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16. Abstract

Advanced fuel economies in both traditional internal combustion engine vehicles (ICEs) and electric vehicles (EVs) have a strong influence on transportation revenue by reducing fuel consumption per vehicle and ultimately drawing down the amount of fuel tax revenue received. It is expected that more ICE vehicles with advanced fuel economies and EVs, especially gasoline hybrid EVs, will enter the roadway in coming years, and fuel tax revenues and the Highway Trust Fund will increasingly become more affected. This study estimates the impact that increased sales of advanced ICEs and EVs will have on future fuel tax revenues by drawing on industry estimates of future EV and ICE market shares and anticipates future fleet mix and fuel economy for both vehicle technologies. An estimation process overview is provided and assumptions are described.

Fuel tax revenue amounts that would be expected from future light vehicle fleets with increased shares of EVs are compared to equivalently sized fleets composed of all ICEs, and future fleet mixes are estimated. Results show that as more EVs enter the light vehicle fleet, greater revenue losses are expected, and total losses from years 2011 through 2050 depend on fleet composition and fuel economy of both vehicle types. It is found that the amount of fuel taxes paid by ICE drivers each year remain greater than fuel taxes paid by EV drivers even with advances in the average ICE vehicle fuel economy. Finally, a review of alternative revenue generation methods that states are employing to cover fuel tax revenue gaps is given.

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# TRANSPORTATION REVENUE IMPACTS FROM A CHANGING LIGHT-DUTY VEHICLE FLEET

by

Andrea Hall
C. Michael Walton
and
Peter J. Jin

**Research Report SWUTC/13/600451-00073-1**

Southwest Regional University Transportation Center
Center for Transportation Research
The University of Texas at Austin
Austin, TX 78712

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# ABSTRACT

Advanced fuel economies in both traditional internal combustion engine vehicles (ICEs) and electric vehicles (EVs) have a strong influence on transportation revenue by reducing fuel consumption per vehicle and ultimately drawing down the amount of fuel tax revenue received. It is expected that more ICE vehicles with advanced fuel economies and electric vehicles, especially gasoline hybrid electric vehicles, will enter the roadway in coming years, and fuel tax revenues and the Highway Trust Fund will increasingly become affected. This study estimates the impact that increased sales of advanced ICEs and EVs will have on future fuel tax revenues by drawing on industry estimates of future EV and ICE market shares and anticipates future fleet mix and fuel economy for both vehicle technologies. An estimation process overview is provided and assumptions are described.

Fuel tax revenue amounts that would be expected from future light vehicle fleets with increased shares of EVs are compared to equivalently sized fleets composed of all ICEs, and future fleet mixes are estimated. Results show that as more electric vehicles enter the light vehicle fleet, greater revenue losses are expected, and total losses from years 2011 through 2050 depend on fleet composition and fuel economy of both vehicle types. It is found that the amount of fuel taxes paid by ICE drivers each year remain greater than fuel taxes paid by EV drivers even with advances in the average ICE vehicle fuel economy. Finally, a review of alternative revenue generation methods that states are employing to cover fuel tax revenue gaps is given.

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# EXECUTIVE SUMMARY

## FUEL TAXES AND TRANSPORTATION FUNDING

The incentives to purchase electric vehicles (EVs) include such motivations as reducing US oil dependence to enhance national security, realization of the harmful impacts of greenhouse gas emissions from traditional internal combustion engine vehicles (ICEs), and the desire to maintain economic competitiveness and be a leader in technological advancements. Whatever the motivation, both consumer interest in and sales of EVs have increased in the past decade. In addition, the federal government has sought to advance traditional ICE fuel economy standards through the Corporate Average Fuel Economy (CAFE), and ICE vehicles are expected to use less gas in the coming decades. As more EVs and advanced ICEs hit the road, transportation officials are watching to see how these vehicles, with their potential for greatly advanced fuel economies, will impact transportation funding through the federal fuel tax.

As traditional ICEs are already becoming more fuel-efficient, revenue from the fuel tax is not keeping pace with roadway funding needs. With the introduction of electric vehicles, this trend is exacerbated. The primary focus of this study is to investigate how advanced ICEs (i.e., ICE vehicles with increased fuel economy) and EVs with higher fuel economies will impact federal fuel tax revenue; to this end, the research team calculated fuel consumption reductions to be expected as these vehicles comprise higher shares of the light vehicle fleet. Additional focus is placed on estimating fuel tax revenue losses that could be expected over the next four decades. Finally, a discussion of how these revenue losses may impact transportation-funding policy is provided.

## FEDERAL FUEL TAX AND FEDERAL HIGHWAY FUNDING

In 1932 the federal government placed an excise tax on gasoline. Initially, this tax revenue was not directly tied to highway funding, which changed with the creation of the Highway Trust Fund in 1956. In addition to the federal fuel tax, the Highway Trust Fund has drawn revenue from sources to add to its balance. Excise taxes were also placed on gasohol, diesel, and other fuels, and nonfuel taxes have included taxes in tires, truck and trailer sales, and heavy vehicle use.

Since 1932 the gas tax has been raised numerous times with the latest increase in 1993—an increase from 14.1 to 18.4¢ per gallon. Nearly twenty years later, no additional increases in the gasoline tax have been made, and efforts to generate support in favor of either raising the gas tax further or indexing it to the dollar value of gasoline have been unsuccessful.

An analysis of the average cents-per-mile paid in fuel taxes per vehicle from 1949 through 2010 by passenger cars and light-duty trucks can be split into a nominal rate, which does not account for inflation effects and then compared to the real, inflation-adjusted dollars. The nominal rate appears to increase over time and shows large increases in years that the gas tax was raised. In contrast, the real rate shows that the cent-per-mile of fuel taxes paid per vehicle has decreased over time. This is likely due to a number of factors, namely, increased fuel economy, increased vehicle miles traveled (VMT), or a tax rate that has not kept pace with inflation.

### FEDERAL FUEL TAX NET INCOME

Of the 18.4¢ per gallon that is charged federally, 15.4¢ (approximately 84%) go into the highway account and 2.86¢ (approximately 16%) are put into the mass transit account. Income from the fuel tax has historically increased until around year 2000 ($25 billion) when revenue began to plateau. In addition to the revenue from federal fuel tax, the Highway Trust Fund receives revenue from other excise taxes on fuels such as diesel and gasohol, and taxes on tires, truck trailers, and heavy truck use. However, taxes on gasoline provide a majority of revenue *(2).*

Fuel economy for both light-duty trucks and passenger cars has improved over the past decades. For both groups of light vehicles, the overall fuel economy has trended up slightly. The implications of this trend are that as fuel economies increase, less gasoline is required to drive the same distance, and fuel tax revenues will fall while demand for infrastructure increases.

## FEDERAL FUEL TAX TRANSFER OF FUND TO STATES AND STATE FUEL TAXES

In all fifty states, two fuel taxes are levied on each gallon of gasoline sold: one for the state's fuel tax and the other for the federal fuel tax. States are required to pay their federal portion of the fuel tax to the Highway Trust Fund, and the state's revenue is given back to the state later through allocation formulas, Congressional directives, and other means.
Federal transportation authorization legislation, such as SAFETEA-LU and MAP-21, addresses state rate of return of fuel taxes; other factors also have a bearing on how much revenue is retuned. Funds are distributed to a state annually, and the amount is determined by a statutory formula; during the SAFETEA-LU period, thirteen such formulas were used. In addition, Congressional directives determined where some funds were sent. In some states the rate of return of gas tax revenues is less than one, meaning that a state may not receive less revenue that what it has paid. Conversely, a state may also receive more than what is paid in. Detailed information on individual state's rate of return can be found in a report by the U.S. Government Accountability Office that was completed in September 2011 and provides a full analysis of state returns of fuel tax from the Highway Trust Fund *(3).*

This information is given to illustrate that the impact of increased shares of advanced fuel economy and EVs is two-fold. Fuel tax revenues will be impacted at the federal and state levels. States that have fuel taxes that are higher than the federal rate will experience greater decreases in state fuel tax revenues than from the state's share of federally transferred fuel tax revenues.

### Transportation Funding in the Future

As fuel efficiency in vehicles increases, the number of miles per gallon (MPG) driven that a driver would expect increases, and ultimately less gas will be needed to be consumed per vehicle to drive the same distance. While gasoline consumption per capita may decrease, if demand for travel (VMT per capita) remains the same or does not decrease as quickly as fuel consumption, then funding shortfalls may be expected. Since the primary source of roadway funding at the state and national level comes from fuel taxes and depends upon gasoline sales, available funding will likely not keep pace with needs.

Many studies by federal and state agencies have investigated a few factors in the fuel efficiency-fuel tax revenue relationship (such as VMT, fuel efficiency trends, etc.), but only a few have pieced together the full relationship in order to understand the complete impact on funding.

Historic data used to estimate fuel tax impacts on all these factors is available from the U.S. Department of Transportation, Department of Energy, and Environmental Protection Agency. Such data reveals the trends of these factors. For example, the light vehicle fleet has continued to grow as well as VMT per capita and fuel efficiency of vehicles. While it may be a safe assumption that these trends will continue to increase, there are limitations to how much. Such assumptions are discussed more in-depth in Chapter 5 where more detail on these factors and their trends are provided.

A base case scenario was used to compare alternative EV and ICE fleet mix scenarios in order to determine the amount of expected revenue change. The base case, which is described more in-depth in Chapter 5, predicts future fuel tax revenues in the case that there are no fuel efficiency improvements in future years and no change in the light-vehicle fleet mix. Finally, the metrics of interest for comparison of each scenario is the future fleet mixes and expected fuel tax revenues compared to the base case.

## METHODOLOGY

A complete description of the data was used to develop and calibrate this model is provided in Chapter 5. The datasets allow for the assessment of historic trends of variables that are believed to have some bearing on fuel tax revenues. Data and variables are described, and the framework for the model is given in the next section.

Future EV sales projections were used to determine future light vehicle fleet composition; these sales estimates came from three academic sources and are described in Chapter 6. The years of interest in this study were from 2011 through 2050, and fleet and revenue projections were made for this time period. Benchmark years used to understand impacts were 2030 and 2050, and fleet mixes, cumulative revenues, and total expected revenue losses are compared for these years.

**Model**

A model was developed using historical data from 1990 through 2010. Initially, future light vehicle fleet size was projected. Light vehicle fleet growth was estimated using the average annual growth rate Light vehicle fleet size was based on average annual light vehicle fleet growth from 1990 through 2010. The total light vehicles sold in a year was computed using the assumption that a light vehicle would remain in the fleet for 10 years, on average, based on existing literature on vehicle retention *(3).*

Existing literature supports the assumption that VMT per capita will increase only slightly in the future and may even plateau; because of this, it was assumed that future VMT would remain at the median VMT per vehicle from years 1990–2010, 11,825 miles per light vehicle. Annual average fuel consumption per vehicle, by vehicle type, in a given year was calculated by dividing vehicle VMT by projected fuel economy for the vehicle type in a given year.

The number of cumulative vehicles in the light vehicle fleet by vehicle type in a given year was estimated by adding remaining vehicles in the fleet from the initial year, 2010, and remaining vehicles in the fleet that were sold since 2010.

Fleet revenue in a year by vehicle type was estimated by multiplying the number of vehicles in the fleet by type and year by the vehicle's respective projected fuel consumption for the same year and then multiplied by the fuel tax rate of 18.4¢ per gallon.

Finally, cumulative revenue in year was calculated by summing annual fleet revenue for 2011.The overall model structure is described in Figure ES1.

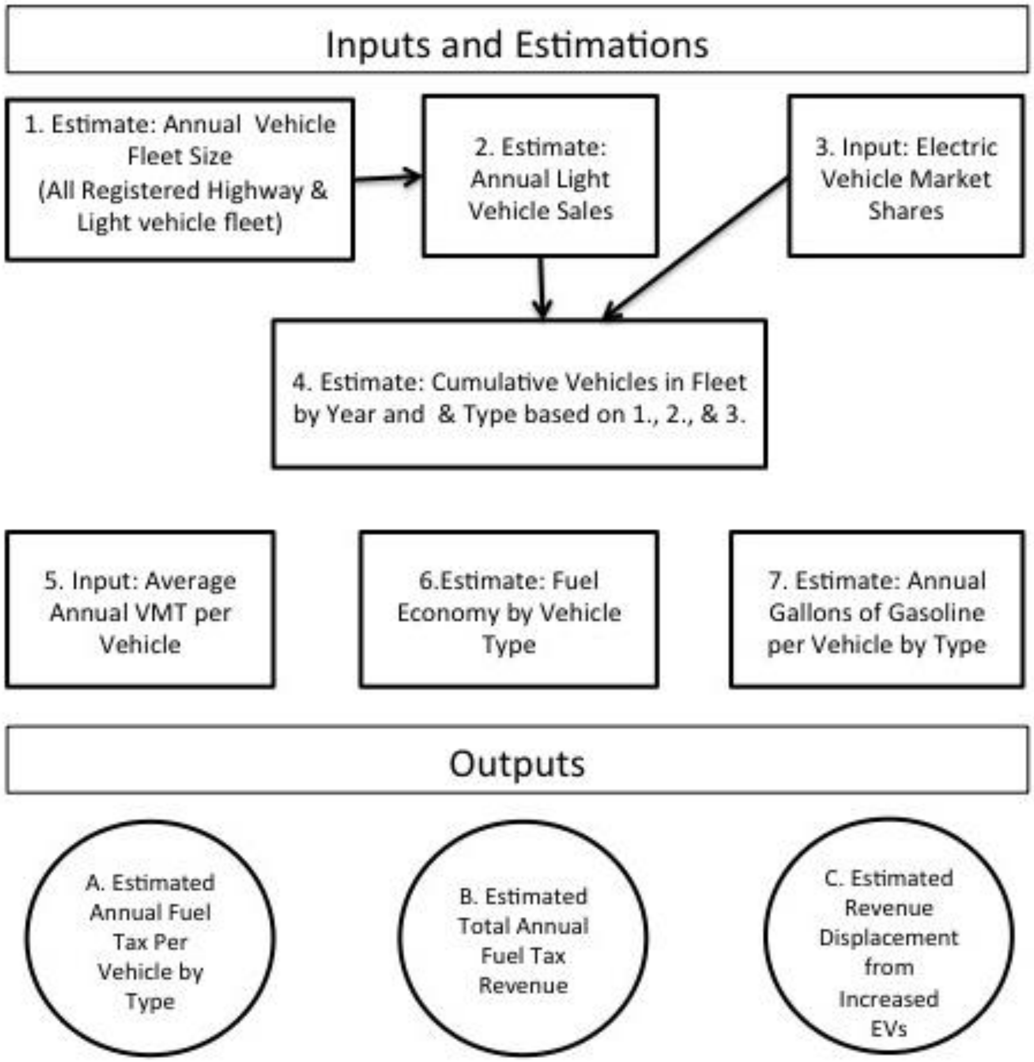


**Figure ES1: Estimation overview with inputs and outputs.**

## LIGHT VEHICLE FLEET MIX PREDICTIONS 2011–2050

In total, impacts from seven EV market sales scenarios were estimated for years 2011 through 2050. Summaries of market sales projection from various academic studies and their resulting future light-vehicle fleet mixes are shown below.

### EV Sales Projections

Three academic studies were chosen from the literature to inform EVs sales projections for future years.

**Scenario 1: CET 1.** Scenario one was based on a baseline scenario in the CET study. EV sales were based on assumptions regarding baseline oil prices reported in the Energy Information Administration's 2009 Annual Energy Outlook. In year 2015, EVs are expected to comprise 3% of light vehicle sales. EVs will comprise 18% of sales in 2020, 45% of sales in 2025, and 64% of sales in 2030. For years beyond 2030 (2031–2050) in this study, 64% sales were assumed.

**Scenario 2: CET 2.** For the second CET scenario, EV sales were based high energy prices from the EIA's 2009 report. It is expected that higher gasoline costs would encourage consumers to buy more fuel-efficient cars such as EVS. Accordingly, year 2015 sales projections show that EVs are expected to comprise 8% of light vehicle sales. They are estimated to comprise 33% of sales in 2020, 75% of sales in 2025, and 85% of sales in 2030. For years beyond 2030 (2031–2050) in this study, 85% sales were assumed.

