuel consumption for FY 2021 exceeded the FY 2020 total by 3.6 percent but was still below the FY 2019 cumulative total by 6.4 percent.

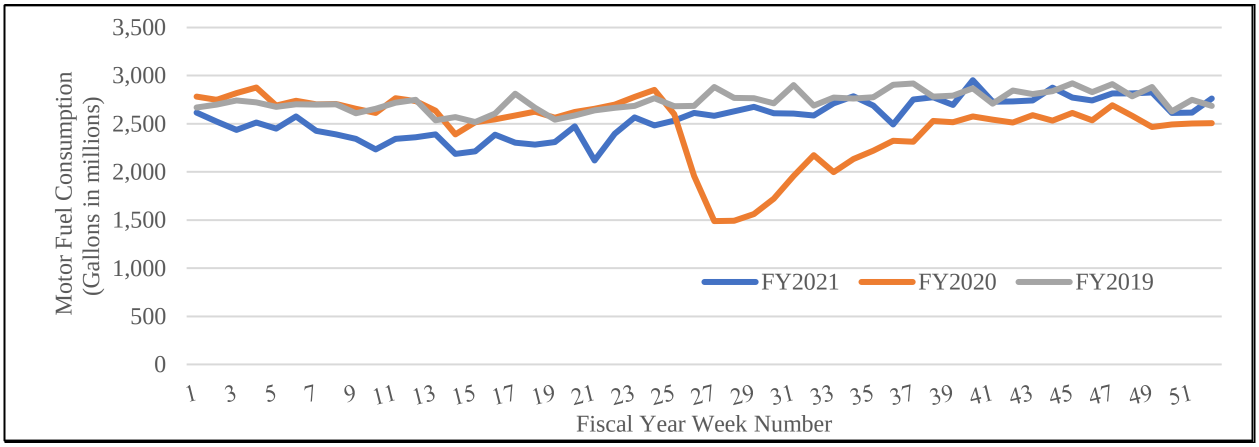

Figure 2. Line graph. Weekly motor fuel consumption, FY 2019–2021.

TRENDS PER CAPITA AND PER GDP

Figure 3 presents per capita motor fuel consumption for Georgia and the U.S. On a per capita basis, motor fuel usage has declined over the 2000–2020 period. Pre-2010, Georgia generally experienced a higher level of per capita usage than the U.S.; however, since roughly 2010, the gap has narrowed and become more consistent with the national average.

Over the 2000–2010 period, per capita motor fuel usage in Georgia declined at an average rate of 1.6 percent annually, while the decline at the national level was at an average rate of 0.9 percent annually. Over the 2010–2020 period, the average annual rate of decline in Georgia equaled 1.1 percent, which was more consistent with the national rate of 0.9 percent. Over the full 2000–2020 period, per capita motor fuel usage declined at an average rate of 1.4 percent in Georgia compared to 0.7 percent nationally.

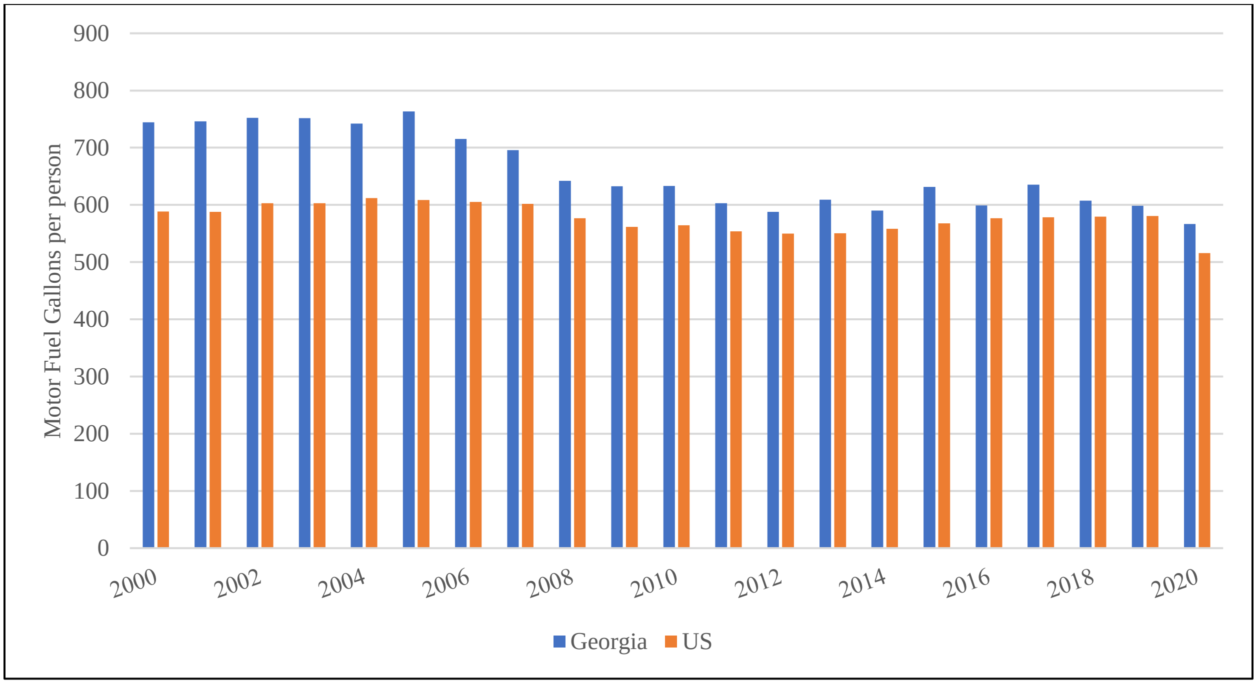

Figure 3. Bar graph. U.S. and Georgia – Total fuel consumption per capita, 2000–2020.

When considered in relation to the economic growth of the state over the past two decades, the trend is even more striking, as shown in figure 4. Over the 2000–2020 period, Georgia experienced an average annual rate of growth in inflation-adjusted (i.e., real) gross domestic product (GDP) equal to 1.6 percent, while the national rate of GDP growth equaled 1.7 percent.[6] During this period, Georgia is found to have a higher level of motor fuel usage per dollar of real GDP than the nation. For instance, in 2000, Georgia used roughly 16,000 gallons of fuel per dollar of real GDP compared to the national average across all states of 13,000. By 2020, these figures in Georgia and the U.S. had fallen to 11,000 and 9,000, respectively. Over the 2000–2020 period, the state and the nation experienced the same rate of decline in this measure at an average 1.6 percent annually.

[6] Real GDP is expressed in chained 2012 dollars from the U.S. Bureau of Economic Analysis (BEA).

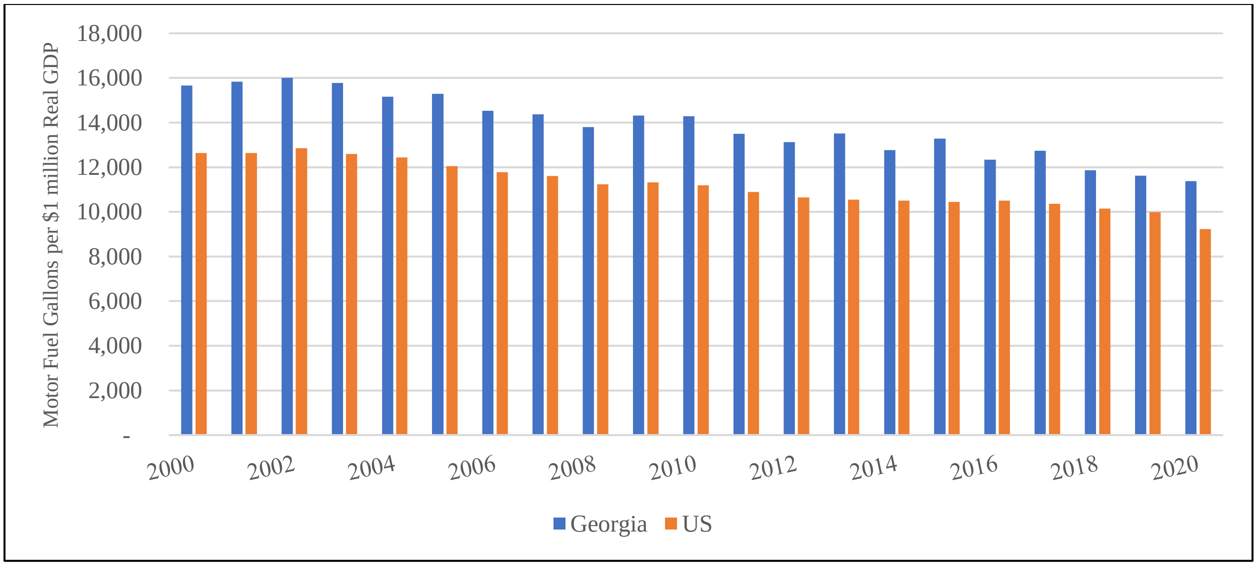

Figure 4. Bar graph. U.S. and Georgia – Total fuel consumption per $1 million of real GDP ($ in 2012).

Thus, although motor fuel usage has grown over time in terms of number of gallons, this rate of growth has not kept pace with the growth in population or state GDP. This trend is the result of the increasing fuel economy of the vehicles in operation in the state, due in part to the adoption of alternative fuel vehicles (see chapter 4) but more so from the increased fuel economy of ICE vehicles in general (see Fuel Economy in chapter 5). Due to advances in technology, this trend will only accelerate in future years.

CHAPTER 4. CURRENT TRENDS IN EV ADOPTION

NATIONAL EV ADOPTION

The market for EVs includes three primary types, as follows:

- Hybrid electric vehicles: For the purposes of this report, HEVs use gasoline to produce electricity that provides propulsion for the vehicle. These vehicles have high MPG ratings but require gasoline for operation. These vehicles include the early Toyota Prius model vehicles or the Toyota Camry Hybrid vehicles.
- Battery electric vehicles: BEVs, on the other hand, are vehicles that operate completely with the use of electricity stored in batteries. The batteries are fueled through an external charging system. Examples of these vehicles include Tesla models and the Nissan Leaf.
- Plug-in hybrid electric vehicles: PHEVs contain both a battery-only propulsion system and an ICE propulsion system. Typically, the vehicle is able to operate for some range via electricity and then converts to gasoline when the batteries are depleted. As in the BEVs, the batteries in a PHEV are recharged via an external charging system.

In the United States, sales of EVs have seen a substantial rise in recent years. Since 2016, EV sales have increased year over year, as shown in figure 5 (Alliance, 2021). In terms of sales levels, the HEV category continues to dominate this market, with HEV sales approximately twice that of BEV sales. On the other hand, BEVs have been experiencing an average annual growth in sales of 36 percent compared to 10 percent of HEVs. The level and annual growth in PHEV sales has remained a small segment of this market. In 2013, PHEV made up 7 percent of all EV sales, rising to a high of 19 percent in 2018 before returning to a share of 8 percent in 2020.

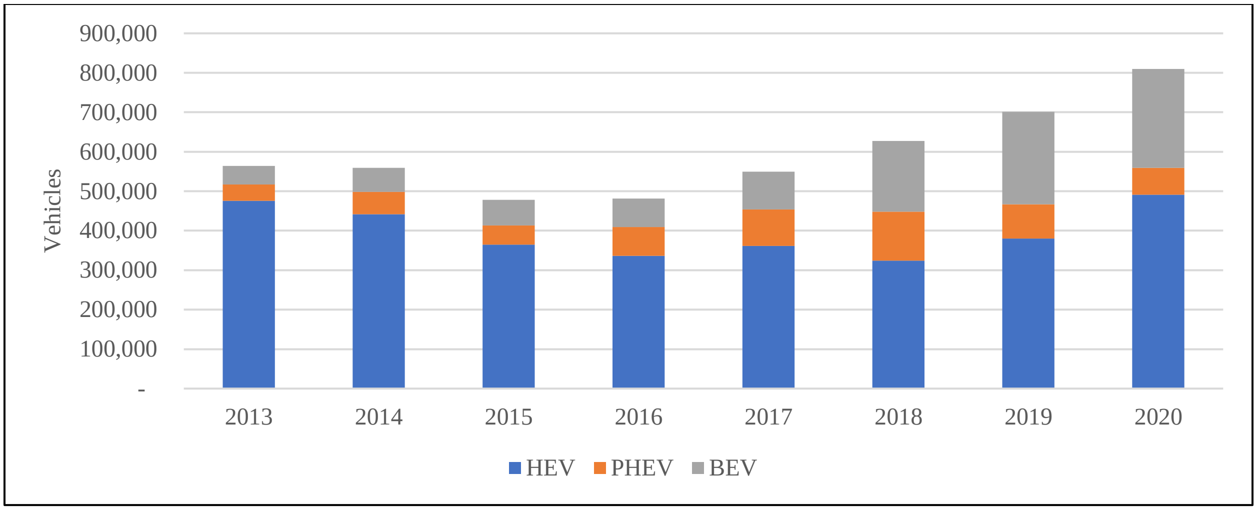

Figure 5. Stacked bar graph. U.S. annual sales of EVs by type, 2013–2020.

As a share of the total new car market, EVs have been increasing, though these vehicles still only constitute a 6 percent share of all new vehicles sold in the U.S. in 2020, as shown in figure 6 (Alliance 2021). Both HEVs and BEVs have experienced an increase in market share since 2017, perhaps due to the introduction of the Tesla 3 model; however, the market share of PHEVs has remained relatively flat.

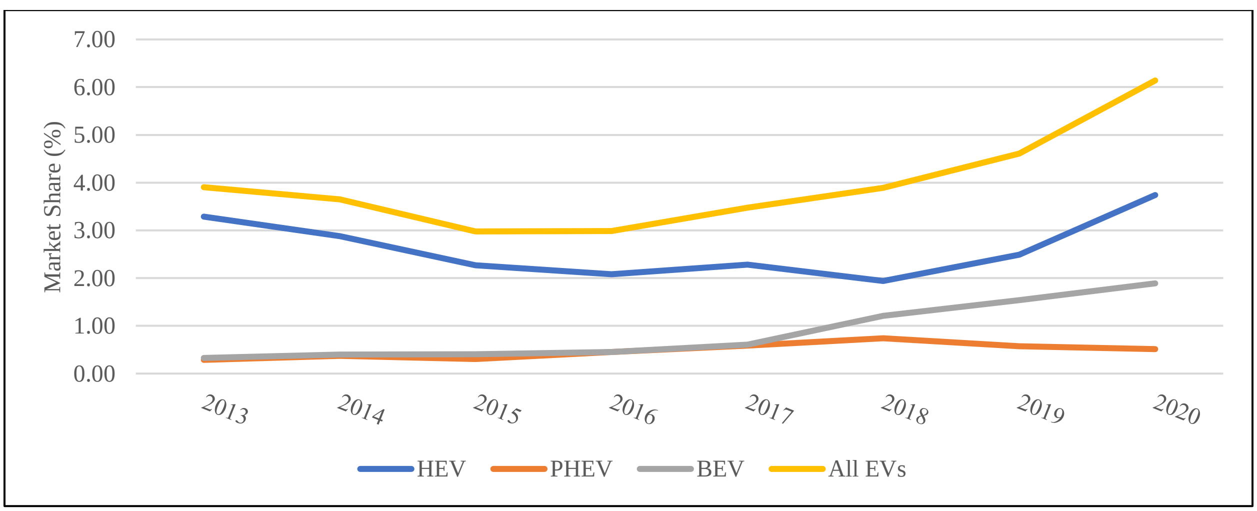

Figure 6. Line graph. U.S. market share of EVs by type, 2013–2020.