**Scenario 3: CET 3.** Oil prices under this scenario are assumed to be the same as the High Energy Price Scenario in the CET study. In addition, it was assumed that charging infrastructure network operators would subsidize EV purchases for customers. With these assumptions, higher market shares would be expected. Accordingly, year 2015 sales projections show that EVs are expected to comprise 10% of light vehicle sales. They will comprise 48% of sales in 2020, 80% of sales in 2025, and 86% of sales in 2030. For years beyond 2030 (2031–2050) in this study, 86% sales were assumed.

**Scenario 4: MIT 1.** Projections from the MIT study showed that EVs would comprise 12% of light vehicle sales in 2020, 21% of sales in 2030, and 40%, of sales in 2050.

**Scenario 5: NA 1.** The first scenario characterized by the National Academies study was described as the most probable market scenario. In it, EV sales are expected to comprise 3% of light vehicles sales in year 2020 and 15% of sales in 2030. It was also projected the entire light vehicle fleet would be composed of 110 million EVs in 2050 (which could equate to 66% of 2050 light vehicle sales being EVs).

**Scenario 6: NA 2.** Maximum practical annual sales of EVs were used for this scenario based on the National Academies study. Under this scenario, it is expected that 240 million EVs will be in the light vehicle fleet in 2050. Yearly sales projections were not given in the study, but corresponding sales shares were estimated so that the fleet mix could be realized. For this study, the sales shares that would give the resulting fleet mix were approximately 10% in 2020, 45% in 2030, and 96% in years 2040 through 2050. These sales shares would give a 2050 light vehicle fleet with just above 240 EVs, which would equate to approximately 61% of the fleet.

**Scenario 7: Combined.** The final scenario was estimated using a combination of all projected market shares from all three previously mentioned studies—the average market shares of all years was used.

EV sales were estimated to be 20% of light vehicle sales in 2020, 47% of sales in 2030, and 61% of sales in 2050.

### Fleet Composition Comparisons

Table ES1 shows a comparison of the light-vehicle fleet by the expected percent of the fleet that will be composed of EVs in year 2030 and 2050. In year 2030, EVs are expected to comprise 3–41% of the light vehicle fleet, with an average of 21% across all scenarios. In year 2050, the light-vehicle fleet is expected to be composed of 33–58% EVs with an average of 44% across all scenarios.

**Table ES1: Comparison of EVs in fleet by scenario, 2030 and 2050**

| | Year | |
|---|---|---|
| **Scenario** | **2030 (%)** | **2050 (%)** |
| CET 1 | 26 | 50 |
| CET 2 | 40 | 58 |
| CET 3 | 41 | 58 |
| MIT 1 | 10 | 23 |
| NA 1 | 3 | 28 |
| NA 2 | 16 | 61 |
| Combined | 14 | 33 |

There is much uncertainty regarding how EV sales may change in the future—all projections modeled do assume that sales will increase, but at different rates. Projections with earlier and quicker sales increases show a more rapidly changing light vehicle fleet mix in coming years. Revenue impacts for each fleet mix scenario are provided in the next section.

### FUEL TAX REVENUE IMPACTS FOR 2011–2050

The following section provides an overview of estimated impacts on federal fuel tax revenues for each EV market sales scenario. For each scenario, total expected fuel tax revenues from gasoline taxes were estimated, and a comparison to expected fuel tax revenue from an equivalently sized fleet composed of only advanced ICE vehicles is provided. Finally, scenarios were compared to fuel tax revenues that would be expected from an equivalently sized fleet composed of ICE vehicles only with no fuel economy advances (fuel economy for each annual fleet was assumed to remain at the current 27.3 MPG CAFE standard).

#### Revenue Comparison

A comparison of expected revenue for all seven scenarios for benchmark years 2030 and 2050 is provided in the next section. The following three comparisons were used to frame the impact on fuel tax revenues due to increased shares of EVs, advanced ICE vehicles, or both.

- Comparison of revenues from a light vehicle fleet with increased EVs and advanced ICEs against an all advanced ICE fleet
- Comparison of revenues from a light vehicle fleet with increased EVs and no ICE advances against an all ICE fleet with no fuel economy advances
- Comparison of revenue from a light vehicle fleet with all advanced ICEs against an all ICE fleet with no advances

### 2030 REVENUE COMPARISONS

Table ES2 shows expected fuel tax revenue in year 2030 by market scenario and fleet mix. A comparison of expected funding in year 2030 to other market scenarios and fleet mixes is provided in Table ES3. Scenario 3 (CET 3) is expected to have the largest impact on funding and is characterized as having 86% EV sales by 2050. The vehicle fleet mix in in this scenario is expected to generate only 85% of funding that would be expected from a fleet with only advanced ICE vehicles. The fleet mix under Scenario 5 (NA 2) would have the smallest impact on fuel tax—this scenario, which is based on the National Academies' "most practical" scenario, would have the highest expected revenue generation of all other scenarios with increased EV shares.

**Table ES2: Expected revenue by scenario and fleet mix in 2030, $millions**

| Scenario | EV Mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 12,529 | 13,823 | 22,903 |
| 2. CET 2 | 11,853 | 13,823 | 22,903 |
| 3. CET 3 | 11,804 | 13,823 | 22,903 |
| 4. MIT1 | 13,347 | 13,823 | 22,903 |
| 5. NA 1 | 13,653 | 13,823 | 22,903 |
| 6. NA 2 | 13,048 | 13,823 | 22,903 |
| 7. Combined | 13,123 | 13,823 | 22,903 |

Table ES3 shows expected funding ratios between fleets; these ratios provide an indication of the percentage of funds that are expected to be lost due to EV and ICE increased shares. In 2030, 1.2–14.6% of funds may be lost if increased shares of both EVs and advanced ICEs are realized. If increased shares of EVs are introduced into the light vehicle fleet but no fuel economy advances are realized in ICE vehicles, 40.4–48.5% of fuel tax revenues may be lost. And finally, if no increased shares of EVs are introduced into the fleet, but advances in ICE vehicle fuel economy are realized, roughly 39.6% of fuel tax revenues will be lost.

**Table ES3: Expected funding ratios by fleet mix for comparable fleet sizes, 2030**

| Scenario | EV mix/ advanced ICE | EV mix/ICE no advances | ICE advanced/ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.906 | 0.547 | 0.604 |
| 2. CET 2 | 0.857 | 0.518 | 0.604 |
| 3. CET 3 | 0.854 | 0.515 | 0.604 |
| 4. MIT 1 | 0.966 | 0.583 | 0.604 |
| 5. NA 1 | 0.988 | 0.596 | 0.604 |
| 6. NA 2 | 0.944 | 0.570 | 0.604 |
| 7. Combined | 0.949 | 0.573 | 0.604 |

### 2050 Revenue Comparisons

Table ES4 shows expected fuel tax revenue in year 2050 by market scenario and fleet mix. This table provides a comparison of expected funding in year 2050 to other market scenarios and fleet mixes. Scenario 6 (NA 2) is expected to have the largest impact on funding and is characterized as having 96% EV sales by 2050. The vehicle fleet mix in this scenario is expected to generate only 78% of funding that would be expected from a fleet with only advanced ICE vehicles. The fleet mix under Scenario 4 (MIT 1) would have smallest impact on fuel tax—this scenario, which is based on projections from MIT suggests light vehicle sales in 2050 would be composed of 40% EVs. Under this only approximately 92% of funding that would be expected from a fleet with only advanced ICE vehicles would be generated.

**Table ES4: Expected Revenue by Scenario and Fleet in 2050, $millions**

| Scenario | EV mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 13,704 | 16,739 | 29,741 |
| 2. CET 2 | 13,242 | 16,739 | 29,741 |
| 3. CET 3 | 13,224 | 16,739 | 29,741 |
| 4. MIT 1 | 15,379 | 16,739 | 29,741 |
| 5. NA 1 | 15,061 | 16,739 | 29,741 |
| 6. NA 2 | 13,047 | 16,739 | 29,741 |
| 7. Combined | 14,730 | 16,739 | 29,741 |

Table ES5 shows expected funding ratios between fleets in 2050; these ratios provide an indication the percent of funds that are expected to be lost due to EV and ICE increased shares. In 2050, 18.1–22.1% of funds may be lost if both, increased shares of EVs and advanced ICEs, are realized. In the case that increased shares of EVs are introduced into the light vehicle fleet but no fuel economy advances are realized in ICE vehicles, 48.3–56.1% of fuel tax revenues may be lost. And finally, in the case that no increased shares of EVs are introduced into the fleet, but advances in ICE vehicle fuel economy is realized, roughly 43.7% of fuel tax revenues will be lost.

**Table ES5: Expected funding ratios by fleet mix for comparable fleet sizes, 2050**

| Scenario | EV mix/ Advanced ICE | EV mix/ ICE no advances | ICE Advanced/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.819 | 0.461 | 0.563 |
| 2. CET 2 | 0.791 | 0.445 | 0.563 |
| 3. CET 3 | 0.790 | 0.445 | 0.563 |
| 4. MIT 1 | 0.919 | 0.517 | 0.563 |
| 5. NA 1 | 0.900 | 0.506 | 0.563 |
| 6. NA 2 | 0.779 | 0.439 | 0.563 |
| 7. Combined | 0.880 | 0.495 | 0.563 |

### CUMULATIVE REVENUE COMPARISONS THROUGH 2030 AND 2050

The following section provides and analysis of the cumulative impact on fuel tax revenue from increased shares of EVs and advanced ICE vehicles in the light vehicle fleet. Cumulative expected revenue impacts are show for benchmark years 2030 and 2050.

**2030 Cumulative Revenue Comparisons.** Table ES6 shows cumulative expected fuel tax revenues by scenario for benchmark years 2030 and 2050. Cumulative fuel tax revenues by 2030 are expected to be between $312 billion and $325 billion in the case that increase shares of EVs and advances in ICE fuel economy are realized. In the case of no increases in EV shares, less than $327 billion in revenue would be generated from fuel taxes from 2011 through 2050. Finally, in the case of no increases in EV shares and no increases in ICE fuel economy, roughly, $422 billion in fuel tax revenue would be generated from 2011 through 2050.

**Table ES6: Cumulative Fuel Tax Revenue by Scenario in 2030, $millions**

| Scenario | EV mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 318,431 | 326,991 | 422,334 |
| 2. CET 2 | 312,598 | 326,991 | 422,334 |
| 3. CET 3 | 312,266 | 326,991 | 422,334 |
| 4. MIT 1 | 322,980 | 326,991 | 422,334 |
| 5. NA 1 | 325,355 | 326,991 | 422,334 |
| 6. NA 2 | 322,080 | 326,991 | 422,334 |
| 7. Combined | 321,539 | 326,992 | 422,334 |

Table ES7 shows cumulative expected fuel tax revenue losses for years 2011 through 2030. For all scenarios that model increased EV shares, Scenario 3 (CET 3) is expected to have the biggest impact on revenue with $14.4 billion in losses through 2030 (when compared to a fleet of all ICEs with advanced fuel economy). When comparing the impacts that increased fuel economy may have on funding, the difference in two fleets with ICE vehicles only, one with advanced ICEs and one without, nearly $95 billion in cumulative fuel tax revenue losses could be expected from 2011 through 2050.

**Table ES7: Cumulative Fuel Tax Revenue Losses by Scenario in 2030, $millions**

| Scenario | EV-All Advanced ICE | EV mix -ICE no advances | Advanced ICE - ICE no advances |
|---|---|---|---|
| 1. CET 1 | 8,560 | 103,902 | 95,342 |
| 2. CET 2 | 14,393 | 109,735 | 95,342 |
| 3. CET 3 | 14,725 | 110,067 | 95,342 |
| 4. MIT 1 | 4,011 | 99,353 | 95,342 |
| 5. NA 1 | 1,636 | 96,978 | 95,342 |
| 6. NA 2 | 4,911 | 100,253 | 95,342 |
| 7. Combined | 5,453 | 100,795 | 95,342 |

Finally, cumulative funding ratios are show in Table ES8. Fleets with EV share increased will generate 95.5–99.5% of the funding that would be expected from an all advanced ICE fleet for years 2011 through 2050. These percentages drop to 73.9–77.0% when comparing fleets with increased EV fleets to an equivalently sized fleet with all ICE vehicles that do not have increased fuel economy. Lastly, a light vehicle fleet with all advanced ICEs will generate 77.4% of the fuel tax revenues that would be expected from a fleet with all ICE vehicles with no fuel economy gains.

**Table ES8: Expected Cumulative Funding Ratios 2011–2030, $millions**

| Scenario | EV mix/ Advanced ICE | EV mix/ ICE no advances | ICE Advanced/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.974 | 0.754 | 0.774 |
| 2. CET 2 | 0.956 | 0.740 | 0.774 |
| 3. CET 3 | 0.955 | 0.739 | 0.774 |
| 4. MIT 1 | 0.988 | 0.765 | 0.774 |
| 5. NA 1 | 0.995 | 0.770 | 0.774 |
| 6. NA 2 | 0.985 | 0.763 | 0.774 |
| 7. Combined | 0.983 | 0.761 | 0.774 |

**2050 Cumulative Revenue Comparisons.** Table ES9 shows cumulative expected fuel tax revenues by scenario for benchmark year 2050. Cumulative fuel tax revenues by 2050 are expected to be between $574 billion and $3614 billion in the case that increase shares of electric vehicles and advances in ICE fuel economy are realized. In the case of no increases in EV shares, less than $630 billion in revenue would be generated from fuel taxes from 2011 through 2050. Finally, in the case of no increases in EV shares and no increases in ICE fuel economy, roughly, $949 billion in fuel tax revenue would be generated from 2011 through 2050.

**Table ES9: Cumulative Fuel Tax Revenue by Scenario in 2050, $millions**

| Scenario | EV mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 574,138 | 629,307 | 949,227 |
| 2. CET 2 | 556,083 | 629,307 | 949,227 |
| 3. CET 3 | 555,161 | 629,307 | 949,227 |
| 4. MIT 1 | 607,197 | 629,307 | 949,227 |
| 5. NA 1 | 613,512 | 629,307 | 949,227 |
| 6. NA 2 | 577,245 | 629,307 | 949,227 |
| 7. Combined | 599,093 | 629,307 | 949,227 |

Table ES10 shows cumulative expected fuel tax revenue losses for years 2011 through 2030. For all scenarios that model increased EV shares, Scenario 3 (CET 3) is expected to have the biggest impact on revenue with $74.1 billion in losses through 2050 (when compared to a fleet of all ICEs with advanced fuel economy). When comparing the impacts that increased fuel economy may have on funding, the difference in two fleets with ICE vehicles only, one with advanced ICEs and one without, nearly $319 billion in cumulative fuel tax revenue losses could be expected from 2011 through 2050.

**Table ES10: Cumulative Fuel Tax Revenue Losses by Scenario in 2050, $millions**

| Scenario | EV-All Advanced ICE | EV mix -ICE no advances | Advanced ICE - ICE no advances |
|---|---|---|---|
| 1. CET 1 | 55,169 | 375,090 | 319,920 |
| 2. CET 2 | 73,224 | 393,144 | 319,920 |
| 3. CET 3 | 74,146 | 394,067 | 319,920 |
| 4. MIT 1 | 22,110 | 342,030 | 319,920 |
| 5. NA 1 | 15,795 | 335,715 | 319,920 |
| 6. NA 2 | 52,062 | 371,982 | 319,920 |
| 7. Combined | 30,214 | 350,134 | 319,920 |

Finally, cumulative funding ratios are show in Table ES11. Fleets with EV share increased will generate 88.2–97.5% of the funding that would be expected from an all advanced ICE fleet for years 2011 through 2050. These percentages drop to 58.5–64.6% when comparing fleets with increased EV fleets to an equivalently sized fleet with all ICE vehicles that do not have increased fuel economy. Lastly, a light vehicle fleet with all advanced ICEs will generate 66.3% of the fuel tax revenues that would be expected from a fleet with all ICE vehicles with no fuel economy gains.