Not unexpectedly, California accounted for the largest share of national EV sales at 28.4 percent, or just under 230,000, in 2020 (see table 6 (Alliance 2021)). Florida, New York, and Texas follow with 6.3, 5.5, and 5.0 percent, respectively. Georgia is ranked 17th in terms of the share of EVs sold and makes up almost 2 percent of the total new national EV sales in 2020.

Table 6. Top 10 states and Georgia for new U.S. EV sales, 2020.

Rank	State	Share of Total EVs Registered Nationally (%) (number)
1	California	28.4 (229,867)
2	Florida	6.3 (50,825)
3	New York	5.5 (44,346)
4	Texas	5.0 (40,770)
5	Washington	3.9 (31,791)
6	Illinois	3.6 (29,204)
7	New Jersey	3.4 (27,694)
8	Pennsylvania	3.3 (26,626)
9	Massachusetts	2.7 (21,694)
10	Virginia	2.6 (21,051)
17	Georgia	1.9 (15,644)

In terms of share of all new vehicles registered in 2020, the District of Columbia had the largest market share at 15.8 percent, followed closely by California, as shown in table 7 (Alliance, 2021). Measured as a share of all new vehicles registered in Georgia in 2020, Georgia ranked 38th, with EVs representing 4 percent of all new vehicle sales in 2020.

Table 7. Top 10 states and Georgia for EV market share, 2020.

Rank	State	Market Share of EVs (%)
1	DC	15.84
2	California	15.78
3	Washington	14.67
4	Oregon	12.69
5	Colorado	8.48
6	Hawaii	8.26
7	Vermont	8.19
8	Maryland	8.12
9	Massachusetts	7.97
10	Utah	7.09
38	Georgia	4.00

EV ADOPTION IN GEORGIA

As shown in figure 7 (Alliance, 2021), sales of EVs in Georgia reached their high-water mark for the 2013–2020 period in 2014 and through the second quarter of 2015. A significant drop in sales occurred in the third quarter of 2015, corresponding to the expiration of the $5,000 state tax incentive for the purchase or lease of new BEVs. Since the expiration of the state BEV credit, EV sales and especially BEV sales, showed little growth until the second quarter of 2018, a time generally corresponding to increased production of Tesla models and the introduction of the Tesla 3. Although EV sales have been growing in Georgia in the past several years, the combined EV volume as of 2020 has still not returned to the levels experienced prior to the phaseout of the credit.

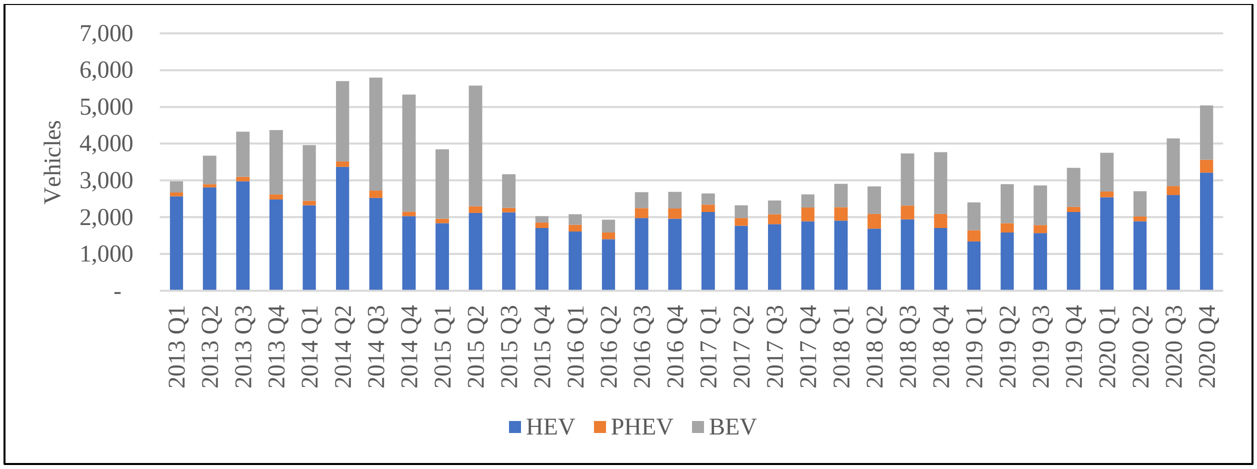

Figure 7. Stacked bar graph. Quarterly sales of EVs by type in Georgia, 2013–2020.

Similar to the national trends, HEV sales in Georgia constitute a larger share of all new car sales than BEVs or PHEVs, but over time the share of BEVs is increasing, as shown in figure 8 (Alliance, 2021).

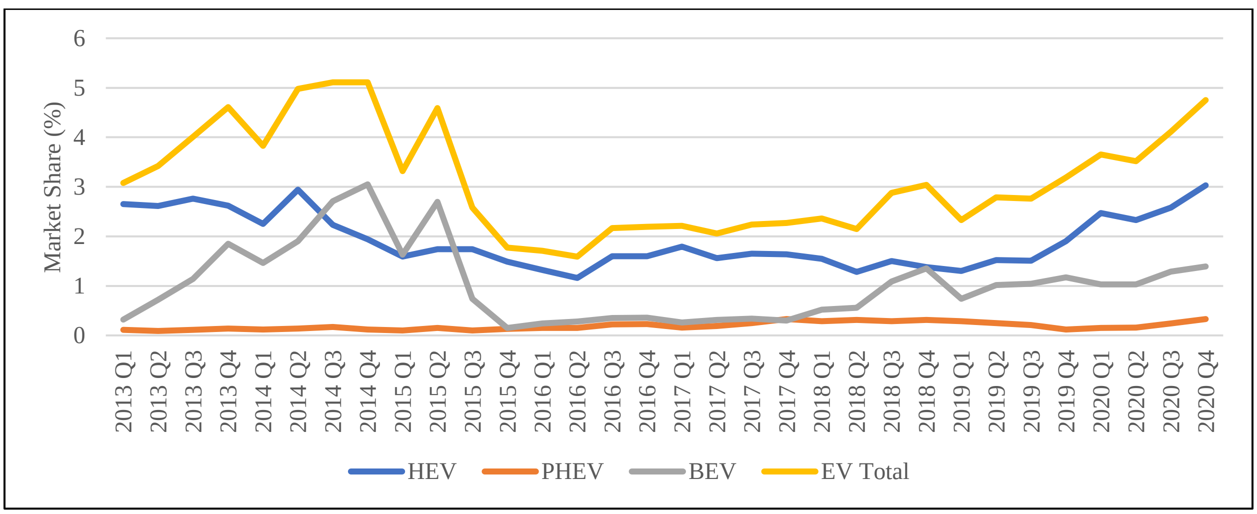

Figure 8. Line graph. Market share of EVs by type in Georgia, 2013–2020.

EV'S ON THE MARKET

According to the 2019 national sales data of BEVs and PHEVs published by Insideevs.com (Loveday, 2018) and shown in table 8, the Tesla Model 3 dominated the market with a significant share at 43 percent. The Toyota Prius Prime followed, making up 7 percent of total BEV and PHEV sales. Combined sales of the top 10 BEV models in the market made up 74 percent of total BEV and PHEV sales, while the top 10 PHEV models only contributed 21 percent.

Table 8. Top 10 BEV/PHEV models by number of BEV/PHEV units sold in 2019 in U.S.

Rank	BEV	Total Sales / Sales as a % of Total	PHEV	Total Sales / Sales as a % of Total
1	Tesla Model 3	158,925 / 48.2	Toyota Prius Prime	23,630 / 7.2
2	Tesla Model X	19,225 / 5.8	Honda Clarity PHEV	10,728 / 3.3
3	Chevrolet Bolt EV	16,418 / 5.0	Ford Fusion Energi	7,524 / 2.3
4	Tesla Model S	14,100 / 4.3	BMW 530e	5,862 / 1.8
5	Nissan LEAF	12,365 / 3.8	Chrysler Pacifica Hybrid	5,723 / 1.7
6	Audi e-tron	5,369 / 1.6	Chevrolet Volt	4,910 / 1.5
7	Volkswagen e-Golf	4,863 / 1.5	Kia Niro PHEV	3,881 / 1.2
8	BMW i3[1]	4,854 / 1.5	Mitsubishi Outlander PHEV	2,810 / 0.9
9	Jaguar I-PACE	2,594 / 0.8	Mercedes–Benz GLC 350e	2,459 / 0.8
10	Hyundai Kona Electric	1,723 / 0.5	Mercedes–Benz C350e	2,172 / 0.7

[1] Total sales figure include the BMW i3 REx version.

All major car companies have announced the launch of several new PHEV and BEV models over the next five years, including significant initiatives by Ford and General Motors. In May 2021, Ford announced a goal of 40 percent of its global sales being all-electric by 2030 (Isidore 2021). In January 2021, General Motors announced a goal that 40 percent of its U.S. models will be battery electric vehicles by the end of 2025 (Chapman 2021). Toyota has expressed similar goals by targeting 40 percent of new vehicles sales as electrified models by 2025 and 70 percent by 2030 (Saldana 2021).

Furthermore, in September 2020, California Governor Gavin Newsom issued an executive order stating that by 2035, all new cars and passenger vehicles sold in California are to be emission-free (Takahashi 2020). Given the number of new vehicle sales in California, this executive order is expected to have repercussions throughout the U.S. market. Similarly, the Biden Administration has issued an executive order stating that half of all new vehicles sold in the U.S. by 2030 will be zero-emission vehicles (Traugott 2021). In response to this order, the three major car manufacturers in the U.S. issued the following statement in support of the initiative: “Today, Ford, GM, and Stellantis announce their shared aspiration to achieve sales of 40–50 percent of annual U.S. volumes of electric vehicles (battery electric, fuel cell, and plug-in hybrid vehicles) by 2030 in order to move the nation closer to a zero-emissions future consistent with Paris climate goals” (Traugott 2021).

As of January 2021, at least 19 BEV models were on the market, and 14 of these were listed with an MSRP below $50,000 (EVAdoption 2021a). As of September 2021, 32 PHEV models were available in the U.S., 13 of which have an MSRP below $50,000 (EVAdoption 2021c). At least 55 additional PHEV and BEV models are slated to enter the U.S. market by the end of 2022 (EVAdoption 2021b).

ELECTRIC VEHICLES IN OPERATION – GEORGIA

The discussion thus far has focused on annual sales of ICE vehicles and EVs. Using data on motor vehicle registrations obtained from IHS Markit Vehicles in Operation database (IHS 2021), we now consider the stock of vehicles in operation in Georgia. Specifically, we analyze the adoption of BEVs, PHEVs, and HEVs in Georgia over the 2012–2020 period. The annual figures represent the number of EVs registered in the state as of January of each year. Thus, these figures include both new vehicles and previously purchased vehicles that are still in operation.

Table 9 shows the share of vehicles in operation by fuel type in Georgia (IHS 2021). The category of ICE vehicles clearly dominates the current stock of vehicles. The category of HEVs represents the largest share of alternative fuel vehicles, consistent with the new vehicle sales data discussed previously. Although this category rose consistently over the 2012–2020 period, it still only represented 1 percent of the total cars in operation in 2020. Between 2012 and 2020, the BEV share rose from 0.01 percent to a high of 0.23 percent in 2016, likely reflecting the expiration of the state electric vehicle credit. The share of BEVs declined in 2017 and 2018 from that peak but rose again in 2019 and 2020. The share of PHEVs has remained a very small component but has risen consistently over the 2012–2020 period. Table 10 provides the distribution of BEVs by county in 2020 (IHS 2021). Unsurprisingly, the majority of these vehicles are registered in the most populous urban counties in the state.

Table 9. Share of vehicles in operation by type, 2012–2020.

Year	ICEs (%)	BEVs (%)	PHEVs (%)	HEVs (%)
2012	99.5	0.01	0.00	0.52
2013	99.4	0.01	0.01	0.63
2014	99.0	0.05	0.04	0.90
2015	98.9	0.16	0.02	0.89
2016	98.8	0.23	0.02	0.96
2017	98.7	0.21	0.03	1.02
2018	98.7	0.15	0.04	1.07
2019	98.6	0.17	0.06	1.12
2020	97.9	0.21	0.07	1.20

Table 10. Top 10 counties by number of BEVs, 2020.

County	Number
Fulton	5,448
Forsyth	2,925
Dekalb	2,655
Cobb	2,194
Gwinnett	1,192
Fayette	506
Cherokee	375
Clarke	214
Oconee	196
Coweta	194

In 2020, Nissan LEAF models made up 35 percent of all BEVs on the road, while various Tesla models made up 54 percent. The PHEV category of vehicles was dominated by the Chevrolet Volt and various BMW models.

CHAPTER 5. CALCULATING MOTOR FUEL RECEIPTS

This chapter focuses on the various factors impacting motor fuel consumption, providing an understanding of the direction of how these different factors work together and in opposition to each other to influence the volume of motor fuel consumed annually. We begin by expressing the general calculation used to compute the number of gallons consumed by a single vehicle in a year and expanding that calculation for all vehicles registered in the state annually.

For a given vehicle, annual fuel consumption is computed as the *miles traveled per year* divided by the *fuel economy of the vehicle*. For jurisdiction, *j*, total annual fuel consumption is the sum of this quotient over all vehicles in the jurisdiction as expressed in equation 1. We calculate motor fuel tax receipts then simply as the product of the annual motor fuel tax rate, *t*, and the number of gallons consumed, as expressed in equation 2. Thus, these two equations identify the four main components of motor fuel receipts, i.e., the motor fuel tax rate, the number of vehicles, miles traveled per vehicle, and the vehicle fuel economy. The model described in equations 1 and 2, while overly simple, serves as a starting point for understanding the factors influencing motor fuel receipts.

$$\text{Motor Fuel Gallons} = \sum_{j,t=0}^{j} \text{VMT}\left(\frac{1}{MPG}\right) \tag{1}$$

$$\text{Motor Fuel Receipts} = t \times \text{Motor Fuel Gallons} \tag{2}$$

Each of these four components displays distinct trends over time, and each has unique impacts on total motor fuel receipts in any given year. Some factors, such as growth in population, lead to increases in motor fuel usage, while others, such as increases in fuel economy, lead to reductions in gallons used. But increases in fuel economy of vehicles may be somewhat offset by adoption of larger or heavier vehicles or by increases in miles driven. The general anticipated effect for each component overall is presented in table 11. These components are each explored in more detail below to provide insight into current and future trends of these factors and their relative impact on motor fuel receipts.

Table 11. Factors affecting motor fuel receipts.

Determinant of Motor Fuel Receipts	Direction of Effect on Motor Fuel Receipts
Number of vehicles	Increases in the number of ICE vehicles registered in the state <u>increase the motor fuel receipts</u> by increasing the amount of motor fuel used
Vehicle miles traveled per vehicle	Increases in VMT per vehicle increase the amount of fuel used resulting in an <u>increase in tax receipts</u>
Fuel economy	Increases in fuel economy of vehicles result in a reduction in motor fuel usage per mile traveled and a <u>reduction in motor fuel receipts</u>
Tax rate	Increases in the tax rate <u>increase motor fuel receipts</u>

NUMBER OF REGISTERED VEHICLES

The first determinant of motor fuel receipts is the number of registered vehicles in the state. The number of registered vehicles is strongly correlated with state population, and specifically the population between ages 18 and 85. Increases in population and motor vehicle registrations have an unequivocal positive effect on motor fuel consumption and, thus, on motor fuel receipts.