**Table ES11: Expected Cumulative Funding Ratios 2011–2050, $millions**

| Scenario | EV mix/ Advanced ICE | EV mix/ ICE no advances | ICE Advanced/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.912 | 0.605 | 0.663 |
| 2. CET 2 | 0.884 | 0.586 | 0.663 |
| 3. CET 3 | 0.882 | 0.585 | 0.663 |
| 4. MIT 1 | 0.965 | 0.640 | 0.663 |
| 5. NA 1 | 0.975 | 0.646 | 0.663 |
| 6. NA 2 | 0.917 | 0.608 | 0.663 |
| 7. Combined | 0.952 | 0.631 | 0.663 |

The total impact that EVs and advanced ICEs will have on fuel tax funding varies according to the light vehicle fleet mix and is relative to expected funding from an all ICE fleet with no fuel efficiency gains. Regardless of increased EV sales (which are likely), fuel tax revenues will decline due to fuel economy increases alone, and the inclusion of EVs only increases the losses.

## Alternative Funding Mechanisms

An overview of three alternative funding solutions that states within the U.S. have considered or implemented in order to partially or wholly fill the funding gap left by fuel taxes. The three alternative funding solutions are described as 1) additional vehicle registration fees, 2) indexed fuel taxes, and 3) the vehicle-miles traveled (VMT) tax.

### Additional Vehicle Registration Fees

A few states have begun to charge registration additional fees to owners of all all-electric vehicles (State of Washington), or all-electric and hybrid vehicle owners (Oregon), to cover revenue shortfall from gasoline tax revenue displacement. These fees have shown to be equivalent to about half of what a driver would be expected to pay in equivalent gasoline taxes, which still leaves a gap in funding.

### Indexed Fuel Tax

Indexing fuel taxes to gasoline price is not a new idea, but the State of Virginia is a pioneer in its implementation. Virginia has passed a new law that indexes the fuel tax to fuel price and authorizes the following provisions (which also relate to sales taxes in an effort to keep pace with inflation):

- Implements a 3.5% tax on wholesale gasoline and 6.0% tax on wholesale diesel
- Raises vehicle sales taxes from 3% to 4.3%
- Implements a $100 tax for electric *and* hybrid vehicles at the time of their purchase

### Vehicle Miles Traveled (VMT) Fee

VMT fees charge drivers a flat rate on the amount of miles that are driven on a system. By taxing every car at the same flat rate (versus a traditional gas tax), VMT fees ensure that drivers pay taxes in an amount proportional to how much they actually drive. Perhaps the state that is furthest ahead in the effort to implement a VMT tax is Oregon, which has not only completed a pilot program but has proposed Senate Bill 810 based on the finding from its pilot. The VMT charge would become effective beginning July 1, 2015, if passed in the Legislature. The new law would impose a flat charge on vehicles at the rate 1.5¢ per-mile instead of the state's gas tax of 30¢ per gallon. Numerous studies have been completed on VMT fees based on trials in Oregon, who is setting the stage for the rest of the nation to follow.

## CONCLUSION

It is clear from the results that as more EVs enter the fleet, and as ICE and EV fuel economies advance, revenue from the federal fuel tax will decline. The results of this study suggest that up to 41.5% of federal fuel tax funds may be lost. It is important to note that the rate at which revenue declines depends on many factors, such as the rate of fuel economy gains, timing of fuel economy gains, VMT, and total vehicle fleet size. The relationship among these factors is complex and further investigation is warranted to better understand vehicle fleet mix, fuel economy, and fuel tax revenue. The following factors are identified limitations of this research; future work should address these limitations.

- Fuel economy projections were made based on realistic manufacturer capability and do not account for the influence that politics may have on fleet fuel economy. Future work should assess political will for increasing fuel economy standards, which may be a limiting factor. For hybrid EVs, which are continually developing their technology, fuel economy may indeed differ from the initial estimates used in this study. Also, should the battery capability increase greatly, all-electric vehicles may require no gasoline (or very little gasoline).

- VMT was assumed to be the same for both EV drivers and ICE drivers in this study. It may be a reasonable assumption that EV drivers may differ in the miles traveled compared to ICE driver (due to battery constraints and many other factors), but at the time of this report, no concrete evidence existed to verify this assumption.

- Sales projections for EVs were informed by three academic studies. Market projections for EVs are continually being updated as technology gains are realized and more information becomes available. Fuel tax revenue losses are heavily dependent upon EV sales as their fuel economies are far greater than ICE vehicles. As time goes on, sales are likely to increase as fuel consumption per vehicle decreases, causing revenue impacts. While shortfall is almost certain, the amount of revenue lost is not.

Finally, if the fuel tax is to remain a source of funding, then transportation officials need to create and implement transportation revenue generation strategies that tie actual roadway use to amount of taxes paid for a driver (and not their gasoline consumption). Already an extensive body of literature exists on the topic of alternative transportation taxation strategies, and this study has been completed to help support and motivate the implementation of such strategies.

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# CHAPTER 1. FUEL TAXES AND TRANSPORTATION FUNDING

The incentives to purchase electric vehicles (EVs) include such motivations as reducing US oil dependence to enhance national security, realization of the harmful impacts of greenhouse gas emissions from traditional internal combustion engine vehicles (ICEs), and the desire to maintain economic competitiveness and be a leader in technological advancements. Whatever the motivation, both consumer interest and sales of EVs have increased in the past decade. In addition, the federal government has sought to advance traditional ICE fuel economy standards through the Corporate Average Fuel Economy (CAFE), and ICE vehicles are expected to use less gas in the coming decades. As more EVs and advanced ICEs hit the road, transportation officials are watching to see how these vehicles, with their potential for greatly advanced fuel economies, will impact transportation funding through the federal fuel tax.

As traditional ICEs are already becoming more fuel-efficient, revenue from the fuel tax is not keeping pace with roadway funding needs. With the introduction of EVs, this trend is exacerbated. The primary focus of this study is to investigate how advanced ICEs (i.e., ICE vehicles with increased fuel economy) and EVs with higher fuel economies will impact federal fuel tax revenue; to this end, the research team calculated fuel consumption reductions to be expected as these vehicles comprise higher shares of the light vehicle fleet. Additional focus is placed on estimating fuel tax revenue losses that could be expected over the next four decades. Finally, a discussion of how these revenue losses may impact transportation-funding policy is provided.

An overview of the federal fuel tax is given in this chapter. The problem statement and motivation for this study are given in Chapter 2, and Chapter 3 provides an overview of the state of practice on this topic. Chapter 4 provides an overview of the methodology used to answer the research question, and Chapter 5 gives an overview of data that was used to determine the impacts of the changing light vehicle fleet. Market studies and future light vehicle fleet compositions are described in Chapter 6, and overviews of future vehicle sales studies are given. Revenue impact estimates are provided in Chapter 7, where the results of the future fleet projection scenarios are given. And finally, concluding remarks on the policy implications of the revenue loss estimates, limitations to the research, and recommendations for future work are provided.

## 1.1. BACKGROUND INFORMATION

The following sections in this chapter provide a historic overview of the federal fuel tax, along with an analysis of real and nominal fuel tax rates and the historic trend of net fuel tax income. Finally, an overview of how federal fuel taxes are passed to states for state transportation funding is provided.

### 1.1.1. Federal Fuel Tax and Federal Highway Funding

In 1932, the federal government placed an excise tax on gasoline. At its inception, the gasoline tax rate was 1¢ per gallon, and vehicle fuel economy of highway vehicles was likely below 13 MPG, according to earliest found data from the US Energy Information Administration (EIA)(*1)*. Although the fuel tax has been in place since 1932, it was not directly tied to highway funding until the creation of the Highway Trust Fund in 1956. In addition to the federal fuel tax, the Highway Trust Fund has drawn revenue from sources to add to its balance. Excise taxes were also placed on gasohol, diesel, and other fuels, and nonfuel taxes have included taxes on tires, truck and trailer sales, and heavy vehicle use.

Since 1932 the gas tax has been raised numerous times with the latest increase in 1993—an increase from 14.1 to 18.4¢ per gallon. Nearly twenty years later, no additional increases in the gasoline tax have been made, and efforts to generate support in favor of either raising the gas tax further or indexing it to the dollar value of gasoline have been unsuccessful.

Early data from the EIA for passenger vehicle fuel economy, gasoline consumption, and vehicle miles traveled (VMT) was found for year 1949; the data shows an average light fleet fuel economy of 15 miles per gallon (MPG), 9,388 average VMT, and 627 gallons of gasoline consumed per vehicle in that year *(1)*. Calculating the average cents-per-mile rate paid per vehicle in 1949 and adjusting for inflation shows that the average driver of a passenger car paid 1.3¢ per mile traveled (reported in 2010 dollars). In comparison, in 2010, with increased average VMT per vehicle and fuel economy advances, an average driver paid 0.8¢ per mile. It is expected that without changes in the structure of transportation funding, the ratio of cents paid to miles driven will decrease even more.

Figure 1 shows the average cents-per-mile paid in fuel taxes per vehicle from 1949 through 2010. These rates are separated by passenger cars and light-duty trucks with missing data for light trucks, as it was not available prior to year 1965. Solid lines show the nominal rate, which does not account for inflation effects. Dotted lines show the cents-per-mile rate paid in real, inflation-adjusted dollars. The nominal rate appears to increase over time and shows large increases in years that the gas tax was raised. In contrast, the real rate shows that the cent-per-mile of fuel taxes paid per vehicle has decreased over time. This is likely due to a number of factors, namely, increased fuel economy, increased VMT, or a tax rate that has not kept pace with inflation.

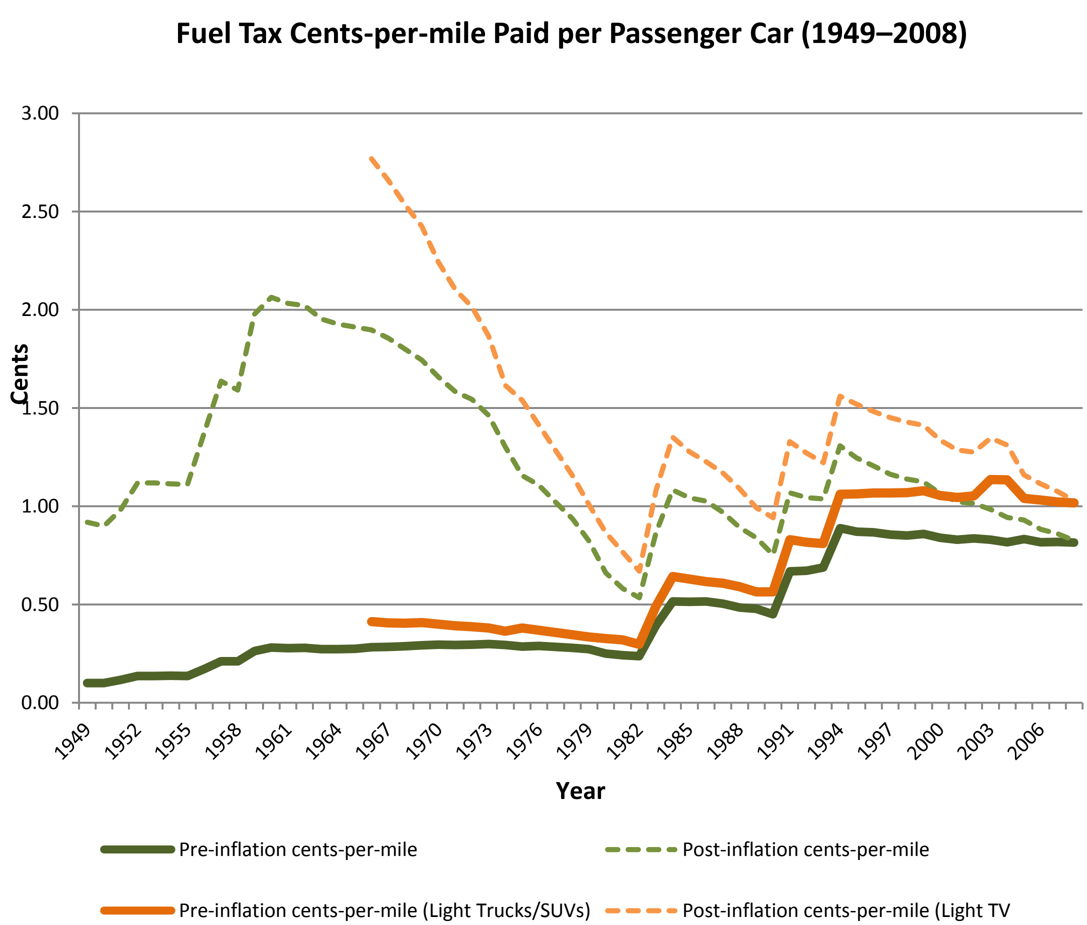


**Figure 1: Fuel tax cents-per-mile rate, 1949–2008**

### 1.1.2. Federal Fuel Tax Net Income

Figure 2 shows net income from the federal fuel tax from 1990 through 2010 by account. Of the 18.4¢ per gallon that is charged, 15.4¢ (approximately 84%) goes into the highway account and 2.86¢ (approximately 16%) are put into the mass transit account. Income from the fuel tax has historically increased until around year 2000 ($25 billion) when revenue began to plateau. In addition to the revenue from federal fuel tax, the Highway Trust Fund receives revenue from other excise taxes on fuels such as diesel and gasohol, and taxes on tires, truck trailers, and heavy truck use, but taxes on gasoline provide a majority of revenue *(2).*

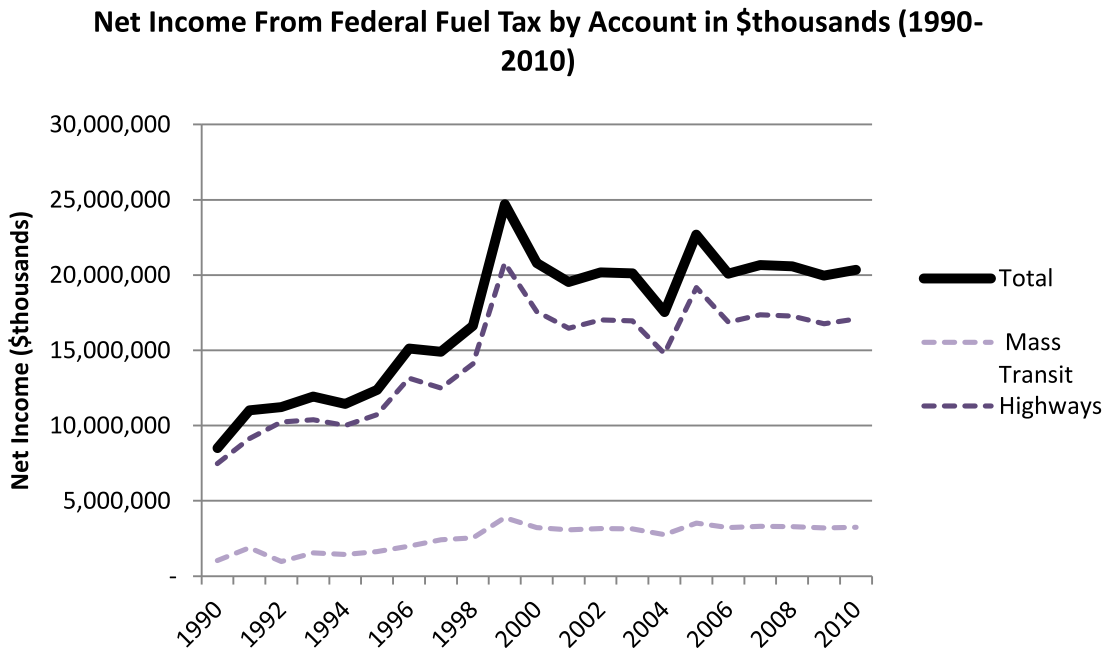


**Figure 2: Net income from federal fuel taxes by account in $thousands, 1990–2010**

Figures 3 and 4 show fuel economy trends in light vehicles (separated for cars and light trucks). The fuel economy for light trucks has had a smaller variance in fuel economy across all light trucks compared to the variance of fuel economy for all cars. For both groups of light vehicles, the overall fuel economy has trended up slightly. The implications of this trend are that as fuel economies increase, less gasoline is required to drive the same distance, and fuel tax revenues will fall while demand for roadway use will remain the same.

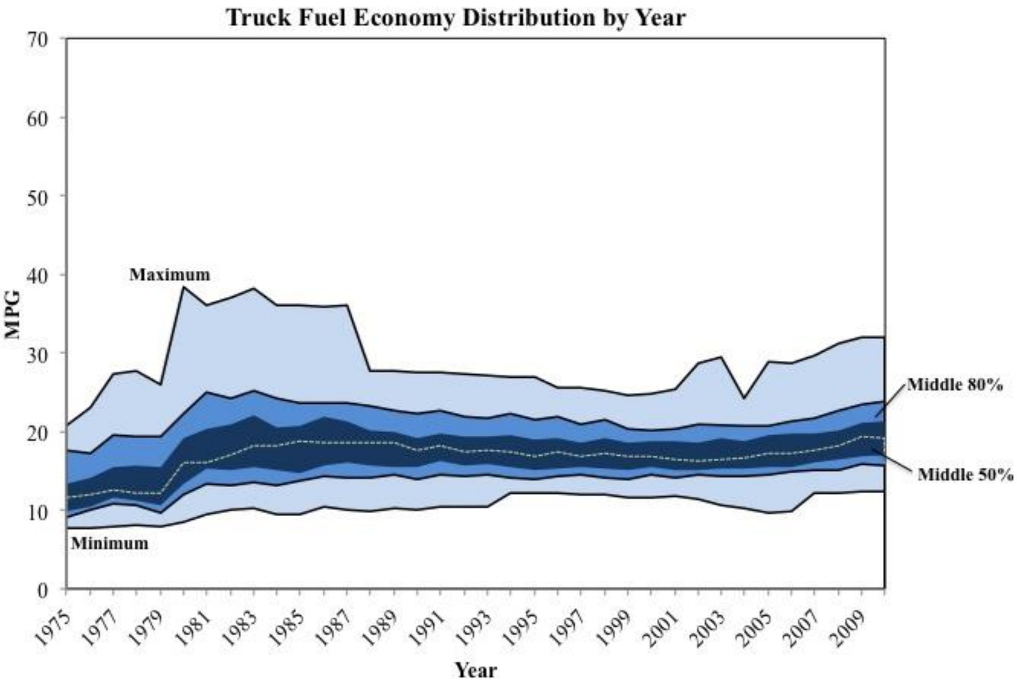


**Figure 3: Truck fuel economy trends, 1975–2010**

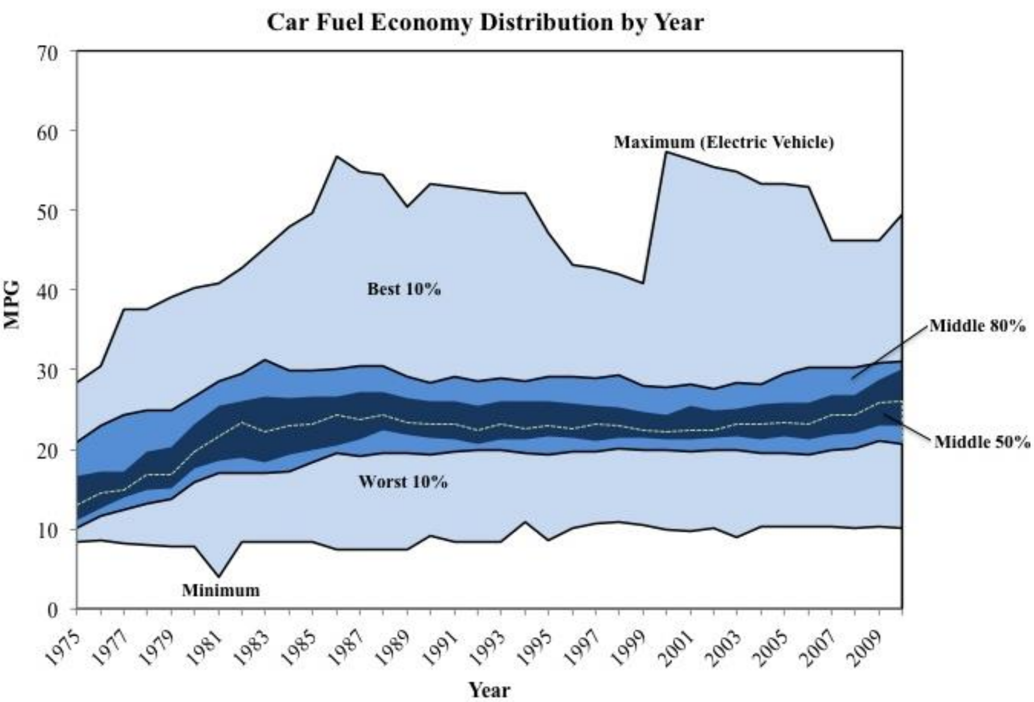


**Figure 4: Car fuel economy trends, 1975–2010**

### 1.1.3. Federal Fuel Tax Transfer of Fund to States and State Fuel Taxes

In all fifty states, two fuel taxes are levied on each gallon of gasoline sold: one for the state's fuel tax and the other for the federal fuel tax. States are required to pay their federal portion of the fuel tax to the Highway Trust Fund, and the state's revenue is given back to the state later through allocation formulas, Congressional directives, and other means.

Federal transportation authorization legislation, such as SAFETEA-LU and MAP-21, addresses state rate of return of fuel taxes, and other factors have a bearing on how much revenue is retuned. Funds are distributed to a state annually, and the amount is determined by a statutory formula; during the SAFETEA-LU period, thirteen such formulas were used. In addition, Congressional directives determined where some funds were sent. In some states the rate of return of gas tax revenues is less than one, meaning that a state may not receive less revenue that what it has paid. Conversely, a state may also receive more than what is paid in. Detailed information on individual state rate of return can be found in a report by the U.S. Government Accountability Office that was completed in September 2011 and provides a full analysis of state returns of fuel tax from the Highway Trust Fund *(3)*.

This information is given to illustrate that the impact that increased shares of advanced fuel economy and EVs is two-fold. Fuel tax revenues will be impacted at the federal and state level, and states that have fuel taxes that are higher than the federal rate will experience greater decreases in state fuel tax revenues than from the state's share of federally transferred fuel tax revenues.

## 1.2. TRANSPORTATION FUNDING IN THE FUTURE

As fuel efficiency in vehicles increases, the number of MPG driven that a driver would expect increases, and ultimately less gas will be needed to be consumed per vehicle to drive the same distance. While gasoline consumption per capita may decrease, if demand for travel (VMT per capita) remains the same or does not decrease as quickly as fuel consumption, then funding shortfalls may be expected. Since the primary source of roadway funding at the state and national level comes from fuel taxes and depends upon gasoline sales, available funding will likely not keep pace with needs. This illustrates the main focus of this study: the impact that technological improvements (electric drivetrains, advanced ICEs, or both) will have on the nation's primary transportation revenue source.

Many studies by federal and state agencies have investigated a few factors in the fuel efficiency-fuel tax revenue relationship (such as VMT, fuel efficiency trends, etc.), but only a few have pieced together the full relationship in order to understand the complete impact on funding. While the scope of this study does not include proposals for alternative methods for transportation revenue generation, it does provide valuable information to transportation officials regarding expected revenue losses and provide motivation for the investigation of new funding options. An overview of two existing studies on this topic is provided in Chapter 3, and their limitations are highlighted.

The evaluation of the impact of increase EV and advanced ICE vehicles in the fleet on transportation revenues required knowledge of past trends of the size and sales of the light vehicle fleet, VMT, vehicle fuel efficiency, and various other related factors. Historic data on all these factors is available from the U.S. Department of Transportation, Department of Energy, and Environmental Protection Agency (EPA). Such data reveals the trends of these factors. For example, the light vehicle fleet has continued increase as well as VMT per capita and fuel efficiency of vehicles. While it may be a safe assumption that these trends will continue to increase, there are limitations to how much. Such assumptions are discussed more in-depth in Chapter 5 where more detail on these factors and their trends are provided.

A base case scenario was used to compare alternative EV and ICE fleet mix scenarios against in order to determine the amount of expected revenue change. The base case, which is described more in-depth in Chapter 5, predicts future fuel tax revenues in the case that there are no fuel efficiency improvements in future years and no change in light-vehicle fleet mix. Finally, the metrics of interest for comparison of each scenario is the future fleet mixes and expected fuel tax revenues compared to the base case.

## 1.3. SUMMARY

With this knowledge, it can be argued that the fuel tax at its current rate is no longer a proper measure of driver roadway use and other finance options should be explored in order to raise funds necessary to build, maintain, and operate transportation infrastructure. In order to develop new options for transportation funding, it is first necessary to understand the impact that far more fuel-efficient cars, such as advanced ICES and EVs, will have on revenue. Partitioning revenue losses attributable to advanced ICEs and EVs will help inform the creation of taxation strategies that target additional revenue capture from EV drivers.

# CHAPTER 2. PREVIOUS STUDIES ON THE FUEL TAX AND FUEL EFFICIENCY GAINS

Many studies have been completed on the realistic expectations for light vehicle fleet fuel economy improvements, and many more have been completed on the estimation of how fuel economy improvements would reduce greenhouse gas emission. Few comprehensive studies, so far, have been completed on the subject of the link between fuel economy and transportation funding and less has been written about how EVs, specifically, will impact fuel tax revenue.

## 2.1. Congressional Budget Office Study

One of the most notable studies, authored by the Congressional Budget Office (CBO), identified how increased fuel economy standards would affect the highway trust fund through revenue from the fuel tax *(4).* The CBO study found that proposed CAFE standards calling for more fuel-efficient light vehicles that achieve an average fuel economy of 49.6 MPG by 2025 would reach full impact on funding in 2040. It estimated that there would be a 21% decrease in fuel tax revenue in that year. It was also estimated cumulative losses in years 2012 through 2022 would total $57 billion.

## 2.2. National Academies Study

In 2006, the National Academies published a study on the viability of the gas tax as a future revenue source and offered alternative future funding strategies. The study revealed that the federal government could expect a 20% fuel tax revenue loss by 2025 from increased ICE fuel efficiency gains alone (5). This study did not factor in the impact that could be expected from EVs, and since the time of the National Academies study more up-to-date information on realistic fuel economy gains has become available.

## 2.3. Summary

While state and federal agencies recognize that increased fuel economy and larger shares of EVs impact revenue, few comprehensive studies have been found that evaluate the impact of these technological changes. The most recent study by the CBO considered the impacts the CAFE standards may have on funding, but the technological capabilities of vehicles in terms of fuel economy are not modeled—meaning that technology may allow fuel economy gains to surpass

CAFE standards and any projected revenue shortfalls may be underestimated. Both studies mentioned previously do, however, provide supporting evidence that the federal fuel tax may in fact be an outdated transportation revenue generation mechanism, and new funding methods should be sought.

# CHAPTER 3. METHODOLOGY

This chapter outlines the methodology that was used to answer the research question and ultimate understand the impact of advanced ICE vehicles and EVs on future fuel consumption and ultimately on future federal fuel tax revenues.

A complete description of the data used to develop and calibrate this model is provided in Chapter 5. The datasets allow for the assessment of historic trends of variables that are believed to have some bearing on fuel tax revenues. Data and variables are described, and the framework for the model is given in the next section.

Regarding future EV sales projections used to determine future light vehicle fleet composition, sales estimates came from three academic sources and are described in Chapter 6. The years of interest in this study were from 2011 through 2050, and fleet and revenue projections were made for this time period. Benchmark years used to understand impacts were 2030 and 2050, and fleet mixes, cumulative revenues, and total expected revenue losses are compared for these years.

## 3.1. MODEL

The model was developed using historical data from 1990 through 2010. Initially, the future light vehicle fleet size was projected, and the projection method is shown in Equation 1 and 2. Year of interest was indexed with the notation *t*: *t=0* denotes year 2010, the final year of historic data; *t=40* denotes year 2050, the final projection year; and negative values of *t* denote years with historic data; t=-20 denotes year 1990. Light vehicle fleet growth was estimated using the average annual growth rate, which was calculated using Equation 1.

$$r_L = \frac{1}{T} \sum_{t=-20}^{0} \left( \frac{L_t - L_{t-1}}{L_{t-1}} \right) \qquad \text{(Eq. 1)}$$

$r_L$ = *average annual growth rate*
$L_t$ = *total number of light vehicles in fleet in year t*
$t$ = *year*
$T$= *total number of years*

Light vehicle fleet size $L_t$ was calculated using Equation 2, and was based on average annual light vehicle fleet growth from 1990 through 2010.

$$L_t = L_{t=0}(1 + r_L) \qquad \text{(Eq. 2)}$$

The number of total light vehicles sold in a year was computed using the assumption that a light vehicle would remain in the fleet for 10 years, on average, based on existing literature on vehicle retention *(3).* The proportion of vehicles that remain in a fleet in year *t* , given that it was in the fleet in year *t-1*, was found to be approximately 94.8% in order to reflect that assumption in the model. The figure for light vehicle sales in year *t* was found to be the difference in total light vehicle fleet size in year *t,* and the sum of remaining light vehicles in the fleet from year one plus remaining vehicles from sales in previous years. This relationship is reflected in Equation 3.

$$S_t = L_t - \left[\left(L_{t_0}\right)\left(p^{t-t_0}\right) + \sum_{t-1}^{1}\left(S_{t-1}\right)\left(p^{t-2}\right)\right] \qquad \text{(Eq. 3)}$$

$S_t$ = new light vehicle sales in year t
$p$= proportion of fleet remaining from year t-1

Existing literature supports the assumption that VMT per capita will increase only slightly in the future and may even plateau; because of this, it was assumed that future VMT would remain at the median VMT per vehicle from years 1990–2010, 11,825 miles per light vehicle. Annual average fuel consumption per vehicle, by vehicle type, in a given year was calculated by dividing vehicle VMT by projected fuel economy for the vehicle type in a given year. Equation 4 reflects this estimation.

$$G_{v,t} = \frac{VMT_t}{F_{v,t}} \qquad \text{(Eq. 4)}$$

*$G_{v,t}$ = gallons of gasoline consumed per vehicle by type (v) in year (t)*
*where v is either EV (e) or internal combustion engine vehicle (i)*
*t= year*
*VMT = vehicle miles traveled*
*$F_{v,t}$ = fuel economy for vehicle type v in year t*

Cumulative vehicles in the light vehicle fleet by vehicle type in a given year was estimated by adding remaining vehicles in the fleet from the initial year, 2010, and remaining vehicles in the fleet that were sold since 2010. Equation 5 reflects this estimation.

$$C_{v,t} = \left(L_{v,t}\right)\left(p^{t-t_0}\right) + \sum_{t}^{t_0}\left(S_{v,t}\right)\left(p^{t-t_0}\right) \qquad \text{(Eq. 5)}$$

$C_{v,t}$ = *Cumulative vehicles of type v in year t*

Fleet revenue in year *t* by vehicle type was estimated by multiplying the number of vehicles in the fleet by type and year by the vehicles' respective projected fuel consumption for the same year and then multiplied by the fuel tax rate of 18.4¢ per gallon. This estimation is reflected in Equations 6, 7, and 8.

$$R_{e,t} = (C_{e,t})(G_{e,t})(.184) \quad \text{(Eq. 6)}$$

$$R_{i,t} = (C_{i,t})(G_{i,t})(.184) \quad \text{(Eq. 7)}$$

$$R_{v,t} = R_{e,t} + R_{i,t} \quad \text{(Eq. 8)}$$

Finally, cumulative revenue in year *t* was calculated by summing annual fleet revenue for year 2011 through year t.

$$CR_{v,t} = \sum_{t_0}^{t} R_{e,t} + R_{i,t} \quad \text{(Eq. 9)}$$

### 3.2. SUMMARY

The overall model structure that described above is illustrated in Figure 5. In total, seven inputs were used to predict three outcomes of interest: 1) estimated annual fuel tax per vehicle by type, 2) estimated total annual fuel tax revenue, and 3) estimated revenue displacement from increased EVs and advanced fuel economy vehicles.