Georgia has seen an average annual growth in population of 1.4 percent for the 2000 to 2019 period, according to data from the U.S. Bureau of the Census (Governor's Office of Planning and Budget [OPB] 2020). Furthermore, the state's population is expected to increase at an annual rate of 0.9 percent for the period from 2020 to 2050, as projected by the Georgia Governor's OPB. Over the 2000–2019 period, FHWA data show that vehicle registrations in Georgia grew at an average annual rate of 0.9 percent, which is less than the population growth (FHWA n.d.-b). Thus, it is likely that vehicle registrations will increase in the 2020–2050 period but at a slower rate than population.

VEHICLE MILES TRAVELED

Holding all other factors constant, an increase in miles traveled has a positive effect on fuel consumption. The National Household Travel Survey (NHTS) data from 2017 provide an *average vehicle miles traveled per vehicle* based on the responses of survey participants. From those responses, vehicle miles traveled for the U.S. was on average 11,130 miles. Respondents from Georgia reported an average vehicle miles traveled of 11,940 miles, which was 7 percent higher than the national average.

Similar to the per vehicle measure is vehicle miles traveled as defined by the Federal Highway Administration. This measure is defined as the total miles traveled by all vehicles over a given distance. *Vehicle miles traveled per capita* as defined by the FHWA is equal to the total annual miles of vehicle travel divided by the total state population (U.S. Department of Transportation [USDOT] 2015). Using the state VMT figure for Georgia for 2017 of 124,733 million miles and dividing by the state population in 2017 of 10,410,330 yields a VMT per capita figure of 11,982, which is consistent with the estimate produced by the NHTS data for a per capita measure of vehicle miles traveled.[7]

On a per capita basis, VMT declined between 2010 and 2014 but has risen since that time, as shown in figure 9 (FHWA n.d.-c). Over the 2010–2019 period, this measure grew 1.0 percent annually, while over the 2000–2019 period, this measure fell 0.09 percent annually.

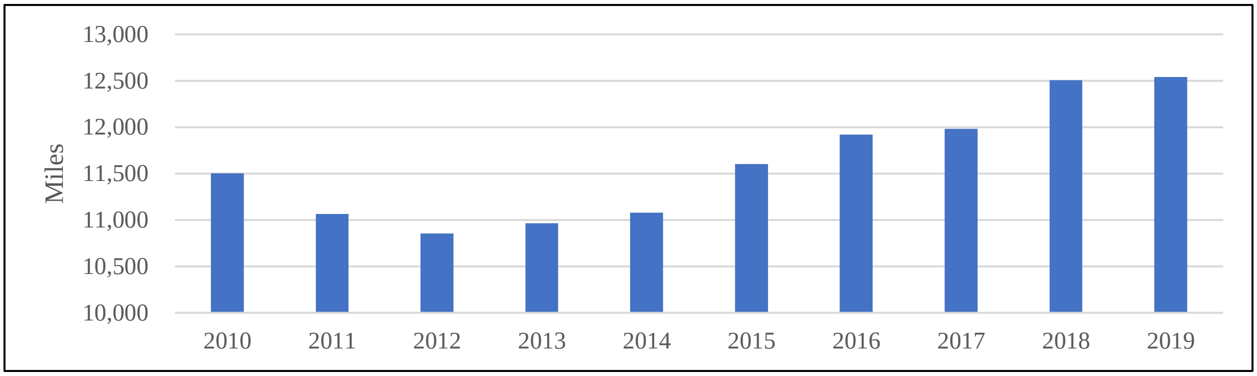

Figure 9. Bar graph. Annual Georgia vehicle miles traveled per capita, 2010–2019.

Over the 2010–2019 period, total VMT grew at an annual rate of 2.0 percent, stronger than the national rate of 1.1 percent for the same period, as shown in figure 10 (FHWA n.d.-c). Given that on a per capita basis VMT showed significantly less growth, the growth in total VMT is due largely to the increase in the number of vehicles traveling, as opposed to the number of miles traveled per vehicle.

[7] VMT for Georgia for 2017 is from the FHWA Table VM-2 for 2017 from the 2017 edition of the Highway Statistics (FHWA 2017). Georgia state population is from Table 1. Annual Estimates of the Resident Population, Population Estimates (as of July 1) (U.S. Census Bureau 2020).

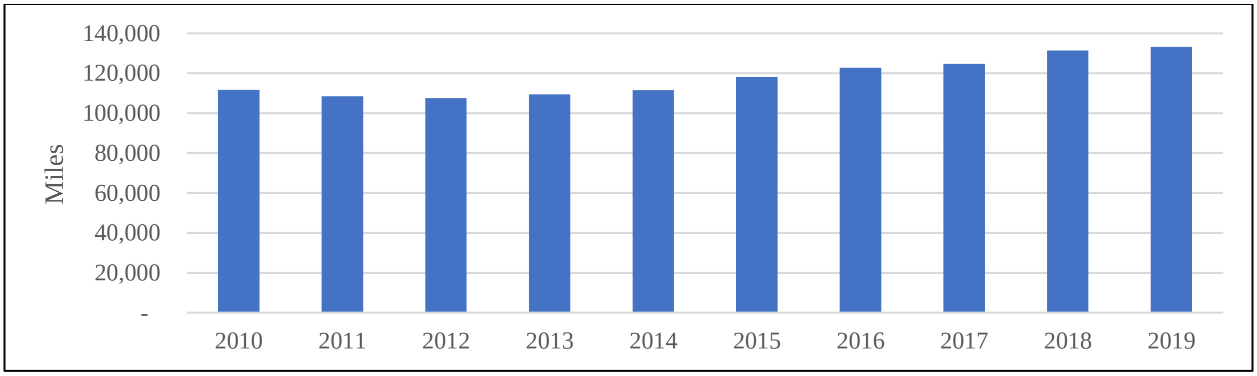

Figure 10. Bar graph. Annual Georgia VMT, 2010–2019.

FUEL ECONOMY

The third determinant in the motor fuel calculation is the fuel economy of vehicles in operation during the year as captured by the average annual MPG of the vehicle stock. Over time, with improvements in technology and due to higher federal mileage standards, the fuel economy of the vehicles on the road has improved. As an example, a 2000 Ford F-150 had a combined fuel economy ranging between 13 and 16 MPG, while a 2021 Ford F-150 has an MPG between 19 and 25.[8] A 2000 Toyota Corolla had an MPG rating between 26 and 30, while a 2021 has a rating between 31 and 35. The 2021 Corolla Hybrid model has an MPG rating of 52 (U.S. Environmental Protection Agency [USEPA] 2021b). Figure 11 shows the average MPG of all light-duty vehicles registered in the U.S. for the period 2000–2019 (BTS 2021a). Since 2000, the MPG has clearly risen from an average of 20 MPG in 2000 to a high of 22.5 in 2018 before declining slightly to 22.2 in 2019.

[8] Based on MPG for gasoline consumption. The MPG for 2021 models using E85 fuel is lower.

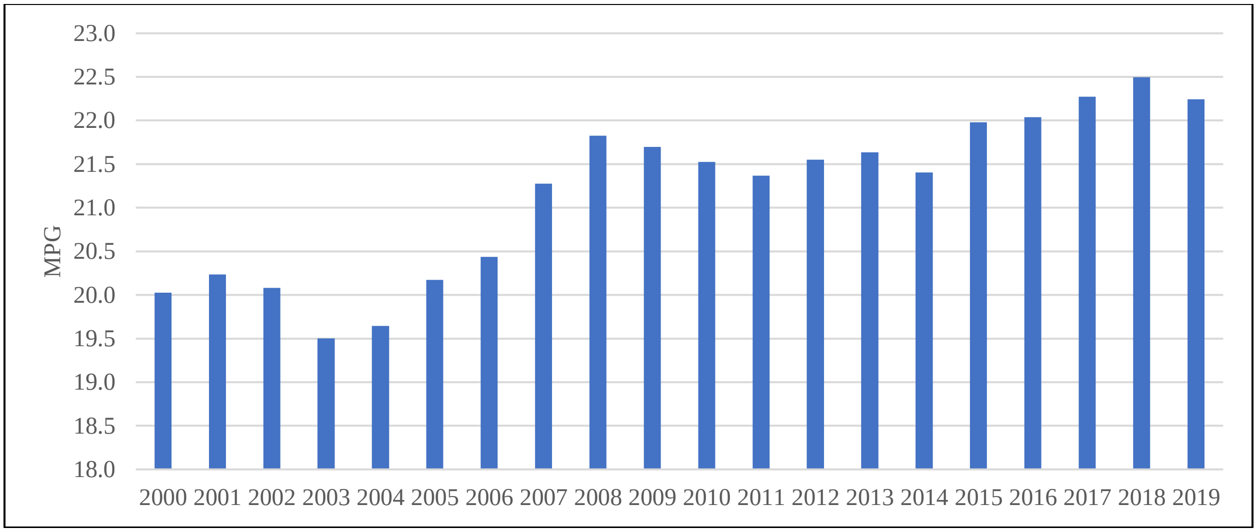

Figure 11. Bar graph. Average U.S. light-duty vehicle fuel efficiency, 2000–2019.

Corporate average fuel economy (CAFE) standards regulate the mileage standards for auto manufacturers selling vehicles in the U.S. Based on sales of vehicles from a manufacturer's fleet, the average fuel economy is required to meet a given minimum standard expressed in MPG. These standards were originally enacted for model year 1978 for passenger vehicles and for model year 1979 for light trucks. The standards for passenger cars remained unchanged between 1985 and 2011 at 27.5 MPG. Standards for light trucks remained unchanged at 20.7 MPG between 1996 and 2005. Congressional legislation and executive action in the first decade of 2000 put policies in place that increased the standards for both cars and light trucks to 35 MPG by 2020.

By 2008, the U.S. Environmental Protection Agency was granted authority by means of the Clean Air Act to regulate fuel standards due to their impact on air quality. In addition, the Clean Air Act provides special authority for the state of California to impose higher fuel economy standards. In 2009, a deal was negotiated between the auto manufacturers, the state of California, and the Obama Administration to develop the National Program, which set fuel economy standards applicable to all states for model years 2017–2025. Under these standards, auto manufacturers agreed to increase fuel standards to 49.7 MPG by 2025, up from 35.4 MPG in 2017.

These standards were subject to a mid-term evaluation by the Obama Administration's USEPA in 2016 and were found to be acceptable and achievable. Under the Trump Administration, however, the previous evaluation of the standards was reexamined, and the standards were deemed to be "too stringent." As a result, the Trump Administration relaxed the Obama Administration standards, resulting in lower fuel economy requirements for future vehicles. The new standards were specified in the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks. In addition, the new rule sought to remove the special exception for California.

Various local governments and environmental groups issued challenges to the relaxed standards and, as a result of these challenges, the future trajectory of the CAFE standards remains in flux. To address the uncertainty, President Biden signed an executive order on August 5, 2021, that sets new fuel standard goals. Under the order, at least 50 percent of all new passenger vehicles sold in 2030 are to be zero-emission vehicles. Furthermore, the order directs the appropriate federal agencies to establish new emissions standards for light- and medium-duty vehicles beginning with model year 2027 and including at least model year 2030, and for heavy-duty pickup trucks and vans beginning with model year 2028 and including at least model year 2030.[9]

[9] Executive Order on Strengthening American Leadership in Clean Cars and Trucks. August 5, 2021. https://www.whitehouse.CAFE/briefing-room/presidential-actions/2021/08/05/executive-order-on-strengthening-american-leadership-in-clean-cars-and-trucks/.

Another trend affecting the fleet MPG, is the choice of vehicle. Over the 2000–2019 period, consumers have expressed a clear preference for larger sport-utility vehicles (SUVs) and trucks over sedan vehicles in both Georgia and the U.S. For instance, sedans accounted for 57 percent of all vehicle registrations in Georgia in 2000, but by 2019 they accounted for only 42 percent, as shown in figure 12 (FHWA n.d.-b). For the nation, the decline has been more substantial, falling from 61 percent in 2000 to 41 percent in 2019. A synonymous trend is one toward heavier and more powerful vehicles. Based on data from USEPA, vehicle weight has increased on average 0.4 percent annually between 2000 and 2020, and vehicle horsepower has increased 1.6 percent (USEPA 2021a).

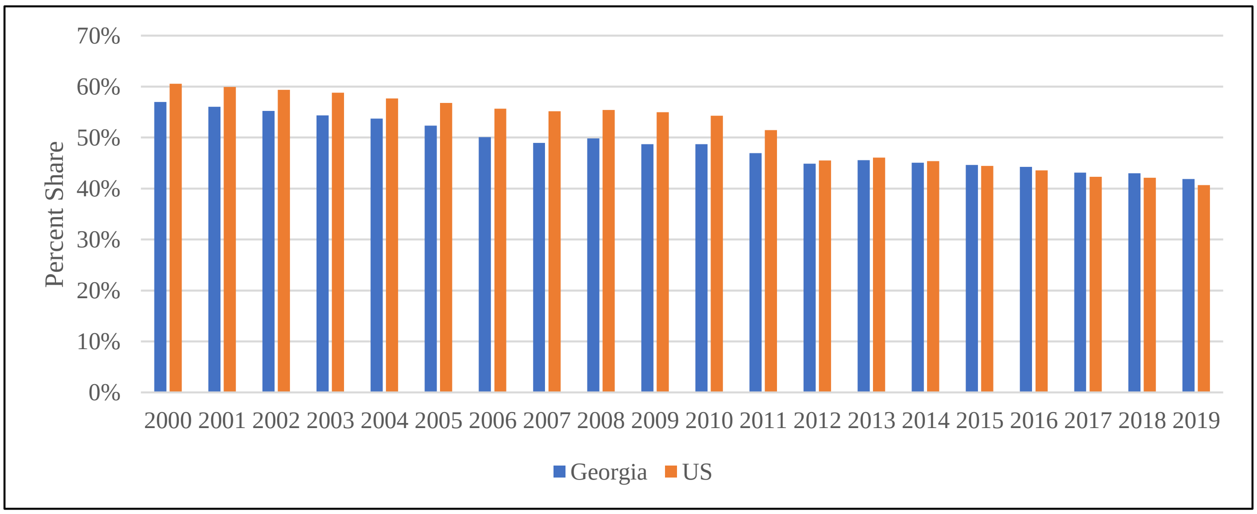

Figure 12. Bar graph. Cars as a percent of total number of registered vehicles, 2000–2019.

MOTOR FUEL TAX RATE CALCULATION

The final component in the motor fuel receipts calculation is the tax rate. The state levies a separate rate for diesel fuel and non-diesel fuel, including gasoline, ethanol, aviation fuel, and compressed natural gas, as discussed in chapter 2. In general, increases in the tax rate will lead to increases in motor fuel revenue in the immediate future. Over time, however, increases in the tax rate serve to increase the cost of vehicle operation. In the longer run, this increase will encourage vehicle owners to drive less and adopt more fuel-efficient vehicles as the cost of travel increases. This will serve to offset some of the revenue gains expected from a higher tax rate.

As discussed above, by state policy, the motor fuel tax rate is indexed for changes in inflation and adjusted annually for increases in the fuel economy of new vehicles sold. Since 2016, the tax rate for motor fuels has increased about 2 percent annually as a result of these adjustments. Between 2016 and 2020, the indexing factor for the MPG has actually fallen by 0.1 percent annually as consumers chose less fuel-efficient vehicles. The CPI factor has grown on average 1.9 percent. Thus, the motor fuel tax rate has been increasing over time solely as a result of the CPI factor.

CHAPTER 6. ANALYSIS OF MOTOR FUEL USAGE

The above discussion of factors influencing motor fuels consumption reveals several offsetting trends in the major components of the motor fuel usage identity. Increases have occurred in miles traveled per vehicle and the number of vehicles, while reductions have continued in the amount of fuel used per vehicle. Before turning to the forecast of motor fuel receipts, we explore the relationship between vehicle miles traveled and fuel economy, and their effect on motor fuel usage. The models presented in this chapter do not focus on forecasting future usage or receipts but on understanding the direction and impact of the various factors on motor fuel usage. An important caveat of the results presented in this chapter is that they are limited to light-duty vehicles only and cannot be used to draw conclusions applicable to fuel usage, VMT, or MPG of medium- or heavy-duty vehicles.

THE MOTOR FUEL IDENTITY

Analysis of historic data of motor fuel usage in Georgia shows important differences in the impact of VMT relative to MPG. To determine the relative size and importance of the individual determinants, we regress MPG and VMT[10] on total gallons of motor fuels used annually in the state over the 2012–2019 period. Because the number of years in the analysis is limited to eight, we run the regression by county to increase the number of observations over the time period. Thus, the results should be interpreted as the average county effect for counties in Georgia. To smooth the data and for ease of interpretation of the regression coefficients, we convert all values to natural logs.

[10] Due to data constraints, we use VMT defined as total vehicle miles traveled instead of the per capita measure of vehicle miles traveled.

The data used to estimate the relationship are obtained from several sources. The data on total gallons used by county are from the Georgia Department of Revenue. As part of the Prepaid Local tax, DOR collects monthly data on total gallons of fuel used by county and fuel type by month. This monthly information by fuel type is consistent with the statewide total amounts by fuel type for Georgia available from the FHWA Monthly Motor Fuel Reported by States (FHWA n.d.-a). The monthly fuel amounts are summed to generate an annual total fuel amount by county. The information on VMT is from the Georgia Department of Transportation Office of Transportation Data and represents the total vehicle miles traveled in a county in a year. Although this is not a perfect measure of VMT, as studies have found this measure to be less reliable in rural areas, it is consistently measured over time. The MPG variable used in the regression model is a weighted average of the MPG of the vehicle stock registered in each county each year for years 2012–2019. It was constructed by the project research team by matching the MPG information by vehicle make and model available from FuelEconomy.gov to the make and model of each vehicle registered in the counties in the state over this time period using the Vehicles in Operation database obtained from IHS Markit. Because the information on MPG available from FuelEconomy.gov applies only to light-duty vehicles, the regression results do not include medium- and heavy-duty vehicles. Additionally, we restrict the analysis to gallons of gasoline only.[11]

The results of the regression analysis are shown in table 12. Columns 1 through 3 represent alternative approaches to modeling the relationship as it relates to gasoline consumption in the urban and rural counties. Each of the three models is run as an ordinary least squares (OLS)

[11] Because the analysis presented in this section does not include medium- and heavy-duty vehicles which disproportionately use diesel fuel, we restrict the data to include motor fuel classified as gasoline and not other fuel classified as special fuels.

model. The column 2 results are limited to urban counties, while the column 3 results are limited to rural counties. The column 4 results are based on gasoline consumption in all counties with the rural variable equal to 1 for rural counties.

Table 12. Total gasoline used by county, 2012–2019.

VARIABLES	Urban[1]	Rural	All Counties
LnVMT	1.096***	1.288***	1.197***
	(0.0222)	*(0.0353)*	*(0.0200)*
LnMPG	−1.647***	−6.364***	−3.899***
	(0.470)	*(0.774)*	*(0.428)*
Rural			−0.379***
			(0.0375)
Constant	6.627***	17.64***	11.92***
	(1.209)	*(2.208)*	*(1.144)*
Observations	648	624	1,272
R^2	0.866	0.683	0.892

[1]Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

The three models yield similar results in terms of the direction of the effect on gasoline consumption but differ in the magnitude of the effects. Overall, the models perform well, and the variables are found to have an impact on gasoline consumption at the county level that is significantly different from zero. The results for urban counties in column 2 and all counties in column 4 are found to explain a larger amount of the county variation compared to the results for rural counties in column 3. This is likely due to the fact that VMT, as reported, is a weaker proxy for VMT in rural areas compared to urban areas. The estimated values in column 4 lie between those in columns 2 and 3. For simplicity, we focus on the results in column 4 for the remainder of this discussion.

As anticipated, VMT is shown to have a positive and statistically significant effect on total gallons of gasoline used, while MPG is found to have a negative and statistically significant effect. Furthermore, the results indicate that rural counties have lower motor fuel consumption after controlling for the MPG of the vehicle stock and total VMT per county. This is evidenced by the negative coefficient on the rural variable in column 4. Most importantly for our purposes, the results reveal that the negative effect of increased MPG is over three times the effect of increases in VMT. This indicates that increases in the MPG have a much greater effect than increases in VMT on the volume of motor fuel used in a county. Thus, MPG is found to be the more powerful factor of the two in determining motor fuel usage.

Because the estimated coefficients in table 12 are expressed in logs, they can be interpreted as percent changes. For instance, the regression analysis indicates that a 1 percent change in the value of county VMT results in a 1.2 percent increase in total gallons of fuel consumed, while a 1 percent increase in vehicle MPG results in a 3.9 percent reduction in gallons used. To put this in context, average VMT in 2019 across all counties equaled 2.3 million miles, and a 1 percent increase is approximately 23,000 miles per county. Thus, for every additional 23,000 miles traveled per county, the average number of gallons used per county increases by 1.2 percent or 527,000 gallons. Similarly, average MPG for the stock of vehicles in operation per county in 2019 equaled 20.5. A 1 percent increase results in an average MPG of 20.71, which would reduce gallons used by 3.9 percent or 1,712,644 gallons.

DETERMINANTS OF MPG

The models above are useful in understanding the relative importance of changes in VMT and MPG on motor fuel usage. As constructed though, they do not offer any insight into the factors that influence VMT or MPG in a county. Specifically, these models do not address the effects of increased adoption of EVs or heavier vehicles or increases in population. To gain a better understanding of the relative importance of these factors, table 13 provides the results of the regression analysis for county level of MPG and the following section on Determinants of VMT provides the results for a similar analysis of VMT. The data for these models are the same as for the overall gasoline consumption model but also incorporate data from various U.S. government sources, such as the Bureau of Labor Statistics and the Census Bureau.

Table 13. MPG by county, 2012–2019.

VARIABLES	Urban[1]	Rural	All Counties
Ln(Average Vehicle Age)	−0.102***	−0.0448***	−0.0890***
	(0.00674)	*(0.00922)*	*(0.00521)*
Ln(Share of Trucks)	−0.173***	−0.169***	−0.183***
	(0.00486)	*(0.00648)*	*(0.00370)*
Ln(Share of EVs and Hybrids)	0.0233***	0.0159***	0.0211***
	(0.00109)	*(0.00100)*	*(0.000793)*
Year	0.00552***	0.00769***	
	(0.000395)	*(0.000488)*	
Rural			−0.00467***
			(0.000750)
Constant	−7.827***	−12.41***	3.249***
	(0.813)	*(1.006)*	*(0.0135)*
Observations	648	624	1,272
R^2	0.947	0.875	0.889
OLS/Fixed Effects	OLS	OLS	Fixed Effects

[1]Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 13 provides the results of the OLS regression used to explain the variation in MPG over time. Columns 2 and 3 present the results when the model is run separately for urban and rural counties, respectively. The fourth column provides the results of a fixed effects model when all counties are included in the model and a categorical variable is included to indicate rural counties. The results of column 4 control for unobservable characteristics across counties and time.

All three models perform very well, as evidenced by the high R^2 values. Furthermore, all variables are found to be highly statistically significant. All three models provide roughly similar results in terms of size and the anticipated effects of the independent variables. Across the models, as the average age of vehicles in the county increases, MPG declines, reflecting the fact that older vehicles are less fuel efficient compared to newer models.[12] Similarly, as the share of trucks increases in a county, the county MPG declines because trucks, including SUVs, typically have lower fuel economy ratings than sedans. The results also indicate that the average MPG of the county increases with the share of EVs and hybrids, as expected. Lastly, the coefficient on variable *Year* provides evidence that the average MPG in a county is increasing over time. Of particular interest is the relatively small effect of the share of EVs and hybrids on the county MPG compared to that from the share of trucks.

Using the results from column 4, a 1 percent increase in the average age of the vehicle stock in the county decreases MPG by about 9 percent, and a 1 percent increase in the share of trucks in a county decreases MPG by about 18 percent. Conversely, a 1 percent increase in the share of EVs and hybrids in a county increases MPG by 2 percent. Thus, the current trend by consumers of purchasing larger SUVs and trucks has a greater impact on MPG and ultimately on fuel consumption than the negative impact of EV and hybrid adoption.

DETERMINANTS OF VMT

Table 14 presents the results for the VMT model. Similar to the gasoline consumption model and the MPG model, the VMT model includes annual values for VMT at each county level for the years 2012–2019. The variables used to explain county VMT are based on our review of the

[12] The average vehicle age is measured such that new vehicles have an age of 0.

academic literature and from other models used by states to forecast VMT. For example, the Bureau of Transportation Statistics (BTS) developed the Local Area Transportation Characteristics for Households (LATCH) model, which estimates vehicle miles traveled at the state level using data from the American Community Survey (ACS) (BTS 2021b). This model includes independent variables for household income, number of available vehicles, number of workers in the household, and the age composition of household members. The Volpe National Transportation Systems Center has developed both a short- and long-run forecasting model for light-duty vehicle VMT (Pickrell, Pace, and Wishart 2020). Variables included in the Volpe long-run model include personal income, personal income squared, and fuel cost per mile. Variables included in the short-run model include personal income, one- and two-year lag of personal income, personal income squared, and a measure of consumer sentiment.

Because the goal of our analysis is to understand the underlying determinants of VMT, we mimic, to the extent possible, the variables used in the LATCH model. The Volpe model contains some of the same variables, but the Volpe model is more focused on forecasting and not on explaining the underlying factors. Thus, the model presented in table 14 relies heavily on demographic variables to explain the variation in VMT over time at the county level.

In general, the three alternative model specifications shown in table 14 provide generally similar results. The urban county model in column 2 is more successful at explaining the variation in VMT between counties than the rural model in column 3. This likely reflects the fact that the VMT measure used is an imperfect proxy for VMT in the rural areas.

As found in other studies, VMT increases as population increases when the data are restricted to include only urban counties (column 2). The coefficient on population for the rural model (column 3) is negative but not significantly different from zero. Furthermore, all three models provide generally consistent results for the effects of unemployment, the various demographic variables, and the average number of vehicles per household.[13] Lastly, the models also indicate that, controlling for other factors, VMT is lower in rural areas than in urban areas.

Table 14. VMT by county, 2012–2019.

VARIABLES	Urban[1]	Rural	All Counties
Ln(Population)	0.731***	−0.0740	0.313***
	(0.136)	*(0.118)*	*(0.0867)*
Ln(Unemployment Rate)	−0.263***	−0.176***	0.00972
	(0.0365)	*(0.0454)*	*(0.0693)*
Ln(Households with children under 18)	0.210**	0.244***	0.240***
	(0.0925)	*(0.0778)*	*(0.0600)*
Ln(Share of Population aged 65 and older)	−0.0632	0.654***	0.353***
	(0.0689)	*(0.0602)*	*(0.0451)*
Ln(Average number of vehicles)	−0.693***	−1.219***	−0.733***
	(0.133)	*(0.208)*	*(0.132)*
Rural			−0.0802***
			(0.0288)
Constant	6.082***	8.099***	6.228***
	(0.354)	*(0.394)*	*(0.308)*
Observations	648	624	1,272
R^2	0.915	0.670	0.908
OLS/Fixed Effects	OLS	OLS	Fixed Effects

[1]Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

These results allow us to further our understanding of the direction of the effects of these factors on motor fuel consumption in counties and on MPG and VMT. More importantly for our

[13] In an alternative specification, we include the log of the average price of gasoline in each county. The results are mostly consistent with those presented here with the exception that *Ln(Population)* is no longer significant. On the other hand, the log of the price variable is found to be positive and significant. This result is likely an indication that gasoline prices are higher in areas with greater demand for fuel instead of indicating that increases in gas prices causes an increase in VMT.

purposes, we gain insight into the relative importance of these different factors relative to each other.

These results provide evidence that the dominant factor in fuel consumption is the trend in MPG of ICE vehicles. The results indicate that positive gains to motor fuel consumption through increases in VMT are more than offset by the increases in fuel efficiency of the vehicles in operation. Furthermore, we see that while increased adoption of EVs and hybrids reduces MPG, this effect is offset by the increased fuel consumption resulting from the increased adoption of trucks and SUVs.

CHAPTER 7. MOTOR FUEL TAX RATE FORECAST

Because the motor fuel tax rates are not constant but are adjusted annually to reflect changes in the fuel economy of the vehicles sold each year and for changes in inflation, the tax rate is also a forecasted variable. The rate is indexed annually for changes in the fuel economy of new vehicles. Under current law, the state motor fuel tax is indexed to changes in inflation through 2025. For years after 2025, the rate is not adjusted for changes in inflation but continues to be indexed for changes in the fuel economy of new vehicles.

INDEX FOR INFLATION

To construct the tax rate forecast for gasoline and special fuels, we use the forecast of Consumer Price Index for All Urban Consumers (CPI-U) from the Congressional Budget Office (CBO 2021). According to Georgia law, this adjustment factor is applied annually through July 2025 and is forecast to decline approximately 0.6 percent per year over this period. The CBO forecast incorporates the higher rate of inflation in the economy currently but also assumes that this rate of inflation will decline annually over the 2022–2025 period. Thus, the CPI index factor is forecast to decline annually over the 2022–2025 period.

INDEX FOR CHANGES IN MPG

To forecast the annual change in MPG, we rely on the forecast of the MPG of new vehicles for each year through 2050 produced by the AEO for 2021 (AEO 2021). Based on this forecast, new conventional ICE vehicles in 2022 are anticipated to have an average MPG of 30.3 in 2022 and 30.8 in 2050. Thus, over the 2022–2050 period, the MPG index factor is forecast to increase 0.1 percent annually.

However, the story is more nuanced than that presented above. Based on the AEO forecast, the MPG of new vehicles does not rise consistently over time. As discussed earlier, the AEO projections incorporate the current CAFE standards, but these standards are only set in place for a limited number of years. For instance, the current standards are scheduled to remain in effect through model year 2026. In the absence of new standards, the AEO projections assume the existing standards remain in place over the entire time horizon of the forecast period. Thus, the AEO projections forecast increasing new vehicle MPG through 2032, reflecting the significant lag time between vehicle design and production and response to changes in the CAFE standards. Over the 2022–2032 period, the average annual MPG for conventional vehicles is projected to increase on average 0.4 percent. For years 2033 through 2050, MPG is forecast to decline slightly on an annual basis by 0.2 percent.

FORECAST OF MOTOR FUEL TAX RATE

Combining these factors provides a forecasted motor fuel tax rate of 29.8 cents per gallon in 2022 for gasoline and 33.4 cents per gallon for diesel. By 2050 these rates are forecast to rise to 32.2 cents per gallon for gasoline and 36.5 cents per gallon for diesel (see figure 13). While the 2050 motor fuel rates are higher than the 2022 rates, they are lower than their forecasted peak reached in 2026. This is a result of the elimination of the CPI index factor in the annual motor fuel index formula per state law. In addition, this reflects the slight decline in the average annual MPG for conventional vehicles incorporated into the AEO projections. If future fuel economy standards are at least equal to those currently in place, this decline will not occur.