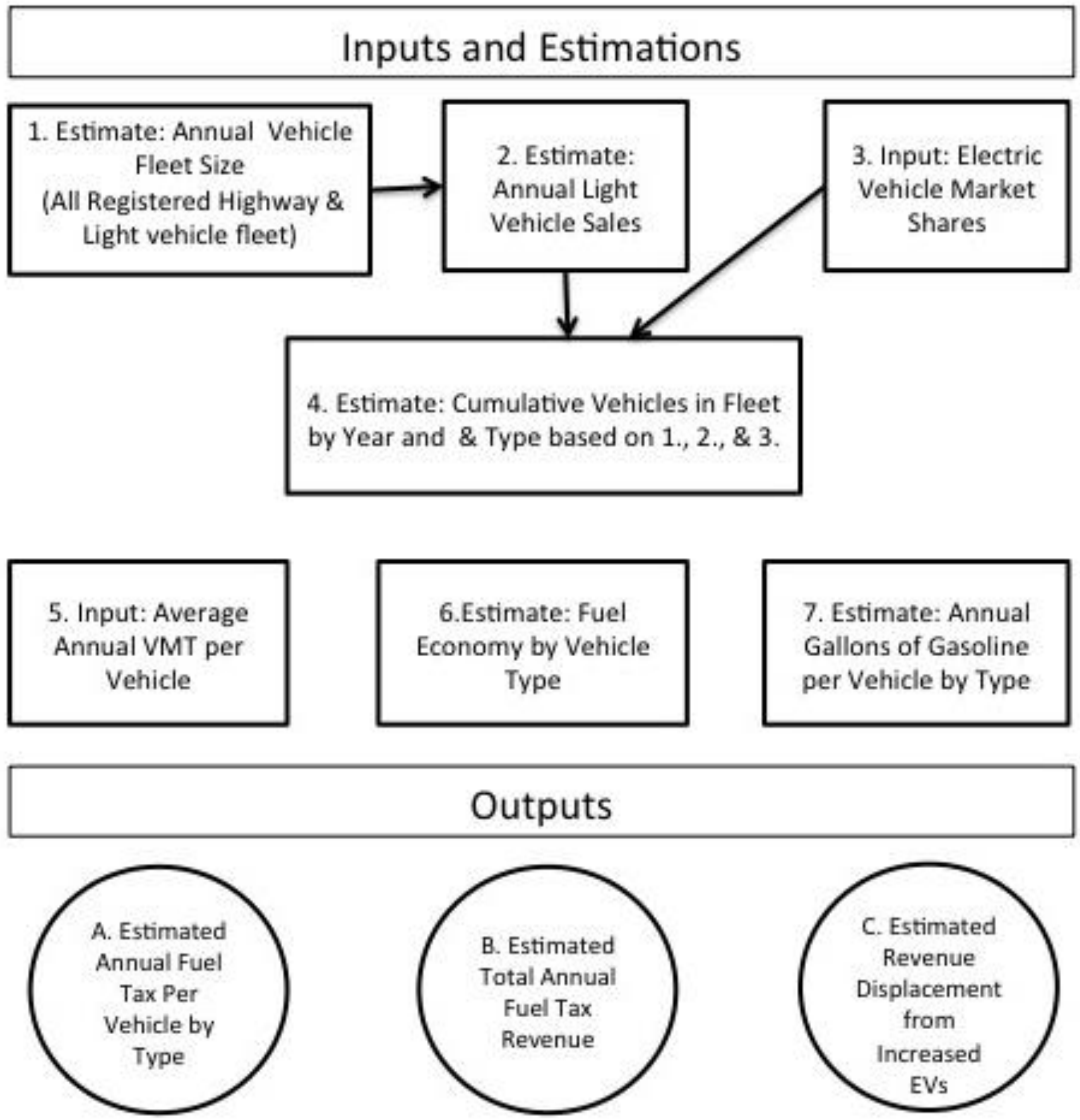


**Figure 5: Estimation overview with inputs and outputs.**

# CHAPTER 4. DATA AND EXPERIMENTAL DESIGN

The following section provides an overview of the data and assumptions used to answer the research question and calibrate and develop the model. Also an overview of the experimental design is provided.

## 4.1 Data

Data came from various reporting agencies; for each dataset, data for years 1990 through 2010 were used. Data, publications, and sources are listed in Table 1.

**Table 1: Data and Sources**

| **Data** | **Source** |
|---|---|
| Number of registered highway vehicles by year (1990–2010) | FHWA, Office of Highway Policy Information, Highway Statistics Series, Annual Publications *(6)* |
| Number of light-duty vehicles in fleet (1990–2010) | FHWA, Office of Highway Policy Information, Highway Statistics Series, Annual Publications *(7)* |
| Annual light vehicle sales (1990–2010) | Federal Reserve Economic Data *(8)* |
| Annual vehicle miles traveled (1990–2010) | FHWA, Office of Highway Policy Administration, Travel Monitoring and Traffic Volume *(9)* |
| Annual manufacture year fuel economy (1990–2010) | EPA, Office of Transportation and Air Quality *(10)* |

### 4.1.1. Annual Fleet Size

Annual registered highway vehicles and total light vehicles in the fleet were projected using the mean annual fleet growth rate (1.3%). Data shows that in the years 1990 through 2010, the fleet experienced 4 years of negative growth and 15 years of positive growth and that light vehicles made up, on average, 93.9% of all registered highway vehicles (mean: 93.9%, minimum: 92.1%, maximum: 94.6%). Fleet size projections result in 305 million expected light vehicles in the highway fleet in year 2030, which matches projections from studies from Becker, Sidhu, and Tenderich (*11)* that show 300 to 350 million light vehicles in that year. Year 2050 projections show 396 million expected light vehicles in the fleet, which match projections from a study completed by the National Academies, which shows 350 to 400 million light vehicles in the fleet in 2050 *(12).* Figure 6 shows actual fleet size for years 1990 through 2010 and projections for 2011 through 2050.

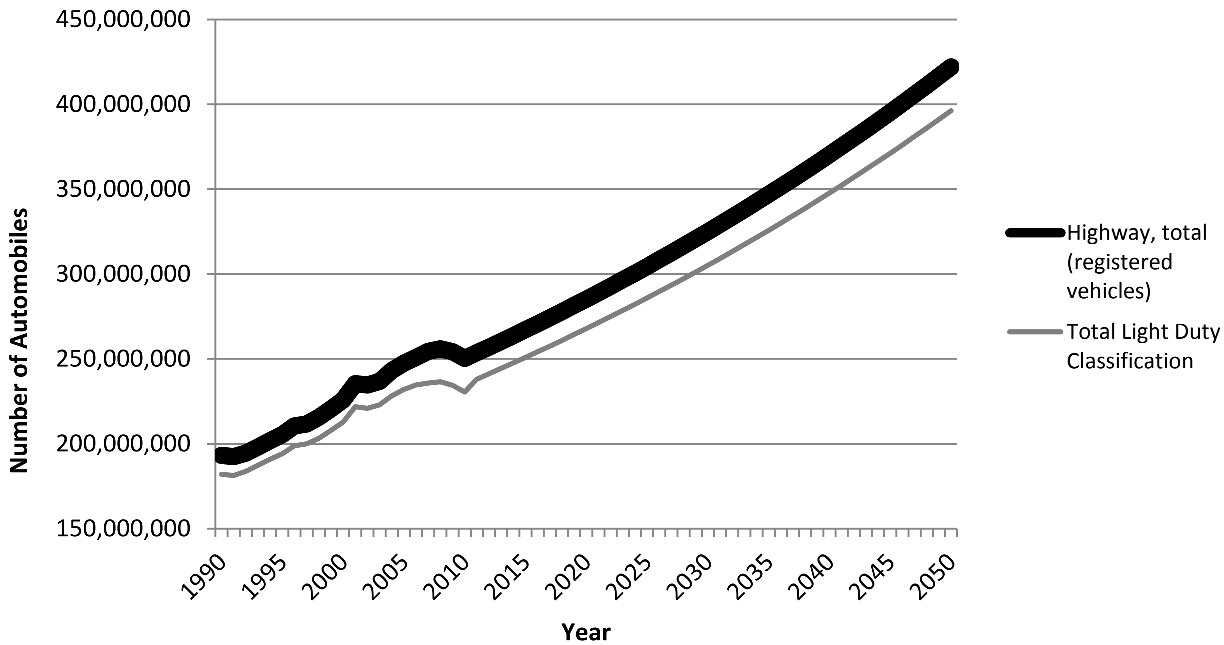


**Figure 6: Number of registered highway vehicles and light vehicles by year, actual and projected, 1990–2050**

#### 4.1.2. Annual Vehicle Sales

Annual light vehicle sales were estimated based on total fleet size projections and assume that, on average, a vehicle will remain in the light vehicle fleet for 10 years after its manufacture year based on data on vehicle turnover time (length of time that the vehicle remains in the fleet) from Polk & Co. *(13*). Figure 7 shows actual annual light vehicle sales for years 1990 through 2010 and projected sales for 2011 through 2050. Light vehicle sales appeared to increase annually from 1990 to 2007, and during the recession, vehicle sales declined. Data from 2010 shows that annual sales were estimated at 11.6 million vehicles, and in 2011 annual sales were estimated at 12.7 million vehicles (9.5% increase) *(8).*

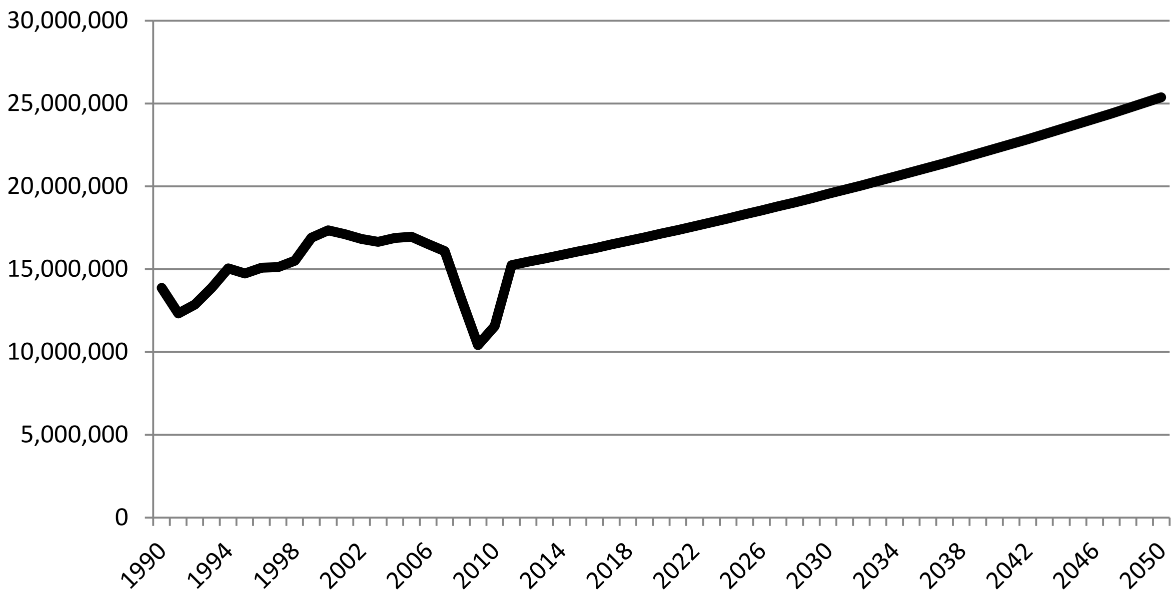


**Figure 7: Actual and projected light vehicle sales (1990–2050)**

### 4.1.3. EV Market

Future EV market shares come from various industry studies, which give expected percentage of annual sales that will be EVs or total number of expected of vehicles sold in a year. Sales projections are given for hybrid and all-electric vehicles, with an emphasis on hybrid vehicles that are expected to dominate the EV market. JD Power and Associates projects that 94.1% of 2020 EV sales will be hybrids *(14)*. Exxon Mobile has predicted that hybrids will also make up the vast majority of the EV market *(15)*, and Bloomberg New Energy Finance projections show a majority of the EV market composed of hybrids *(16)*.

### 4.1.4. Cumulative Vehicles in Fleet

The number of vehicles remaining in the light vehicle fleet in a given year was estimated using a decay rate that would give an average life of a vehicle of 10 years. Supporting research by Polk & Co. shows that the average age of vehicles has been increasing and has changed from 8.5 years in 1995 to 10.6 years in 2010 *(13)*.

#### 4.1.5. Average Annual Vehicle Miles Traveled (VMT)

Average annual VMT per vehicle were calculated based on VMT data from the Federal Highway Administration (FHWA). The average VMT per vehicle, 11,729 miles, was used across all data years in this study. Previous research supports the notion that VMT has, or will continue to, plateau or that growth will be modest *(17) (18).* As a result, VMT per vehicle was assumed to remain constant for all vehicle types and years of the study, 2011 through 2050. Figure 8 shows VMT per vehicle per year and the average VMT per vehicle for years 1990–2010. Additionally, Figure 9 shows the relationship between VMT and total fuel taxes paid per vehicle in years 1990 through 2010. Generally, as VMT increases per driver, so does the amount of fuel taxes that are paid.

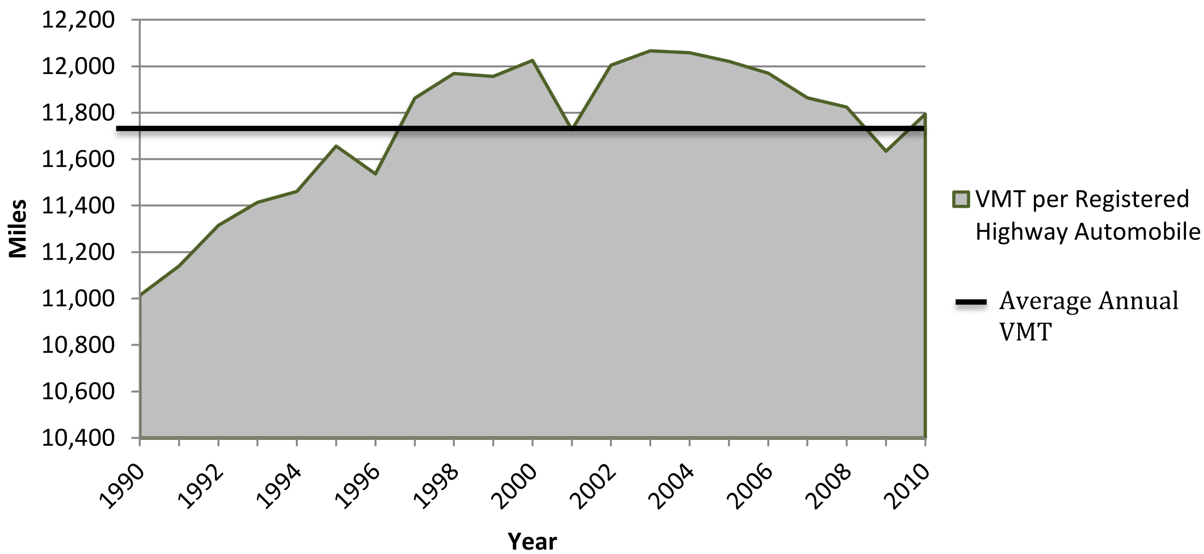


**Figure 8: VMT per registered highway automobile (1990–2010)**

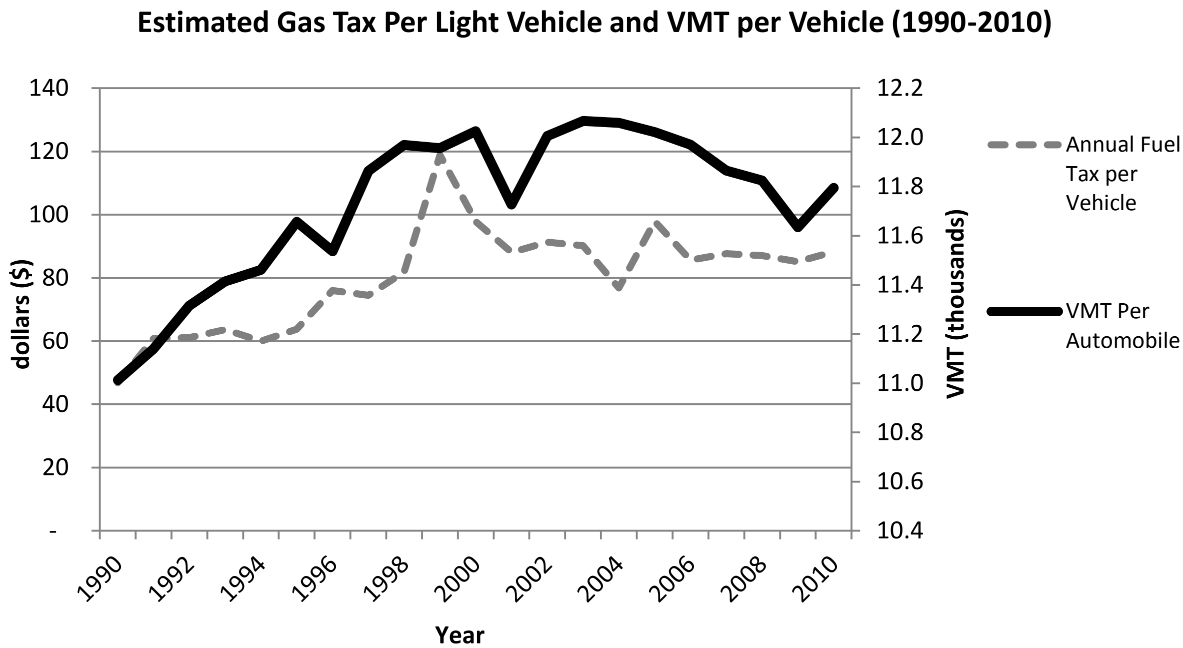


**Figure 9: Estimated gas tax per light vehicle and VMT per vehicle (1990–2010)**

### 4.1.6. Fuel Economy

Light vehicle fuel economy data for years 1990–2010 comes from the EPA. For future estimates of fuel economy of both EVs and ICEs, projections were used from various fuel economy projections but most notably from Burke and Zhao at the University of California, Davis *(19).* In summary, the projections from this study show that the fuel economy of hybrid EVs may be greater than 85.5 MPG in 2050 for mid-size hybrid electric cars and greater than 58 MPG for compact hybrid electric sport utility vehicles (SUVs) in the same year. A more detailed overview of fuel economy estimates are given in the tables in this section.