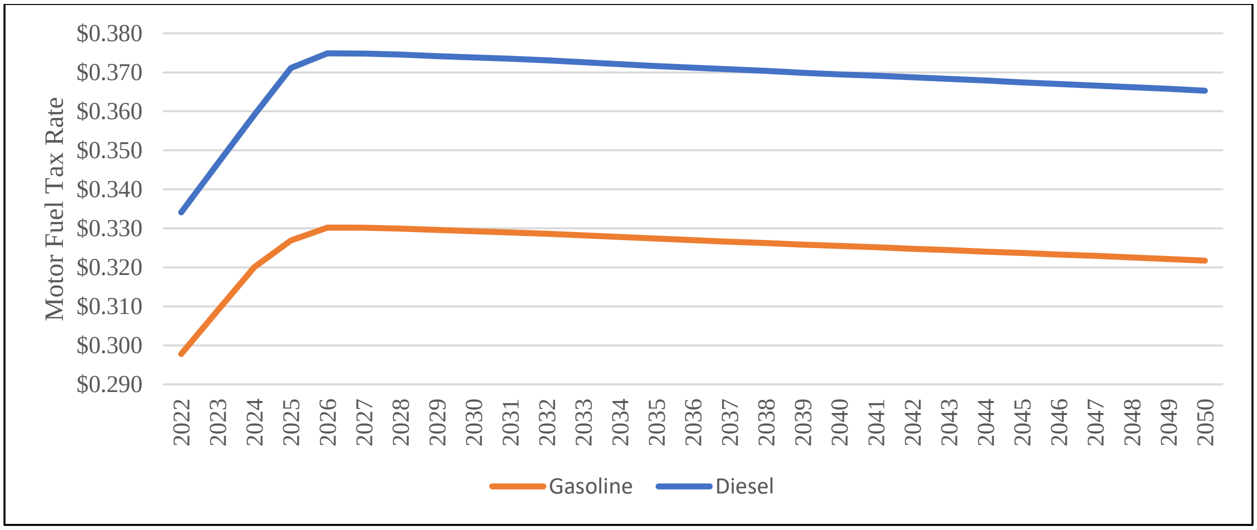

Figure 13. Line graph. Motor fuel tax rate forecast.

CHAPTER 8. MOTOR FUEL FORECAST MODEL #1 – ECONOMETRIC MODEL

To forecast the motor fuel receipts for future years, we begin by forecasting motor fuel usage and then apply a tax rate to the base of forecasted gallons. As part of our research, we reviewed the forecasting procedures of several states, including Washington State, California, Virginia, and Indiana. Most of these models employ some type of statistical modeling approach, such as regression analysis or an autoregressive integrated moving average (ARIMA) model. In general, the models forecast fuel receipts based on the historical relationship between population or state economic activity, such as GDP.

These models are designed to focus on a short-run time period in which demographic factors and changes in technology are not likely to have a large impact. Thus, these models do not explicitly model these factors because over the short run they are considered fixed.

A North Dakota report provides results of an extensive review of state procedures and estimation techniques used to forecast state motor fuel receipts (Berwick and Malchose 2012). That research surveys a number of states to ascertain each's method for forecasting motor fuel receipts and its accuracy. The survey results indicate that states used a variety of methods to forecast receipts, including linear regression, simple trends, and ARIMA. Furthermore, states also included a variety of variables in their models, such as fuel prices, state GDP, and unemployment. Based on the results of this research, North Dakota developed a pure ARIMA model with no additional independent variables.

More recently, South Carolina used an econometric model to separately forecast gasoline and diesel fuels consumption during the COVID pandemic (Dunbar and Martin 2020). The model is specified as an OLS model, and all variables are expressed in logarithmic form. The model for gasoline includes price of fuel per gallon and disposable income, with the quadratic forms of these variables also included. The model for diesel fuel includes state GDP and employment in the trade, transportation, and utilities industries in the state. Recent results of the model performance were favorable. The model performed well during the pandemic months with an R^2 statistic for the gasoline model equal to 95 percent and an R^2 statistic for the diesel model equal to 98 percent.

The Oregon motor fuel forecast model includes fuel prices, a measure of fuel economy of the fleet, total state employment, state personal income and population, and a measure of consumer sentiment (Oregon DOT 2015). This model is found to perform well and is similar in construction to the South Carolina model.

Based on this review of the current practices, we provide a forecast for Georgia using a similar econometric approach to that found in other states. The forecast model regresses quarterly values of state motor fuel gallons consumed on the price of gasoline, employment per capita, and a time index using historical data from 2000 through 2019. We exclude data for 2020 due to the disruptions caused by the COVID-19 pandemic. For ease of interpretation and to smooth the observations over time, all variables, with the exception of the time index, are expressed in natural logs. Data on quarterly motor fuel consumption for Georgia is obtained from the FHWA Monthly Motor Fuels report. Past and future values of the independent variables are obtained from Moody's Analytics September 2021 forecast. The coefficients generated from this regression represent the magnitude of the effect of the independent variables on the gallons of motor fuel consumed over the 2000–2019 period. The forecast applies these coefficients to the forecasted future values of the independent variables to produce the predicted values of motor fuel consumption for years 2022–2050.

The model performs reasonably well with an adjusted R^2 of 0.87, implying that the model explained 87 percent of the variation in motor fuel receipts over the 2000–2019 period. All the estimated coefficients are of the expected sign and significantly different from zero at the 5 percent confidence interval. The variable for time has a negative coefficient, indicating declining values for gasoline consumption per capita over time. The coefficient on gas prices is also negative, affirming that an increase in gas prices leads to a reduction in gasoline consumption per capita. Employment per capita is found to have a positive effect on gasoline consumption per capita.

The special fuels model includes the natural log of the state's gross state product per capita and a time index. This model is also run as an OLS model on quarterly state data from quarter 1 of 2000 through quarter 4 of 2019. This model performs fairly well with an adjusted R^2 of 72 percent. Multiple versions of the model are tested, and the results are found to be robust to alternative model specifications.

ECONOMETRIC-BASED FORECAST

Figure 14 visualizes the performance of the econometric forecast model against the historic values of gallons of gasoline and special fuels from 2000 through 2019. Over this time period, the forecasted values from the gasoline model tend to over-forecast actual values by 1.4 percent on average per year, or about 22 million gallons. The forecasted values for the special fuels model tend to under-forecast actual values by 4.3 percent on average per year, or about 5 million gallons.

In addition, figure 14 shows the trajectory of the forecast of gallons of fuel for gasoline and special fuels from 2022 through 2050. Over the 2022–2050 period, gallons of gasoline are projected to fall by an average of 0.4 percent annually. For the same period, special fuels are forecast to increase 1.9 percent annually.

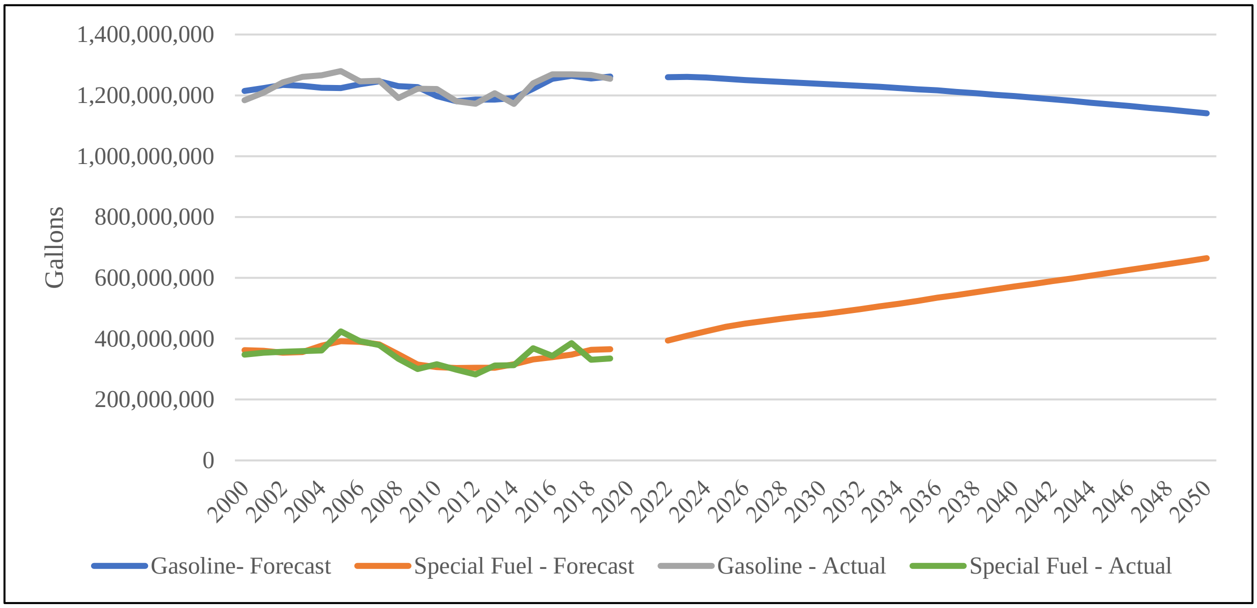

Figure 14. Line graph. Gallons of fuel – gasoline and special fuels.

We apply the forecasted tax rates discussed in chapter 7 to the forecast of motor fuel usage to produce the forecast of motor fuel receipts shown in figure 15. Total motor fuel revenues are forecast to increase at an average rate of 0.6 percent annually over the 2022–2050 period, from $2.0 billion in 2022 to $2.3 billion in 2050. The annual increase in receipts is due to the annual increase in the tax rate and the increase in the use of diesel fuel. Over the 2022–2050 period, revenues from gasoline are forecast to decline on average 0.1 percent annually, while revenues from diesel are forecast to increase 2.2 percent annually. The detailed annual forecast is shown in table 15 in the appendix

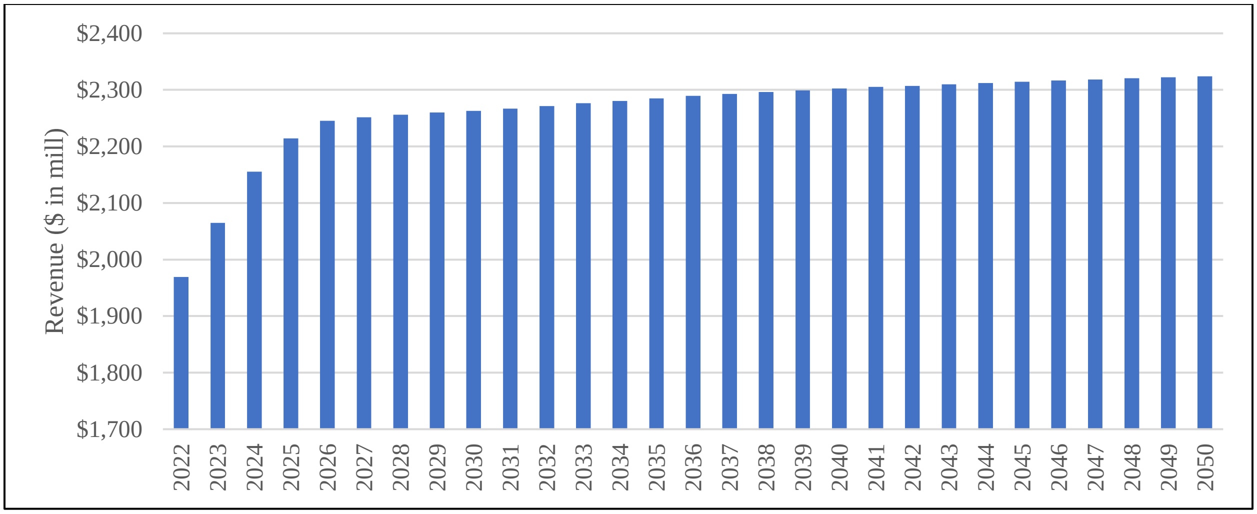

Figure 15. Bar graph. Motor fuel revenue forecast – econometric model.

CHAPTER 9. MOTOR FUEL FORECAST #2 – NEMS MODEL

The econometric forecast presented in chapter 8 has the advantage of being specific to Georgia because it is generated using historic data for Georgia, but the model also has a significant disadvantage. By forecasting values of future motor fuel consumption based on the historical data, the model implicitly assumes the relationship between fuel consumption and the model variables, such as population and economic activity, remains constant over future periods. As more EVs are adopted into the fleet of vehicles on the road, this relationship will break down over time and the econometric model will not reflect this change. The model does incorporate the gradual increase in MPG of ICE vehicles because that has been occurring for some time. But the adoption of more EVs is expected to provide a less smooth and more substantial change in the trajectory of MPG, and one that is not reflected in the historical data. Because the econometric model does not explicitly model the adoption of EVs, it will likely over-estimate motor fuel consumption in future years. Thus, while the econometric model provides reliable estimates in the short-run, it is anticipated to be less reliable for the long-run forecast.

As an alternative to the econometric forecast, we rely on the long-run projections from the NEMS model (EIA 2019). The NEMS model explicitly projects levels of EV adoption, as well as other factors, such as future values of MPG of ICE vehicles, and VMT by type of vehicle. This model is not necessarily a forecast, but a projection of motor fuel usage based on various assumptions of model inputs. We use the information generated from the NEMS model to construct a simulation tool that can be used to improve the reliability of long-run projections of motor fuel consumption and receipts. Furthermore, this simulation tool can be easily updated annually to assist GDOT in monitoring motor fuel receipts over time.

NEMS MODEL

The NEMS model is a national energy modeling system first developed in 1993 by the U.S. Department of Energy, Energy Information Administration (EIA) to forecast national energy demand, supply, imports, and prices. The model is updated annually to reflect recent macroeconomic conditions, changes in technology, and changes in federal and some state policies. The model is used to generate the projections presented in the annual AEO publication. The current version of the NEMS model contains 13 multiple equation modules constructed to model all aspects of the U.S. energy market. The complete model includes four demand modules (residential, commercial, industrial, and transportation), four fuel supply modules (oil and gas, natural gas, coal, and renewable fuels), and two fuel conversion modules (electricity and liquid fuels). In addition, the overall energy model includes a macroeconomic module incorporating forecasted future values of GNP, inflation, and other national economic variables that influence both demand and supply of fuel. Lastly, the model includes a system-integrating module to ensure that demand and supply and fuel prices projected by the model equilibrate over time.

Of particular interest for our purposes, the transportation module of the NEMS model provides an annual forecast to 2050 of the energy consumption of light-duty passenger vehicles, medium- and heavy-duty vehicles, and buses for specific fuel types, including gasoline, diesel, ethanol, natural gas, propane, electric, and hydrogen fuels. Of significant importance is that the NEMS model explicitly models the adoption of different types of vehicles, including ICEs, three different types of BEV, two types of PHEV, and gas- and diesel-hybrid vehicles. Furthermore, the model provides detail on the number of each type of new light-duty car or truck adopted annually, as well as the number of existing types of vehicles in operation annually. In addition, the model provides detailed information on VMT, and the MPG of new light-duty vehicles sold annually by vehicle type.