All EVs in this study were assumed to have the fuel economies predicted for hybrid EVs since hybrids are expected to dominate the EV market. Advanced ICE vehicles are projected to have a fuel economy of greater than 54.3 MPG for mid-size cars and 40.1 MPG for compact SUVs in 2050. Average fuel economy is estimated for each annual fleet based on the assumption that there will be slow replacement of vehicles and that older vehicles remaining in the fleet will have lower fuel economies than newly entering ones. Also a weighted average of fleet fuel economy was calculated based on expected proportions of vehicles in the fleet, i.e., passenger cars and

SUVs. Proportions of passenger cars and SUVs were taken from a study by Musti and Kockelman, which projects the proportions of these vehicle types it the fleet in 2034 *(20).*

Tables 2–5 show fuel economy projections by vehicle technology (EV and ICE) and by vehicle type (midsize car and compact SUV). Projections come from four sources: UC Davis (UCD), the Department of Energy (DOE), Massachusetts Institute of Technology (MIT), and the National Research Council (NRC). Fuel economy projections only extend to year 2045, and fuel economy for vehicles manufactured in years 2046–2050 were assumed to be constant and equivalent to 2045 estimates for both EVs and ICE vehicles. Fuel economy projections for year 2050 were not available.

Fuel economy is usually determined by driving vehicles through various driving conditions called *drive schedules,* which are determined by the EPA. Fuel economy estimates were given for the following two drive schedules, which are described below.

- The Federal Urban Drive Schedule (FUDS), which simulates city driving conditions where a vehicle is started with the engine cold and driven in rush hour, stop-and-go conditions.
- The Federal Highway Drive Schedule (FHDS), which simulates interstate and rural highway driving conditions for longer trips with free-flow traffic and a warmed-up engine.

**Table 2: Hybrid Electric Midsize Passenger Car Fuel Economy**

| **Year** | **Source** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **UCD** | | **DOE** | | **MIT** | | **NRC** | |
| **Drive Scenario** | **FUDS** | **FHWDS** | **FUDS** | **FHWDS** | **FUDS** | **FHWDS** | **FUDS** | **FHWDS** |
| **2015** | 73.3 | 74.1 | 73 | 61 | - | - | - | - |
| **2030** | 85.7 | 84 | 84 | 82 | 95 | 88 | - | - |
| **2045** | 87.9 | 89.2 | 89 | 88 | - | - | - | - |

**Table 3: Hybrid Electric Compact SUV Fuel Economy**

| Year | Source | | | |
|---|---|---|---|---|
| | UCD | | DOE | |
| **Drive Scenario** | **FUDS** | **FHWDS** | **FUDS** | **FHWDS** |
| **2015** | 52.7 | 44.7 | 54.6 | 46.4 |
| **2030** | 58.7 | 51 | 61 | 51 |
| **2045** | 61 | 54.1 | 63 | 54 |

**Table 4: Advanced ICE Midsize Passenger Car Fuel Economy**

| Year | Source | | | | | |
|---|---|---|---|---|---|---|
| | UCD | | DOE | | MIT | |
| **Drive Scenario** | **FUDS** | **FHWDS** | **FUDS** | **FHWDS** | **FUDS** | **FHWDS** |
| **2015** | 41.4 | 62.3 | 29 | 47 | | |
| **2030** | 47.4 | 73.3 | 33 | 54 | 42 | 68 |
| **2045** | 48.9 | 77.1 | 34 | 57 | | |

**Table 5: ICE Compact SUV Fuel Economy**

| Year | Source | | | |
|---|---|---|---|---|
| | UCD | | DOE | |
| **Drive Scenario** | **FUDS** | **FHWDS** | **FUDS** | **FHWDS** |
| **2015** | 34 | 44.4 | 24 | 34 |
| **2030** | 38.9 | 50.3 | 27 | 38 |
| **2045** | 40.2 | 53 | 28 | 39 |

Figure 10 shows estimated full fleet fuel economy for both vehicle technologies for each year, 2011 through 2050. Gains in fuel economy are expected to be greater in the first 10 years of the study and more subtle in later years.

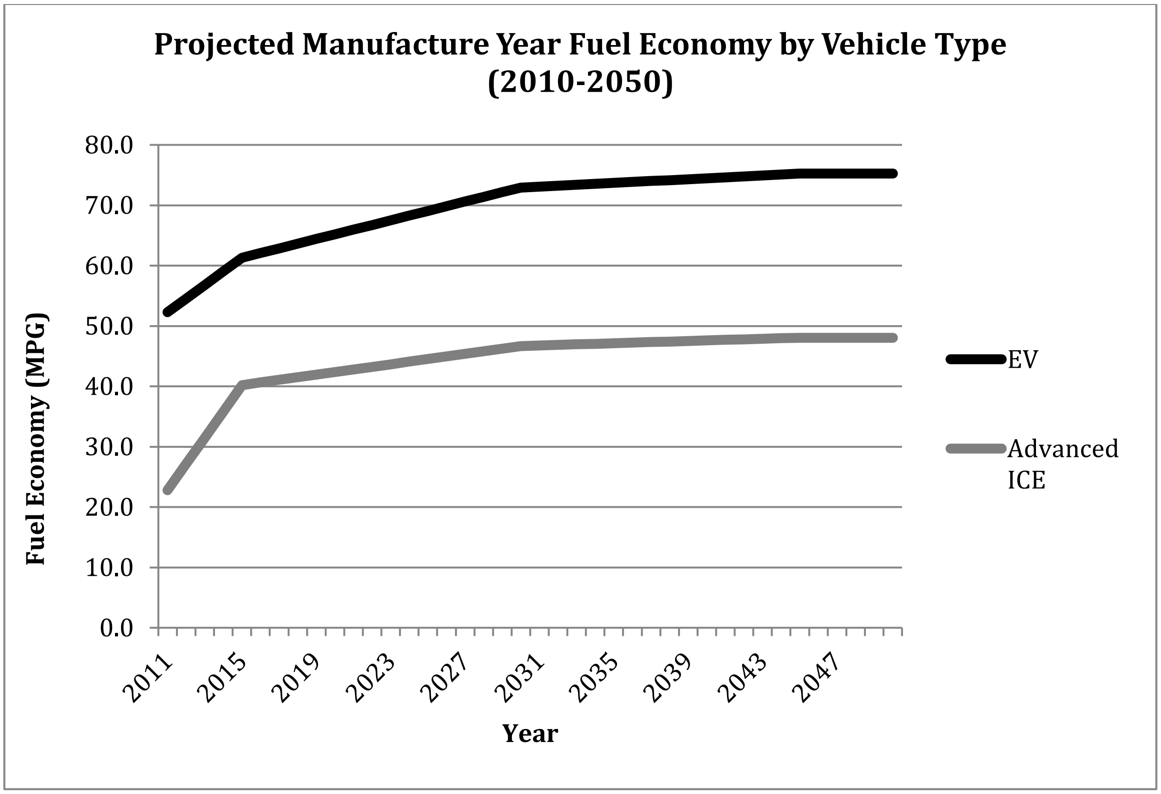


**Figure 10: Projected average fuel economy by vehicle technology, 2011–2050**

### 4.1.7. Estimated Annual Gasoline Consumption

Gallons of gasoline consumed per vehicle were calculated using the previously mentioned annual VMT estimates and fuel economy projections. Calculations of gallons of gasoline consumed for 1990–2010 data show average annual consumption of 586 gallons of gasoline. EPA estimates show the expected average annual gallons of gasoline consumed per passenger vehicle at 581 gallons per passenger car *(21)*.

## 4.2. MODEL EVALUATION

The estimation equations fir growth rate and number of vehicle sales were used against historical data to assess whether they could recover the original data, which was used in order to develop them. For example, the average annual vehicle fleet growth rate was applied to the initial year of the historic data on vehicle fleet size in order to assess how well it would capture the true vehicle fleet size in years 1990 through 2010, the years for which historical data was available. This provided fleet size estimates for years 1990 through 2010 that were 2% below the actual number to 1% above the actual number of vehicles. For annual vehicle sales, the application of the equation to the historic sales data returned annual vehicle sales estimates that were 4% below observed sales to 1% above sales data. Finally, estimates of annual fuel tax revenue during the years for which data was available returned revenues that were higher than actual revenue number; this is most likely due to the assumption that per-vehicle VMT would plateau and remain higher than VMT per vehicle in early historic years. When adjusting for this, estimated fuel tax revenues more closely matched actual fuel tax revenues.

### 4.3 Experimental Design

In order to have a base for comparing the impact that increased numbers of EVs and advanced ICEs will have on federal fuel tax revenues, a scenario was modeled that assumed no increased market shares of EVs or increases in fuel economy. This base case was used to estimate fuel tax revenues losses as this scenario would generate the most revenue. By comparing against this base case, revenue reductions could be quantified. In addition, this allows for a comparison across all scenarios so that conclusions regarding how the rate at which EVs and advanced ICEs enter the market and affect revenues can be drawn.

# CHAPTER 5. LIGHT VEHICLE FLEET MIX PREDICTIONS 2011–2050

In total, impacts from seven market sales scenarios were estimated for years 2011 through 2050. The following section provides an overview of market sales projection from various academic studies and their resulting future light-vehicle fleet mixes.

## 5.1 EV Sales Projections

Three academic studies were chosen from the literature to inform EV sales projections for future years. These three studies are described in this chapter and details regarding their respective sales projections are described for each scenario.

### 5.1.1. Projections Based on the Center for Entrepreneurship and Technology, UC Berkeley Study

In a 2009 study that was commissioned by the Center for Entrepreneurship and Technology (CET) at the University of California, Berkeley, three scenarios were developed that predicted market adoption of EV through the year 2030 *(11).* One of the most notable facets of this study was that its projections were based on a business model with EV batteries that could be swapped out when depleted of charge at stations along highways that are similar to today's gas stations. For short distance trips, plugging into local charging stations could charge vehicles, but for long distance trips, batteries could be switched out to avoid long charge times. This model is expected to allow for a lower upfront vehicle cost to the consumer since batteries would be leased instead of purchased with the vehicle. In addition to these considerations, the total lifecycle cost of the vehicle was considered, which included fuel and maintenance costs. Competing ICE vehicle costs and future oil costs were also considered when predicting EV sales.

The following provides an overview of the three scenarios developed in the CET study. For each scenario, annual EV sales as a percent of total annual sales were reported for years 2015, 2020, 2025, and 2030.

**5.1.1.1. Scenario 1: CET 1.** Scenario 1 was based on a baseline scenario in the CET study. EV sales were based on assumptions regarding baseline oil prices reported in the EIA's 2009 Annual Energy Outlook. In year 2015, EVs are expected to comprise 3% of light vehicle sales. EVs will comprise 18% of sales in 2020, 45% of sales in 2025, and 64% of sales in 2030. For years beyond 2030 (2031–2050) in this study, 64% sales were assumed. Figure 11 shows future fleet mix.

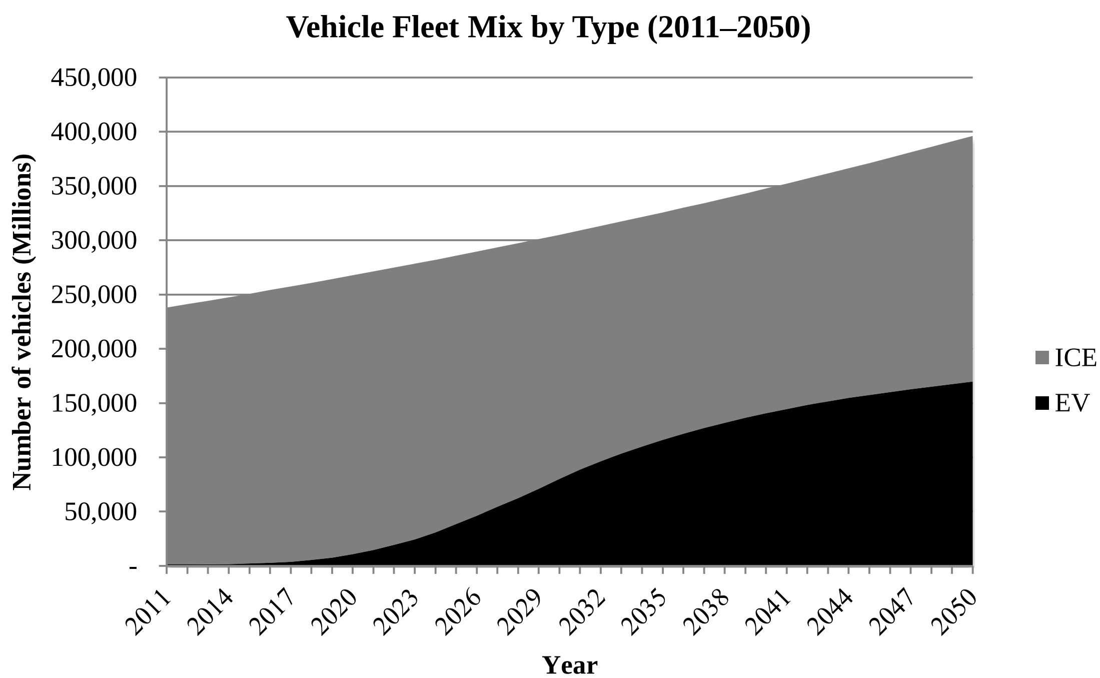


**Figure 11: Vehicle fleet mix by type (2011–2050), CET 1**

**5.1.1.2. Scenario 2: CET 2.** For the second CET scenario, EV sales were based on high energy prices from the EIA's 2009 report. It is expected that higher gasoline costs would encourage consumers to buy more fuel efficient cars such as EVS. Accordingly, year 2015 sales projections show that EVs are expected to comprise 8% of light vehicle sales. They are estimated to comprise 33% of sales in 2020, 75% of sales in 2025, and 85% of sales in 2030. For years beyond 2030 (2031–2050) in this study, 85% sales were assumed. Figure 12 shows future fleet mixes for this scenario.