The current NEMS output was published as part of the 2021 AEO in February 2021. For each annual edition, the NEMS model produces a base case scenario referred to as the *reference case*, which incorporates current policies and economic conditions of the current period. The reference case for 2021 incorporates the CAFE standards adopted in 2020, which are lower than the prior standards, as discussed in chapter 5. Per the parameters in the model, the CAFE standards influence the value of MPG of new vehicles sold in a year, as well as the number and mix of type of vehicles sold, and the volume of fuel consumption over time. According to USEPA regulations, these CAFE standards were adopted in 2020 and are scheduled to remain in effect through 2026. Because there is not current guidance on future CAFE standards, the NEMS model holds these CAFE standards constant for years after 2026. The model also incorporates the federal tax incentives for AFV adoption but does not incorporate the various state AFV incentives.

In addition to the CAFE standards, the projections incorporate an economic forecast that reflects economic conditions and expectations valid during the latter months of 2020. For instance, the 2021 AEO model assumes an inflation-adjusted GDP for 2021 that is approximately 6 percent lower than the 2020 version of the model, reflecting the impact of the COVID pandemic. On the other hand, the pandemic is currently modeled as a short-run issue with the effects limited to 2020–2024. Compared to the 2020 AEO model, the macroeconomic assumptions of the 2021 version are actually higher over the longer run. For instance, the compound annual growth rate (CAGR) of real U.S. GDP over the 2022–2050 period in the 2021 model is assumed to be 2.0, compared to 1.9 in the 2020 model.

One significant drawback of the NEMS model is its lack of geographic detail. The NEMS model is a national model and does not provide vehicle adoption and fuel consumption projections at the state level. The model does incorporate some geographic variation by Census region but does not contain projected values specific to each state. To tailor the model's values to reflect Georgia, we share the national forecasted values to Georgia using the ratios of vehicle stock and vehicle miles driven in Georgia relative to the U.S. These ratios of VMT and registered vehicles have remained relatively consistent over time. The ratio of VMT in Georgia to the U.S. averaged 4 percent over the 2016–2019 period, having equaled 3.8 percent in 2000 and 2010, and 4.1 in 2019 (FHWA n.d.-c; various years). The ratio of vehicle registrations in Georgia to the U.S. averaged 3.1 percent, having equaled 3.2 percent in 2000 and 2010 and 3.1 in 2019 (FHWA n.d.-b; various years).

FORECAST #2 – NEMS-BASED PROJECTION

We use the detailed information published for the 2021 AEO to produce a forecast for Georgia that reflects future MPG standards, increased adoption of electric vehicles, and current VMT trends in Georgia. The published tables from the 2021 AEO can be manipulated to determine the average annual amount of fuel used by different categories of vehicles such as ICE cars, ICE trucks, bi-fuel natural gas vehicles, and gas- and diesel-hybrid vehicles. In addition, using the publicly available tables of vehicle stock and new vehicle purchases by vehicle type, we determine a vehicle salvage rate over time. Using these components, we construct a long-run model of motor fuel consumption in Georgia. figure 16 visualizes the results of this forecast for gallons of motor fuel consumption. By incorporating the new NEMS output each year, this Georgia model can be updated annually to provide a monitoring tool and revenue forecasting tool for use by GDOT.

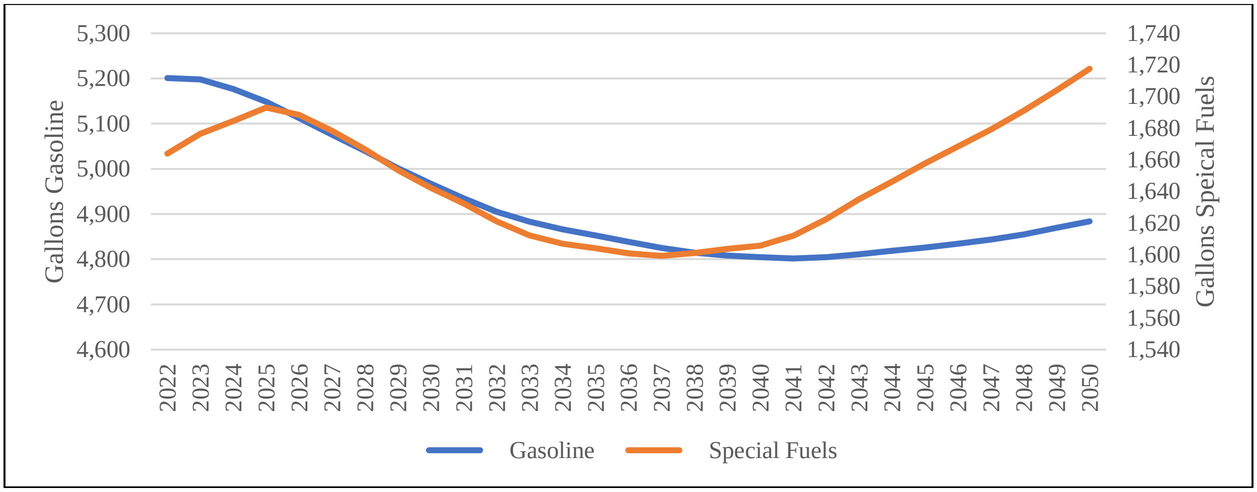

Figure 16. Line graph. Forecast of motor fuel gallons – NEMS base model.

Over the 2022–2050 period, this forecast model projects gasoline consumption to fall on average 0.2 percent annually and special fuel consumption to increase on average 0.1 percent annually. On a year-by-year basis the total gallons of motor fuel are projected to decrease slightly from 6.8 billion to 6.6 billion in 2050. Total motor fuel revenue is projected to rise by an average of 0.2 percent annually, from $2.1 billion in 2022 to $2.2 billion in 2050. Based on the assumptions reflected in the NEMS reference model, the share of light-duty BEVs and PHEVs in Georgia is forecasted to increase from 1.6 percent in 2022 to 11.7 percent of all new vehicles sold in Georgia.

Applying the projected gallons to the same forecasted motor fuel tax rate applied to the econometric forecast for the respective fuel types yields the forecast of revenues shown in figure 17. The detailed annual forecast is provided in table 17 in the appendix Figure 17 also shows the revenue forecast from the NEMS model relative to that of the econometric model presented in chapter 8. On the whole, the models compare favorably, with both indicating a decline in total gasoline consumption and an increase in special fuel consumption over time.

Over the full 2022–2050 period, the annual NEMS projection is, on average, about 3 percent below the annual econometric model forecast. The econometric forecast is based on more recent economic data than the NEMS model, which may account for the lower forecast for the 2022–2030 period reflected in the econometric model. As suggested above, the econometric model provides a higher forecast than the NEMS model in total fuel consumption and in receipts over the longer period. Because the NEMS model explicitly models the change in vehicle technology over time, it is expected that this model incorporates the effects of EV adoption and changes in fuel economy by ICE vehicles better than the econometric model.

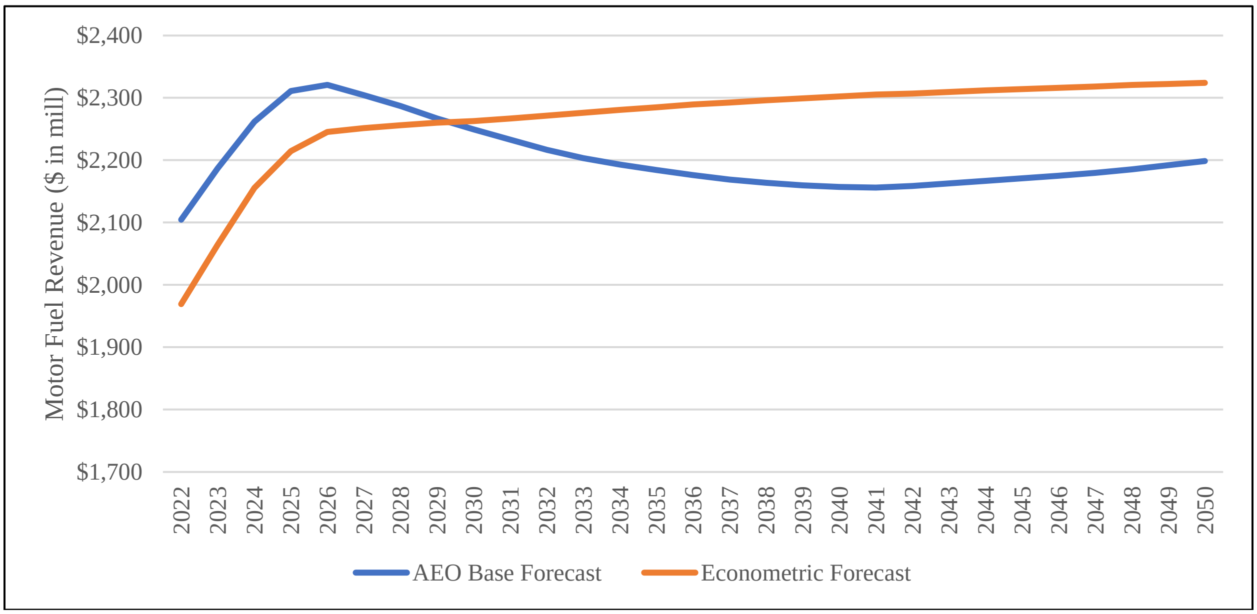

Figure 17. Line graph. Comparison of NEMS base model and econometric model.

CHAPTER 10. ALTERNATIVE SIMULATIONS

The significant advantage of the NEMS model is that the high level of detailed information published as part of the AEO allows for the construction of alternative scenarios. These alternative scenarios allow policymakers to understand the implications of various policy decisions and changes in behavior on motor fuel consumption, vehicle adoption, and motor fuel receipts.

It is important to understand that the forecast model for Georgia is not dynamic. The Georgia model is constrained by underlying assumptions used in the national model. As discussed above, the national NEMS model is a highly sophisticated model representing the entire national energy system. The state model is constructed from detailed spreadsheets which incorporate the underlying relationships between inputs and outputs in the energy system. Large deviations in the underlying model assumptions may disrupt these relationships. Therefore, the simulations presented here must be restricted to marginal changes in consumer choices and behavior that would not be expected to significantly disrupt these relationships at the national level.

In this chapter, we present the results of three alternative simulations. Simulation #1 increases the annual rate of BEV adoption by 10 percent annually over the reference case level but keeps all other assumptions unchanged. Simulation #2 assumes the reference case level of BEV adoption but incorporates the lower CAFE standards that were applicable in 2020. Simulation #3 assumes both an increased rate of adoption for both BEV and PHEV cars and trucks and incorporates the more stringent CAFE standards of 2020.

SIMULATION CASES

In the first simulation, we increase the rate of BEV adoption by 10 percent annually over the reference case. This increase is restricted to light-duty cars only and begins in 2022. For instance, the reference case assumes a BEV car adoption rate of 0.83 percent in 2022 compared to 0.91 percent in this alternative scenario. This change results in the adoption of an additional 370 BEV cars in 2022. To compensate, we reduce the number of ICE cars and trucks adopted annually so that the total number of vehicles remains unchanged each year. By 2050 this change in the rate of vehicle adoption results in nearly 3,000 more new BEV cars being adopted annually than under the assumptions that produced the original NEMS forecast for Georgia. Under this scenario, the rate of BEV adoption increases to 6.9 percent compared to 6.2 percent under the original forecast in 2050.

Simulation #2 retains all the assumptions of the original NEMS forecast model modified for Georgia, including those regarding the rates of AFV adoption and VMT. This simulation differs from the original forecast only in that it incorporates the stricter CAFE standards that were in place prior to 2020. Figure 18 shows the effect of the change in standards on the annual number of gallons of gasoline used by ICE cars over time. Initially, the current CAFE standards result in about 6 percent less fuel consumption per vehicle; however, by 2050, the stricter fuel standards in place prior to 2020 result in a fuel savings of about 11 percent per ICE gasoline vehicle per year.

The third simulation combines aspects of the previous two simulations. First, it assumes the stricter CAFE standards incorporated into Simulation #2. Second, it increases the BEV and PHEV adoption rate for both cars and trucks. The first simulation only increased the adoption rate for BEV cars. This simulation assumes that in 2022 an additional 740 BEVs and PHEVs are adopted and that 740 fewer ICE vehicles are purchased. In 2050, this simulation assumes that 5,560 BEVs and PHEVs are adopted, and 5,560 fewer ICE cars and trucks are purchased.

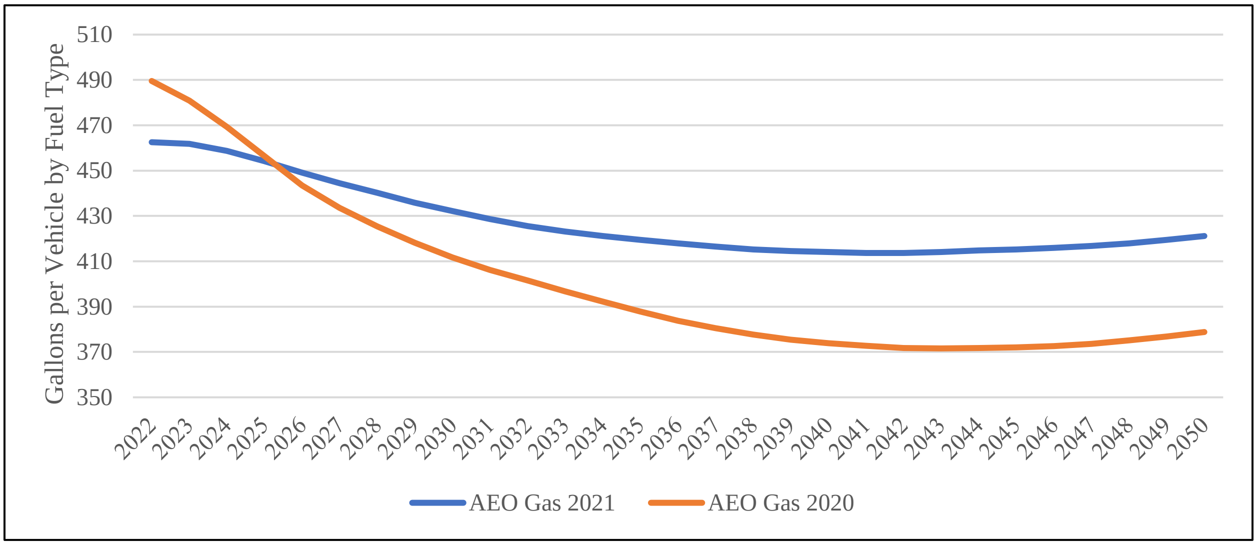

Figure 18. Line graph. AEO 2021 and AEO 2020 CAFE standards.

SIMULATION RESULTS

Figure 19 provides the visualization of the three scenarios against the original forecast. As expected, the original forecast generates the greatest motor fuel revenues, and the model with the lowest revenue is generated from Simulation #3, which incorporates both the higher fuel economy standards and greater rates of BEV and PHEV adoption. Simulation #2 provides more revenue relative to Simulation #1 in the near term, but over the longer run, Simulation #1 generates more total revenue than Simulation #2, reinforcing the finding that increases in the MPG of traditional vehicles has the greater impact on motor fuel revenue than the adoption of BEVs and PHEVs. The detailed annual forecast for Simulations #1, #2, and #3 are presented in table 18 in the appendix

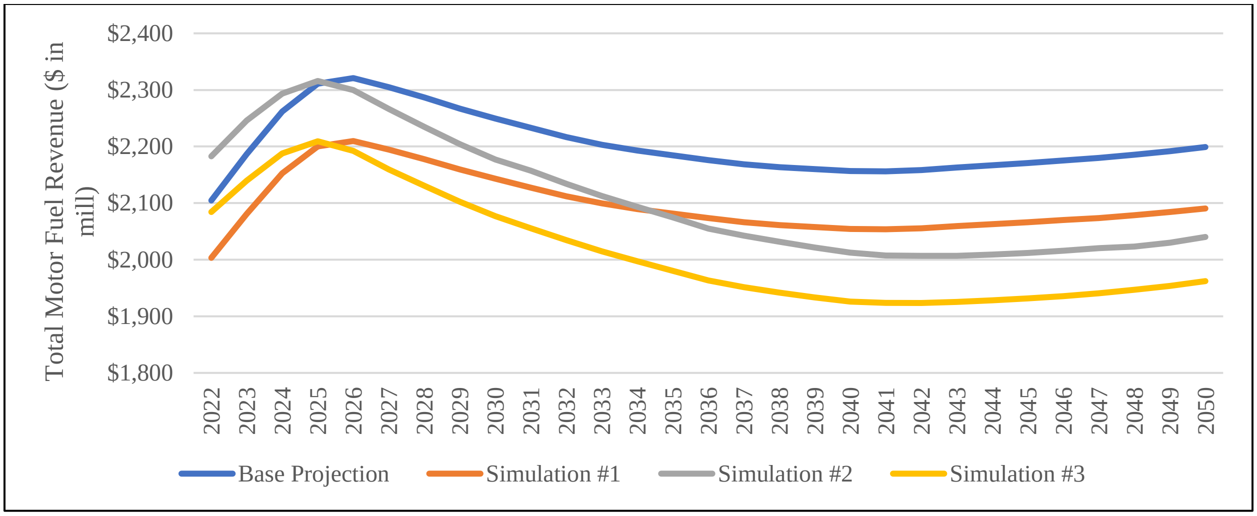

Figure 19. Line graph. Base forecast, Simulations #1–#3.

CHAPTER 11. ALTERNATIVE REVENUE OPTIONS AND ESTIMATES

Most states are as dependent on motor fuel taxes as Georgia. Addressing a need to supplement their motor fuel revenues, some states and countries have begun experimenting with and implementing alternative revenue mechanisms and additional taxes for fees. This chapter provides some examples of these optional sources and offers several additional options that Georgia may consider.

EXAMPLES OF ALTERNATIVE TRANSPORTATION FUNDING IN OTHER STATES AND COUNTRIES

Virginia imposes an optional highway-use fee on vehicles with a combined fuel economy of 25 MPG or more. The highway use fee for BEVs is currently a flat rate of $109 to reflect approximately 85 percent of the annual amount of foregone fuel taxes and $19 for the average fuel-efficient ICE vehicle.

Utah implemented a voluntary road use charge (RUC) in 2020[14] after first piloting a program in 2018 and 2019.[15] A similar program is operating in Oregon. Vehicle types eligible to opt-in to Utah's RUC include BEVs, PHEVs, and gas hybrids. Under this program, a sensor device is placed in the vehicle. The device transmits information on the number of miles driven. As part of the program, drivers establish a virtual wallet and regularly add funds to the account. Charges for miles driven are deducted from the account on an ongoing basis based on use. Drivers who choose to participate can enroll online, as the RUC is linked to Department of Motor Vehicles (DMV) registration. The Utah Department of Transportation (UDOT) oversees privacy and

[14] SB 72 (2019)
[15] Vehicle owners not participating in the RUC are subject to the annual registration fees.

security of the information, as well as agreements with account managers and participants. Utah's Transportation Commission is responsible for establishing the RUC mileage rate,[16] and for depositing the collected revenue. The cost of the initial pilot project is estimated to cost approximately $1.5 million (FY 19–21), and it is projected that 3 percent of all EVs will be in the program by the year 2023.

Japan imposes a total of nine taxes related to automobile purchase, ownership, and use. During ownership, the tonnage tax is charged by the central government according to the car's weight and is paid at the time of the registration and at each mandatory inspection, which is required every two years.

The amount of vehicle tax paid in Germany depends on four factors. These include the type of vehicle, type of drive, CO_2 value, and cubic capacity. In the case of electric vehicles, the tax is based on the gross vehicle weight.

OPTIONS FOR GEORGIA

Currently, the state levies an AFV registration fee. This fee applies only to BEVs. PHEVs and vehicles that are fueled using natural gas or other fuels are not subject to the fee unless a special alternative fuel tag is purchased. Over the longer-term, BEVs are expected to dominate in terms of AFV adoption. Over the short-term, though, as battery technology is still limited and as consumers adapt to the new technology, PHEVs are expected to experience significant rates of adoption. Option #1 recommends that the state apply the AFV registration fee to PHEVs and other alternative fuel vehicles, such as natural gas and hydrogen. Because these vehicles

[16] From January 2020, the RUC per mile rate in Utah is $0.015, and is indexed annually to changes in inflation.

consume some amount of gasoline, the fee could be applied at a reduced rate to reflect their average motor fuel consumption.

Under current law, the state annually indexes the motor fuel tax rate to adjust for changes in inflation. The adjustment for inflation is scheduled to cease after 2025. Our analysis of motor fuel receipts indicates, though, that indexing the motor fuel rate is key to increasing motor fuel receipts over time as the number of gallons used is forecast to decline. As Option #2, we recommend that the state not eliminate the annual CPI adjustment. Furthermore, we recommend that the state reimpose the indexing of the AFV fee for increases in the CPI. As originally implemented the AFV was indexed for changes to the CPI, mirroring the annual adjustment to the motor fuel tax rate. This annual adjustment to the AFV was eliminated for periods after July 1, 2018.

Option #3 recommends that as an alternative to indexing to the CPI, the state consider indexing both the motor fuel tax rate and the AFV fee to the National Highway Construction Cost Index (NHCCI). This is an annual price index of highway construction costs. This inflation measure is a more appropriate measure by which to index motor fuels because the motor fuel revenues are used for transportation maintenance and construction. Figure 20 presents the quarterly change in the value of the NHCCI and the CPI from 2023 through the first quarter of 2021 (FHWA n.d.-d). The values are constructed so that both are equal to 1 in 2003. From the graph, it is evident that the growth in the NHCCI has far exceeded the annual growth in the CPI. Over the 2003 to quarter 1 2021 period, the average quarterly growth of the NHCCI is 1 percent, while the average quarterly growth of the CPI is 0.5 percent.

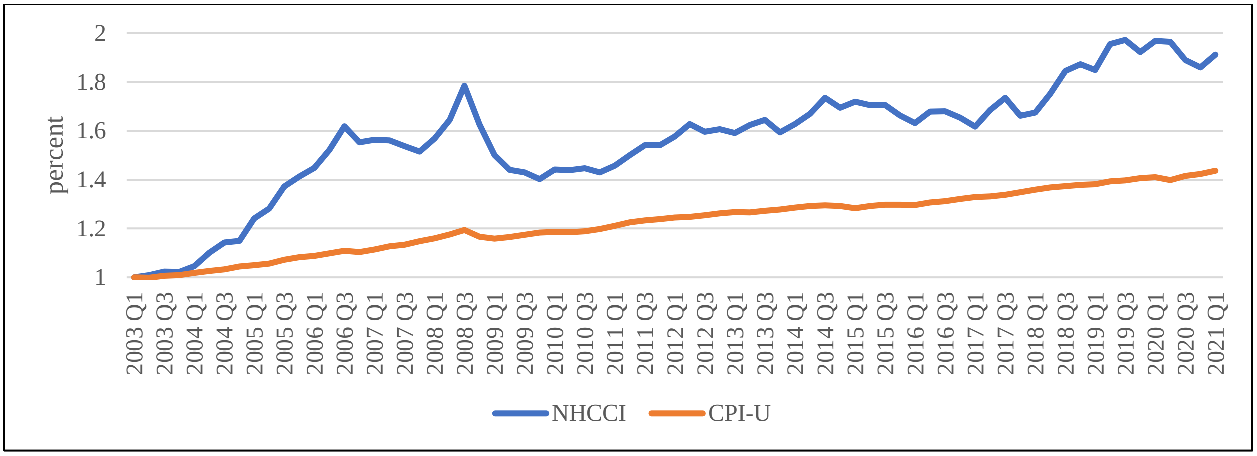

Figure 20. Line graph. National highway construction cost index and consumer price index.

As Option #4 we recommend that the state consider implementing a new fee or modifying the existing registration fee structure to impose a higher tax by vehicle weight. This fee would apply to noncommercial vehicles and would be similar to the fee imposed on commercial vehicles. Heavier vehicles impose greater costs in terms of maintenance to the roads and bridges. Imposing higher fees on these vehicles would better align their registration fee to the costs imposed on the transportation system. This fee would apply to vehicles of all fuel types, including BEVs and PHEVs which can be heavier than some similar ICEs due to the weight of the batteries.

Finally, as Option #5 we recommend that the Georgia DOR maintain a database of motor vehicle registrations. This database should include the make, model, model year, fuel-type, body-style, trim-level, number of cyclinders, gross weight, and county and date of registration for each vehicle registered in the state. This database should be updated at least annually and made available to GDOT for analysis. Furthermore, DOR should maintain these annual databases over a number of years so that time-series analysis may be conducted to understand trends and changes in vehicle ownership and adoption over time. From this data, DOR should provide to

GDOT, an annual report on the number and type of AFVs adopted annually, including the county of registration. Such a report will assist GDOT in monitoring the rate of adoption of AFVs.

CHAPTER 12. CONCLUSIONS

The purpose of this research is to produce a long-run revenue forecast of motor fuels for Georgia. The report begins with a descriptive analysis of motor fuel consumption in the U.S. and in Georgia. From this analysis we find that although motor fuel receipts have been increasing over time, motor fuel consumption on a per capita basis has been declining. Receipts have been increasing solely due to the indexing of the motor fuel tax rate.

The research continues by introducing a framework by which policy makers can organize the various factors affecting motor fuel receipts over time. Based on the calculation of motor fuel consumption for a single vehicle per year, we present the main determinants of motor fuel receipts, including number of vehicles in operation, vehicle miles traveled per vehicle, fuel economy and the motor fuel tax rate. We further explore the impact of these main factors on motor fuel receipts. Our findings suggest that the increasing fuel economy of ICE vehicles is a more important factor in the decline of motor fuel consumption in the short run than the adoption of electric vehicles.

This research presents two revenue forecasts. The first is an econometric forecast based on historical data of motor fuel consumption in Georgia. Over the 2022–2050 period, this forecast estimates that revenues from gasoline will decline on average 0.1 percent annually, while revenues from diesel will increase on average 2.2 percent annually. Total motor fuel revenues are forecast to increase at an average rate of 0.6 percent annually over the 2022–2050 period, from $2.0 billion in 2022 to $2.3 billion in 2050. The second forecast is based on the NEMS model modified to reflect motor fuel consumption in Georgia. This model has the advantage of directly modeling electric vehicle adoption. Thus, this forecast is considered a more reliable long-run forecast than the econometric forecast. This model can also be considered a simulation tool which may be updated annually, providing policy makers a tool by which the motor fuel revenues may be monitored over time. Over the 2022–2050 period, this forecast model projects gasoline consumption to fall on average 0.2 percent annually and special fuel consumption to increase on average 0.1 percent annually. On a year-by-year basis the total gallons of motor fuel are projected to decrease slightly from 6.8 billion to 6.6 billion in 2050. Total motor fuel revenue is projected to rise by an average of 0.2 percent annually, from $2.1 billion in 2022 to $2.2 billion in 2050.

This research presents 5 options for supplementing motor fuel receipts:

- Option #1 recommends that the state apply the AFV registration fee to PHEVs and other alternative fuel vehicles, such as natural gas and hydrogen possibly at a reduced rate.

- Option #2 recommends that the state not eliminate the annual CPI adjustment and extend the indexing to the AFV fee.

- Option #3 recommends that as an alternative to indexing to the CPI, the state consider indexing both the motor fuel tax rate and the AFV fee to the National Highway Construction Cost Index.

- Option #4 recommends that the state consider implementing a new fee or modifying the existing registration fee structure to impose a higher tax by vehicle weight.

- Option #5 recommends that the Georgia DOR maintain a database of motor vehicle registrations, including information on the make, model, model year, fuel-type, body-style, trim-level, number of cyclinders, gross weight, and county and date of registration for each vehicle registered in the state. This database should be updated at least annually and made available to GDOT for analysis. Furthermore, DOR should maintain these annual databases over a number of years so that time-series analysis may be conducted to understand trends and changes in vehicle ownership and adoption over time.

Although primarily a tool for raising revenue, it is also important to understand how the motor fuel tax impacts drivers of different income levels and geographies. As more BEVs and PHEVs are adopted, the motor fuel tax in its current state will be increasingly borne by rural and lower-income drivers. Adoption of BEVs and PHEVs are concentrated in urban areas and among individuals of higher income groups who purchase new vehicles. Under the current system in which the fuel tax is indexed to increases in the MPG, increased adoption of more fuel-efficient ICE vehicles exacerbates the regressive nature of the motor fuel tax by shifting the tax burden to those with less fuel-efficient vehicles or to those in rural areas who must drive longer distances.

An equally important factor to consider is that higher annual vehicle fees will likely create liquidity constraints for some lower-income households. One advantage of the motor fuel tax is that it allows drivers to fund transportation on an incremental basis. Transportation funding proposals that involve one-time annual payments will create liquidity constraints for lower-income individuals. This may be somewhat mitigated by collecting the tax on the state income tax return and allowing a refundable credit for households based on income.

APPENDIX

Table 15. Motor fuel tax rates.

	Tax Rate	
	Gasoline	**Diesel**
2022	$0.298	$0.334
2023	$0.309	$0.347
2024	$0.320	$0.359
2025	$0.327	$0.371
2026	$0.330	$0.375
2027	$0.330	$0.375
2028	$0.330	$0.375
2029	$0.330	$0.374
2030	$0.329	$0.374
2031	$0.329	$0.373
2032	$0.329	$0.373
2033	$0.328	$0.373
2034	$0.328	$0.372
2035	$0.327	$0.372
2036	$0.327	$0.371
2037	$0.327	$0.371
2038	$0.326	$0.370
2039	$0.326	$0.370
2040	$0.325	$0.370
2041	$0.325	$0.369
2042	$0.325	$0.369
2043	$0.324	$0.368
2044	$0.324	$0.368
2045	$0.324	$0.367
2046	$0.323	$0.367
2047	$0.323	$0.367
2048	$0.323	$0.366
2049	$0.322	$0.366
2050	$0.322	$0.365
CAGR 2022–2050	0.3%	0.3%

Table 16. Econometric forecast.