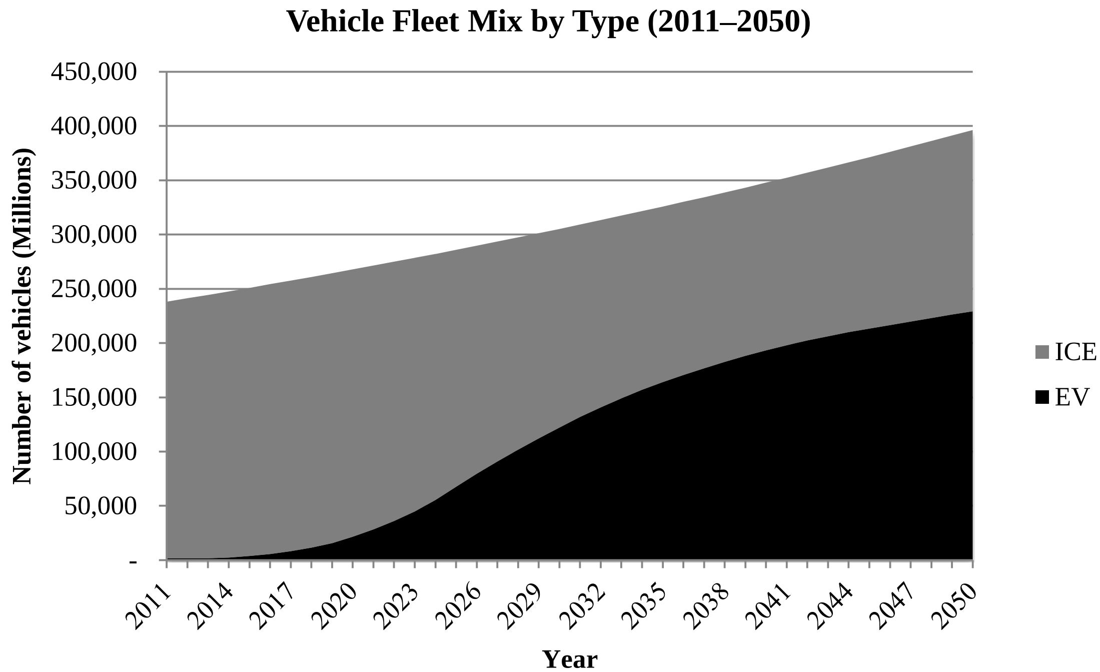


**Figure 12: Vehicle fleet mix by type (2011–2050), CET 2**

**5.1.1.3. Scenario 3: CET 3.** Oil prices under this scenario are assumed to be the same as the High Energy Price Scenario (same as CET 2) in the CET study. In addition, it was assumed that charging infrastructure network operators would subsidize EV purchases for customers. With these assumptions, higher market shares would be expected. Accordingly, year 2015 sales projections show that EVs are expected to comprise 10% of light vehicle sales. They will comprise 48% of sales in 2020, 80% of sales in 2025, and 86% of sales in 2030. For years beyond 2030 (2031–2050) in this study, 86% sales were assumed. Figure 13 shows future fleet mixes for this scenario.

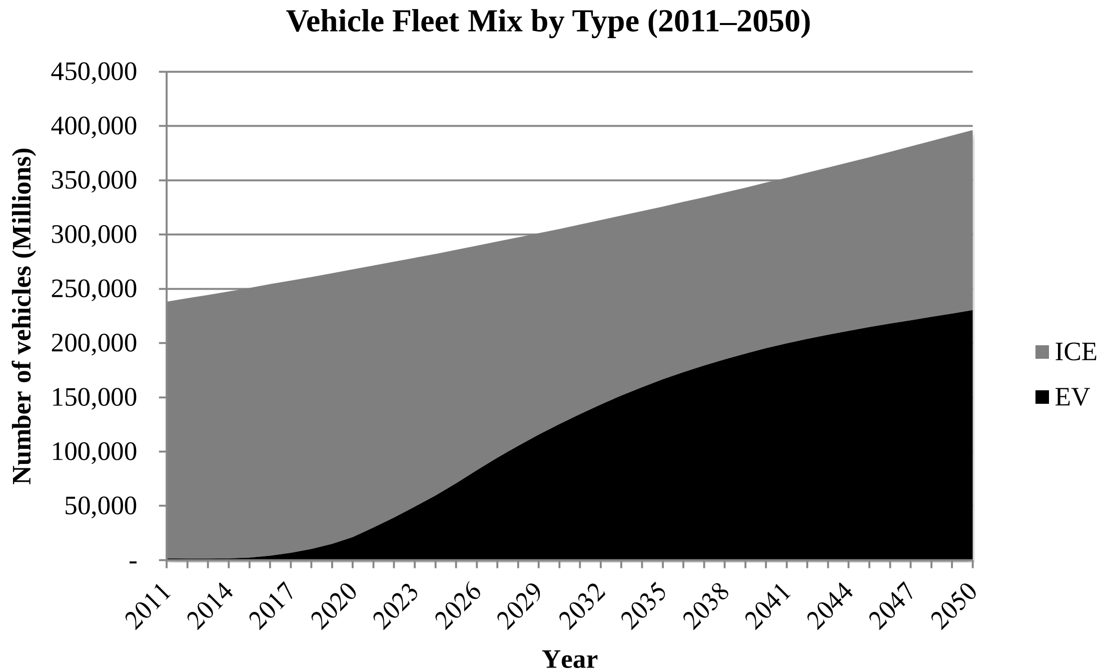


**Figure 13: Vehicle fleet mix by type (2011–2050), CET 3**

### 5.1.2. Projections Based on Massachusetts Institute of Technology Study

A 2011 study by Bastani, Heywood, and Hope from MIT contained approximate EV sales projections for years 2020, 2030, and 2050 *(22).* In addition to predicting EV sales, greenhouse gas emissions and fuel consumption reductions that would result from more fuel efficient light vehicles were estimated. The following scenario characterizes the market projections from the MIT study.

**5.1.2.1. Scenario 4: MIT 1.** Projections from the MIT study showed that EVs would comprise 12% of light vehicle sales in 2020, 21% of sales in 2030, and 40%, of sales in 2050. Figure 14 shows the estimated light vehicle fleet mix by year based on the MIT study.

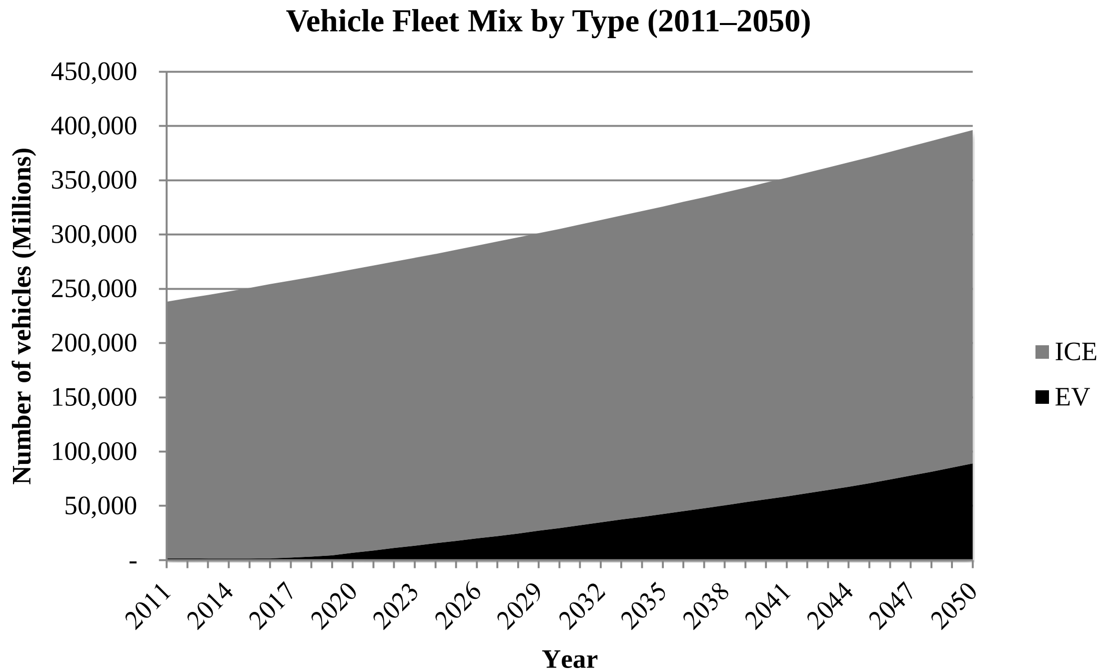


**Figure 14: Vehicle fleet mix by type (2011–2050) MIT 1**

### 5.1.3. Projections Based on National Academies Study

A 2010 study completed by the National Academies looked at the transition of the US light vehicle fleet from one dominated by ICE technologies to one that incorporates growing shares of EVs—namely plug-in hybrid EVs *(12).* The following scenarios characterize market projections from the National Academies study, which extend to 2050.

**5.1.3.1 Scenario 5: NA 1.** The first scenario characterized by the National Academies study was described as the most probable market scenario. In it, EV sales are expected to comprise 3% of light vehicles sales in year 2020 and 15% of sales in 2030. It also projected that the entire light vehicle fleet would be composed of 110 million EVs in 2050 (which could equate to 66% of 2050 light vehicle sales being EVs). Figure 15 shows the light vehicle fleet mix by year under this scenario.

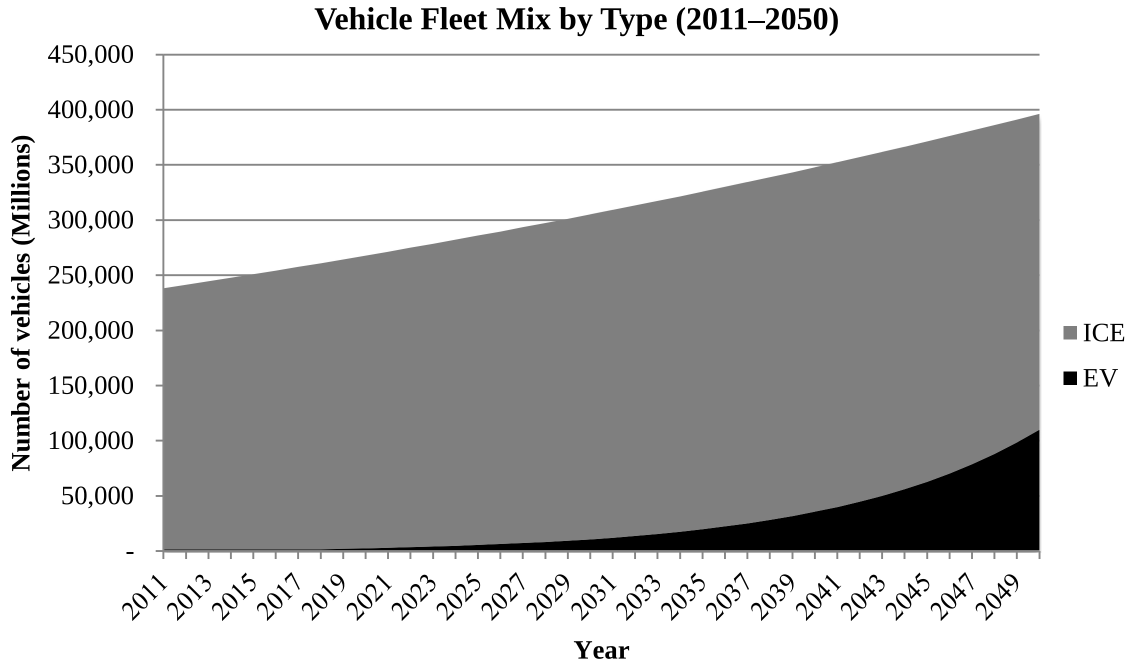


**Figure 15: Vehicle fleet mix by type (2011–2050), NA 1**

**5.1.3.2 Scenario 6: NA 2.** Maximum practical annual sales of EVs were used for this scenario based on the National Academies study. Under this scenario, it is expected that 240 million EVs will be in the light vehicle fleet in 2050. Yearly sales projections were not given in the study, but corresponding sales shares were estimated so that the fleet mix could be realized. For this study, the sales shares that would give the resulting fleet mix were approximately 10% in 2020, 45% in 2030, and 96% in years 2040 through 2050. These sales shares would give a 2050 light vehicle fleet with just above 240 million EVs, which would equate to approximately 61% of the fleet. Figure 16 shows the expected light vehicle fleet mix by year.

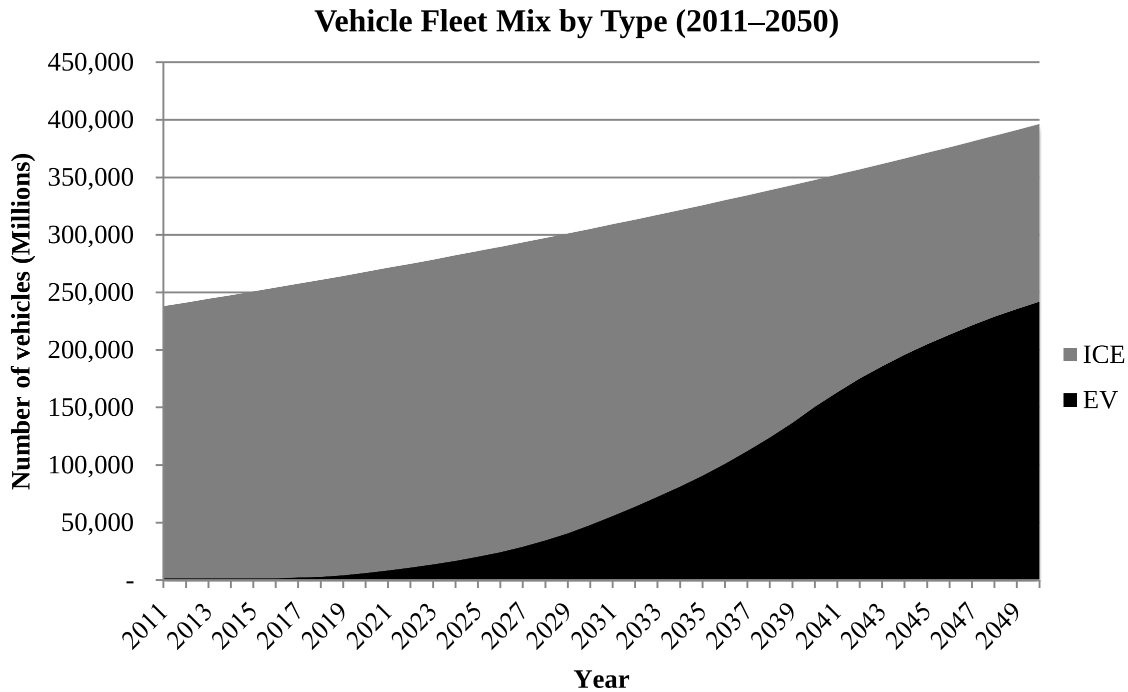


**Figure 16: Vehicle fleet mix by type (2011–2050), NA 2**

### 5.1.4. Projections Based on a Combined Scenario

The final scenario was estimated using a combination of all projected market shares from all three previously mentioned studies—the average market shares by all years was used.

**5.1.4.1. Scenario 7: Combined**. EV sales were estimated to be 20% of light vehicle sales in 2020, 47% of sales in 2030, and 61% of sales in 2050. Figure 17 shows the light vehicle fleet mix by years for the combined scenario.