	Econometric Forecast			
	Gallons of Motor Fuel			
	Gasoline	Special Fuels	Total	Total Revenue ($ in mill)
2022	5,037,911,552	1,575,249,280	6,613,160,832	$1,969.3
2023	5,043,456,000	1,639,858,560	6,683,314,560	$2,064.6
2024	5,034,901,632	1,699,989,088	6,734,890,720	$2,155.6
2025	5,017,894,912	1,756,878,912	6,774,773,824	$2,214.5
2026	4,999,622,784	1,800,088,480	6,799,711,264	$2,245.2
2027	4,987,184,512	1,832,797,568	6,819,982,080	$2,251.6
2028	4,974,282,880	1,864,730,304	6,839,013,184	$2,256.1
2029	4,962,617,728	1,895,528,992	6,858,146,720	$2,260.3
2030	4,949,685,376	1,922,176,576	6,871,861,952	$2,262.8
2031	4,937,289,984	1,953,224,128	6,890,514,112	$2,266.8
2032	4,924,237,952	1,988,530,720	6,912,768,672	$2,271.4
2033	4,911,120,896	2,024,962,784	6,936,083,680	$2,276.3
2034	4,896,299,136	2,061,959,264	6,958,258,400	$2,280.6
2035	4,880,823,168	2,099,820,832	6,980,644,000	$2,285.1
2036	4,864,626,560	2,137,832,608	7,002,459,168	$2,289.3
2037	4,846,542,464	2,173,814,784	7,020,357,248	$2,292.7
2038	4,828,144,000	2,210,429,248	7,038,573,248	$2,296.1
2039	4,808,859,392	2,247,823,168	7,056,682,560	$2,299.2
2040	4,788,791,936	2,285,834,560	7,074,626,496	$2,302.5
2041	4,768,001,408	2,322,201,280	7,090,202,688	$2,305.3
2042	4,746,834,048	2,357,233,088	7,104,067,136	$2,307.2
2043	4,725,454,336	2,393,949,312	7,119,403,648	$2,309.6
2044	4,704,235,520	2,430,689,920	7,134,925,440	$2,312.0
2045	4,682,213,504	2,467,791,168	7,150,004,672	$2,314.1
2046	4,659,809,920	2,505,206,976	7,165,016,896	$2,316.4
2047	4,636,340,352	2,542,885,120	7,179,225,472	$2,318.4
2048	4,612,571,520	2,581,612,736	7,194,184,256	$2,320.6
2049	4,588,473,984	2,620,963,776	7,209,437,760	$2,322.5
2050	4,564,108,672	2,659,421,248	7,223,529,920	$2,324.2
CAGR 2022–2050	−0.4%	1.9%	0.3%	0.6%

Table 17. NEMS forecast.

	NEMS Forecast			
	Gallons of Motor Fuel (in mill)			
	Gasoline	Special Fuels	Total	Total Revenue ($ in mill)
2022	5,201	1,664	6,865	$2,104.7
2023	5,198	1,677	6,874	$2,186.8
2024	5,177	1,685	6,861	$2,261.8
2025	5,148	1,693	6,841	$2,311.1
2026	5,112	1,688	6,801	$2,320.9
2027	5,075	1,678	6,753	$2,304.6
2028	5,040	1,667	6,706	$2,286.7
2029	5,001	1,653	6,654	$2,266.9
2030	4,967	1,642	6,609	$2,249.5
2031	4,935	1,632	6,567	$2,233.0
2032	4,905	1,621	6,526	$2,216.5
2033	4,883	1,612	6,495	$2,203.3
2034	4,866	1,607	6,473	$2,192.9
2035	4,853	1,604	6,457	$2,184.6
2036	4,838	1,601	6,439	$2,176.0
2037	4,825	1,599	6,425	$2,168.8
2038	4,815	1,601	6,416	$2,163.6
2039	4,808	1,604	6,412	$2,159.9
2040	4,804	1,606	6,410	$2,157.0
2041	4,802	1,612	6,414	$2,156.2
2042	4,804	1,622	6,427	$2,158.5
2043	4,811	1,635	6,446	$2,162.8
2044	4,819	1,646	6,465	$2,167.0
2045	4,826	1,658	6,483	$2,170.9
2046	4,834	1,668	6,503	$2,175.2
2047	4,843	1,679	6,522	$2,179.7
2048	4,855	1,691	6,546	$2,185.3
2049	4,869	1,704	6,573	$2,191.8
2050	4,884	1,718	6,602	$2,198.9
CAGR 2022–2050	−0.2%	0.1%	−0.1%	0.2%

Table 18. NEMS forecast and Simulations #1–#3.

	NEMS Simulations			
	Revenue ($ in mill)			
	Original Forecast	**Simulation #1**	**Simulation #2**	**Simulation #3**
2022	$2,104.7	$2,003.3	$2,183.0	$2,084.1
2023	$2,186.8	$2,080.8	$2,245.9	$2,139.6
2024	$2,261.8	$2,152.5	$2,293.7	$2,187.5
2025	$2,311.1	$2,200.0	$2,315.8	$2,209.3
2026	$2,320.9	$2,209.7	$2,300.0	$2,192.3
2027	$2,304.6	$2,194.5	$2,266.6	$2,159.7
2028	$2,286.7	$2,177.9	$2,234.9	$2,130.5
2029	$2,266.9	$2,159.3	$2,204.1	$2,102.1
2030	$2,249.5	$2,143.1	$2,177.2	$2,076.7
2031	$2,233.0	$2,127.6	$2,157.3	$2,055.6
2032	$2,216.5	$2,112.0	$2,134.2	$2,034.7
2033	$2,203.3	$2,099.5	$2,112.6	$2,014.8
2034	$2,192.9	$2,089.6	$2,093.1	$1,997.0
2035	$2,184.6	$2,081.7	$2,074.5	$1,980.2
2036	$2,176.0	$2,073.4	$2,055.1	$1,963.4
2037	$2,168.8	$2,066.4	$2,042.3	$1,951.3
2038	$2,163.6	$2,061.4	$2,031.9	$1,941.7
2039	$2,159.9	$2,057.5	$2,021.6	$1,933.3
2040	$2,157.0	$2,054.5	$2,012.3	$1,926.2
2041	$2,156.2	$2,053.6	$2,007.6	$1,923.6
2042	$2,158.5	$2,055.5	$2,006.8	$1,923.5
2043	$2,162.8	$2,059.3	$2,007.1	$1,925.2
2044	$2,167.0	$2,063.0	$2,009.2	$1,928.1
2045	$2,170.9	$2,066.2	$2,012.1	$1,931.9
2046	$2,175.2	$2,070.0	$2,015.9	$1,935.6
2047	$2,179.7	$2,073.7	$2,020.3	$1,940.7
2048	$2,185.3	$2,078.6	$2,023.3	$1,946.8
2049	$2,191.8	$2,084.3	$2,030.0	$1,953.8
2050	$2,198.9	$2,090.4	$2,040.1	$1,962.2
CAGR 2022–2050	0.2%	0.2%	−0.2%	−0.2%

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support for this project provided by GDOT. We also wish to thank Sunil Thapa of GDOT for his support and assistance with this project. The authors also acknowledge the help of individuals at the Georgia DOR for their assistance in understanding the various aspects of the motor fuel tax and the AFV registration fee. Lastly, the author's wish to thank Michael Dwyer at the U.S. Energy Information Administration for his assistance in using the detailed tables published with the AEO. All errors in use of these tables are our own.

REFERENCES

Alliance for Automotive Innovation. (2021). Advanced Technology Vehicle Sales Dashboard. Data compiled by the Alliance for Automotive Innovation using information provided by IHS Markit (2011-2018, Nov 2019-2021) and Hedges & Co. (Jan 2019-Oct 2019). Data last updated 10/6/2021. Retrieved April 13, 2021, from https://www.autosinnovate.org/initiatives/energy-and-environment/electric-drive.

American Society of Civil Engineers (ASCE). (2021). "Report Card for America's Infrastructure." ASCE, Reston, VA. Available online: https://infrastructurereportcard.org/. Accessed April 13, 2021.

Annual Energy Outlook (AEO). (2021). "AEO Narrative." U.S. Energy Information Administration, Washington, DC, February 21. Available online: https://www.eia.gov/outlooks/aeo/

Berwick, M. and Malchose, D. (2012). *Forecasting North Dakota Fuel Tax Revenue and License and Registration Fee Revenue*. Report DP-249, Upper Great Plains Transportation Institute, Fargo, ND. Available online: https://www.ugpti.org/resources/reports/details.php?id=718.

Bureau of Transportation Statistics (BTS). (2021a). "Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles." U.S. Department of Transportation, Washington, DC, February 21. Available online: https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles

Bureau of Transportation Statistics (BTS). (2021b). "Local Area Transportation Characteristics for Households (LATCH Survey)." U.S. Department of Transportation, Washington, DC, February 21. Available online: https://www.bts.gov/latch.

Chapman, M. (2021). "General Motors Sets Goal of Going Largely Electric by 2035." *AP News*, January 28. Available online: https://apnews.com/article/gm-electric-vehicles-auto-industry-9308f9f3fcfbc1cffd0f9d18864dbcca.

Congressional Budget Office (CBO). (2021). "An Update to the Budget and Economic Outlook: 2021 to 2031." July 2021. Available online: https://www.cbo.gov/data/budget-economic-data#4.

Dunbar, J. and Martin, R.W. (2020). *Estimating Motor Fuel Demand in South Carolina: The Dunbar–Martin Demand Model FY2020–21 and FY2021–22*. State of South Carolina, Revenue and Fiscal Affairs Office, Columbia, SC. Available online: https://rfa.sc.gov/sites/default/files/2020-08/Estimating%20Motor%20Fuel%20Demand%20in%20S.C.%20-%20The%20Dunbar-Martin%20Demand%20Model%20-%202020.pdf.

EVAdoption. (2021a). “BEV Models Currently Available in the US.” EV Models, Information as of January 9. Available online: https://evadoption.com/ev-models/bev-models-currently-available-in-the-us/. Accessed September 5, 2021

EVAdoption. (2021b). “Future EVs.” Available online: https://evadoption.com/future-evs/ Accessed September 5, 2021.

EVAdoption. (2021c). “PHEV Models Currently Available in the US.” EV Models, Information as of September 4. Available online: https://evadoption.com/ev-models/available-phevs/. Accessed September 5, 2021.

Federal Highway Administration (FHWA). (n.d.-a). Table MF-33G and MF-33SF. In *Monthly Motor Fuel Reported by States*, Washington, DC. Available online: https://www.fhwa.dot.gov/policyinformation/motorfuelhwy_trustfund.cfm.

Federal Highway Administration (FHWA). (n.d.-b). “Table MV-1. State Motor Vehicle Registrations.” In *Highway Statistics* reports (various years), Office of Highway Policy Information, Washington, DC. Available online: https://www.fhwa.dot.gov/policyinformation/statistics.cfm.

Federal Highway Administration (FHWA). (n.d.-c). “Table MV-2.” In *Highway Statistics*, Office of Highway Policy Information, Washington, DC. Available online: https://www.fhwa.dot.gov/policyinformation/statistics.cfm.

Federal Highway Administration (FHWA). (n.d.-d). “National Highway Construction Cost Index.” Policy and Government Affairs Transportation Policy Studies, Washington, DC. Available online: https://www.fhwa.dot.gov/policy/otps/nhcci/.

Federal Highway Administration (FHWA). (2017). “Table VM-2.” In *Highway Statistics 2017*, Office of Highway Policy Information, Washington, DC. Available online: https://www.fhwa.dot.gov/policyinformation/statistics/2017/vm2.cfm.

Federal Highway Administration (FHWA). (2021). “Weekly Gasoline Product Supplied.” Office of Highway Policy Information, Washington, DC. Available online: https://www.fhwa.dot.gov/policyinformation/weeklyreports/.

Federation of Tax Administrators (FTA). (2021). “State Motor Fuel Tax Rates, January 2021.” Available online: https://www.taxadmin.org/assets/docs/Research/Rates/mf.pdf. Accessed April 13, 2021.

Georgia Department of Revenue (DOR). (November 30, 2020). “Georgia Department of Revenue Excise Tax Bulletin State Excise Tax on Motor Fuel Sales Effective: January 1, 2021” State of Georgia, Atlanta, GA. Available online: https://dor.georgia.gov/motor-fuel-state-excise-tax-bulletins. Accessed September 2021.

Georgia State Accounting Office (SAO). (n.d.). “Georgia Revenues and Reserves.” State of Georgia, Atlanta, GA. Available online: https://sao.georgia.gov/statewide-reporting/georgia-revenues-and-reserves. Accessed May 2021.

Georgia State Accounting Office (SAO). (2021). “Georgia Revenues and Reserves.” State of Georgia, Atlanta, GA. Available online: https://sao.georgia.gov/statewide-reporting/georgia-revenues-and-reserves. Accessed May 2021.

Governor’s Office of Planning and Budget (OPB). (2022). “The Governor’s Budget Report, Amended Fiscal Year 2021 and Fiscal Year 2022.” State of Georgia, Atlanta, GA. Available online: https://opb.georgia.gov/budget-information/budget-documents/governors-budget-reports. Accessed September 2021.

Governor’s Office of Planning and Budget (OPB). (2020). “Census Data: Population Projections.” State of Georgia, Atlanta, GA. Available online: https://opb.georgia.gov/census-data/population-projections. Accessed August 2020.

IHS Markit Vehicles in Operation database (IHS). (2021). Southfield, MI.

Isidore, C. (2021). “Ford Expects 40% of Global Sales to be Electric Vehicles in 2030.” *CNN Business*, May 26. Available online: https://edition.cnn.com/2021/05/26/investing/ford-electric-vehicle-investment/index.html.

Loveday, Steven. (2018). Monthly Plug-in Report Card Archive. Available online: https://insideevs.com/news/344006/monthly-plug-in-report-card-archive/.

Oregon Department of Transportation (ODOT). (2015). *Transportation Revenue Forecast Model: Methodology Overview*. Oregon Department of Transportation, Salem, OR. Available online: https://www.oregon.gov/odot/Data/Documents/Forecast_Method_Writeup.pdf.

Pickrell, D., Pace, D.M., and Wishart, J. (2020). *FHWA Travel Analysis Framework: Development of VMT Forecasting Models for Use by the Federal Highway Administration*. Volpe National Transportation Systems Center, Federal Highway Administration, Washington, DC, May 18. Available online: https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_model_dev.pdf.

Saldana, T. (2021). “Toyota to Debut Three New Electrified Vehicles for U.S. Market.” Toyota Newsroom, February 10. Available online: https://pressroom.toyota.com/toyota-to-debut-three-new-electrified-vehicles-for-u-s-market/.

Takahashi, M. (2020). “California Mandates Electric Cars for 2035 and Here’s What That Means: The Road to a Green Future Is Going to be Bumpy.” Edmunds, *Car News*, October 19. Available online: https://www.edmunds.com/car-news/california-mandates-electric-cars-for-2035.html.

Traugott, J. (2021). “Biden Announces Goal for 50 Percent EV Sales by 2030.” *News*, CarBuzz, August 5. Available online: https://carbuzz.com/news/biden-announces-goal-for-50-percent-ev-sales-by-2030.

U.S. Bureau of Economic Analysis. (2021). “SAGDP1 Gross Domestic Product (GDP) summary, annual by state.” United States Bureau of Economic Analysis, Washington, DC. Available online: https://apps.bea.gov/itable/iTable.cfm?ReqID=70&step=1.

U.S. Census Bureau. (n.d.). Annual Survey of State and Local Government Finances, 1977–2018. Compiled by the Urban Institute via State and Local Finance Data: Exploring the Census of Governments; accessed April 13, 2021), https://state-local-finance-data.taxpolicycenter.org.

U.S. Census Bureau. (2020). "State Population Totals and Components of Change: 2010–2019." United States Census Bureau, Washington, DC. Available online: https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html.

U.S. Department of Transportation (USDOT). (2015). "VMT Per Capita." USDOT, Washington, DC, August 24. Available online: https://www.transportation.CAFE/mission/health/vmt-capita.

U.S. Energy Information Administration (EIA). (2019). "National Energy Modeling System: An overview 2018." U.S. Department of Energy. Available online: https://www.eia.gov/outlooks/aeo/nems/overview/pdf/0581(2018).pdf.

U.S. Environmental Protection Agency (USEPA). (2021a). *The 2020 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975*. EPA-420-R-21-003, Washington, DC, January. Available online: https://www.epa.gov/automotive-trends/download-automotive-trends-report.

U.S. Environmental Protection Agency. (2021b). "The Official U.S. Government Source for Fuel Economy Information." (website) U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Washington, DC. Available online: https://fueleconomy.gov.