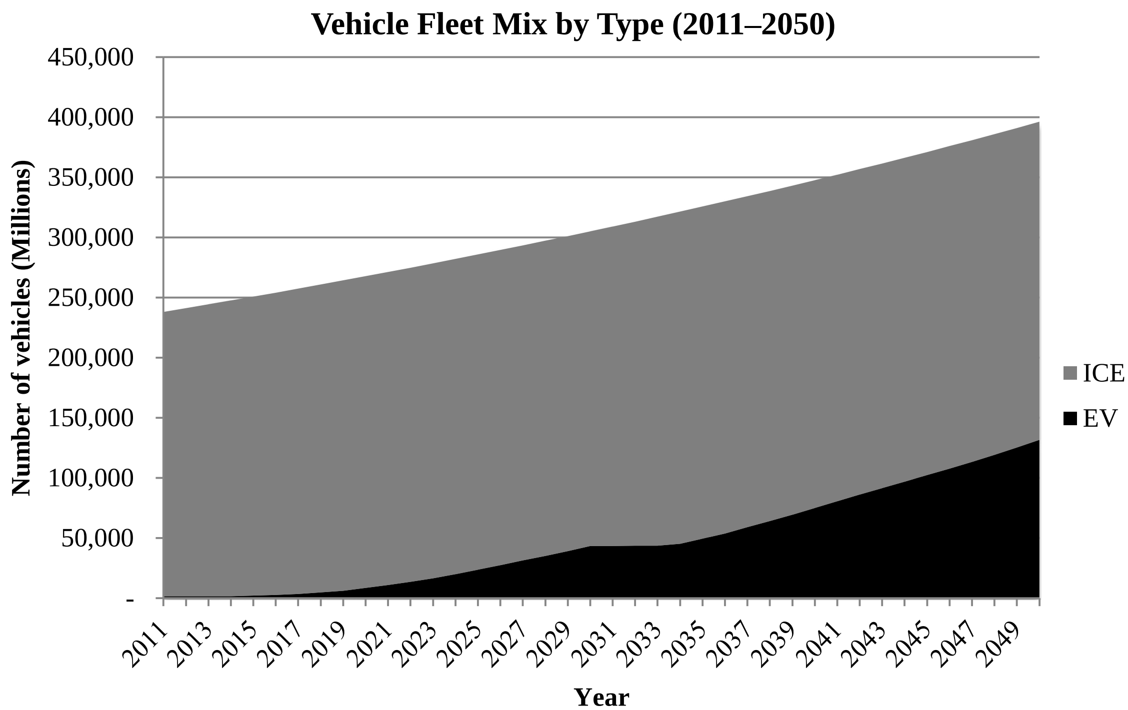


**Figure 17: Vehicle fleet mix by type (2011–2050), Combined**

### 5.2. Fleet Composition Comparisons

Table 6 shows a comparison of the light-vehicle fleet by the expected percent of the fleet that will be composed of EVs in year 2030 and 2050. In year 2030, EVs are expected to comprise 3–41% of the light vehicle fleet, with an average of 21% across all scenarios. In year 2050, the light-vehicle fleet is expected to be composed of 33–58% EVs with an average of 44% across all scenarios.

**Table 6: Comparison of EVs in Fleet by Scenario, 2030 and 2050**

| | **Year** | |
|---|---|---|
| **Scenario** | **2030 (%)** | **2050 (%)** |
| [illegible] | 26 | 50 |
| CET 2 | 40 | 58 |
| CET 3 | 41 | 58 |
| MIT 1 | 10 | 23 |
| NA 1 | 3 | 28 |
| NA 2 | 16 | 61 |
| Combined | 14 | 33 |

### 5.3. Summary

There is much uncertainty regarding how EV sales may change in the future—all projections modeled do assume that sales will increase, but at different rates. Projections with earlier and quicker sales increases show a more rapidly changing light vehicle fleet mix in coming years. Revenue impacts for each fleet mix scenario are provided in the next chapter.

# CHAPTER 6. FUEL TAX REVENUE IMPACTS FOR 2011–2050

The following section provides an overview of estimated impacts on federal fuel tax revenues for each EV market sales scenario. For each scenario, total expected fuel tax revenues from gasoline taxes were estimated, and a comparison to expected fuel tax revenue from an equivalently sized fleet composed of only advanced ICE vehicles is provided. Finally, scenarios were compared to fuel tax revenues that would be expected from an equivalently sized fleet composed of ICE vehicles only with no fuel economy advances (fuel economy for each annual fleet was assumed to remain at the current 27.3 MPG CAFE standard).

## 6.1. CENTER FOR ENTREPRENEURSHIP AND TECHNOLOGY, UC BERKELEY STUDY

The following three sections provide results of the estimated revenues from the CET-study-based scenarios described in Chapter 6.

### 6.1.1 Scenario 1: CET 1

Figure 18 shows a comparison of total expected fuel tax revenues for a fleet with increased EV market shares and an equivalently sized fleet composed of advanced ICE vehicles only. Expected fuel tax revenue in 2030 from the EV mixed fleet is $12.5 billion, compared to expected revenue from an equivalently sized fleet composed of ICE vehicles only with advanced fuel economies, which would have $13.8 billion in expected revenue. Funding from the EV mixed fleet would be equivalent to 91% of the expected revenue from the advanced ICE fleet and 55% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

In 2050, expected revenue from the EV mixed fleet would be $13.7 billion and $16.7 billion for the advanced ICE fleet. Funding from the EV mixed fleet would be equivalent to 82% of the expected revenue from the advanced ICE fleet and 46% of expected funding from an equivalently sized fleet composed of ICE vehicles only with no fuel economy improvements.

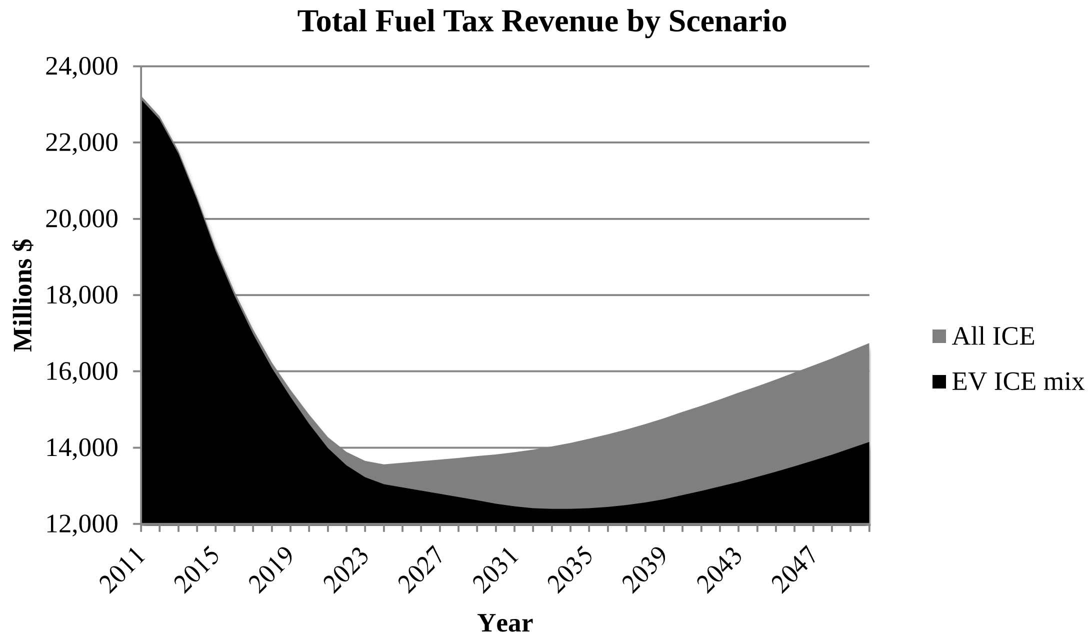


**Figure 18: Total fuel tax revenue (2011–2050), CET 1**

### 6.1.2. Scenario 2: CET 2

Figure 19 shows a comparison of total expected fuel tax revenues for a fleet with increased EV market shares and an equivalently sized fleet composed of advanced ICE vehicles only. Expected fuel tax revenue in 2030 from the EV mixed fleet is $11.8 billion, compared to expected revenue from an equivalently sized fleet composed of ICE vehicles only with advanced fuel economies, which would have $13.8 billion in expected revenue. Funding from the EV mixed fleet would be equivalent to 86% of the expected revenue from the advanced ICE fleet and 52% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

In 2050, expected revenue from the EV mixed fleet would be $13.2 billion and $16.7 for the advanced ICE fleet. Funding from the EV mixed fleet would be equivalent to 79% of the expected revenue from the advanced ICE fleet and 45% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

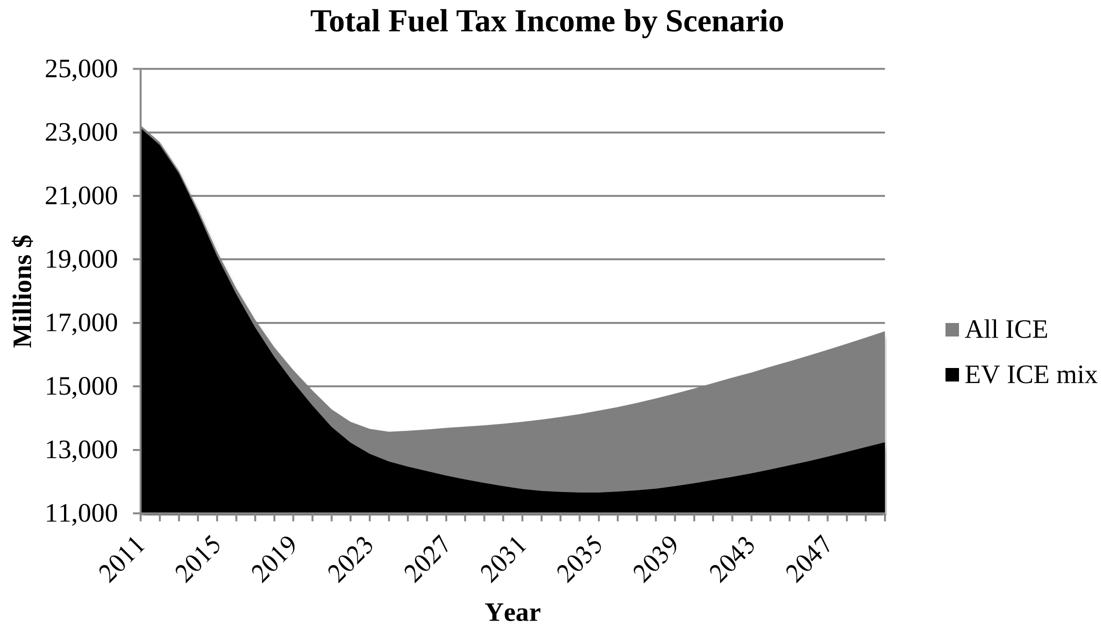


**Figure 19: Total fuel tax revenue (2011–2050), CET 2**

### 6.1.3. Scenario 3: CET 3

Figure 20 shows a comparison of total expected fuel tax revenues for a fleet with increased EV market shares and an equivalently sized fleet composed of advanced ICE vehicles only. Expected fuel tax revenue in 2030 from the EV mixed fleet is $11.8 billion, compared to expected revenue from an equivalently sized fleet composed of ICE vehicles only with advanced fuel economies, which would have $13.8 billion in expected revenue. Funding from the EV mixed fleet would be equivalent to 85% of the expected revenue from the advanced ICE fleet and 52% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

In 2050, expected revenue from the EV mixed fleet would be $13.2 billion and $16.8 billion for the advanced ICE fleet. Funding from the EV mixed fleet would be equivalent to 79% of the expected revenue from the advanced ICE fleet and 45% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

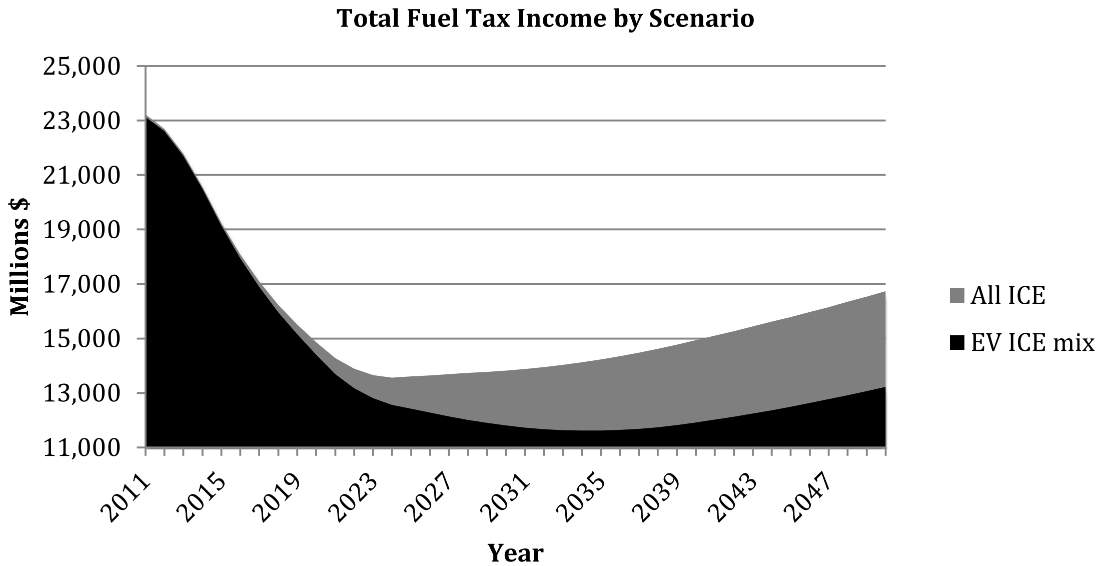


**Figure 20: Total fuel tax revenue (2011–2050), CET 3**

### 6.2. MASSACHUSETTS INSTITUTE OF TECHNOLOGY STUDY

The revenue analysis for projections based on the MIT study is provided below.

#### 6.2.1. Scenario 4: MIT 1

Figure 21 shows a comparison of total expected fuel tax revenues for a fleet with increased EV market shares and an equivalently sized fleet composed of advanced ICE vehicles only. Expected fuel tax revenue in 2030 from the EV mixed fleet is $13.3 billion, compared to expected revenue from an equivalently sized fleet composed of ICE vehicles only with advanced fuel economies, which would have $13.8 billion in expected revenue. Funding from the EV mixed fleet would be equivalent to 96% of the expected revenue from the advanced ICE fleet and 58% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

In 2050, expected revenue from the EV mixed fleet would be $15.4 billion and $16.8 billion for the advanced ICE fleet. Funding from the EV mixed fleet would be equivalent to 92% of the expected revenue from the advanced ICE fleet and 52% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

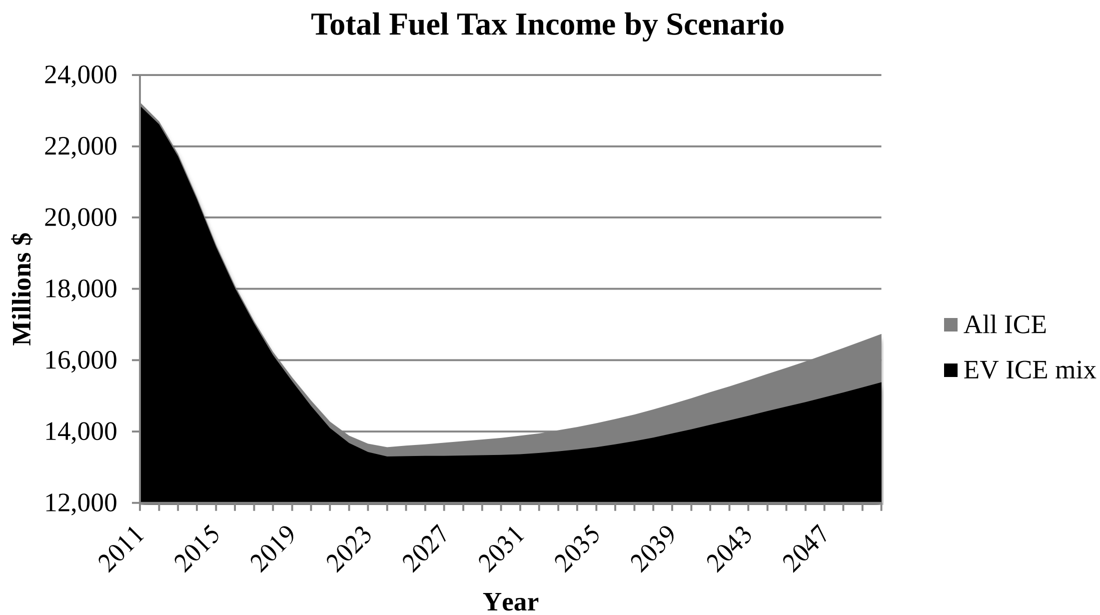


**Figure 21: Total fuel tax revenue (2011–2050), MIT 1**

### 6.3. National Academies Study

Fuel tax revenue impacts for both National-Academies-based projections are provided below.

#### 6.3.1. Scenario 5: NA 1

Figure 22 shows a comparison of total expected fuel tax revenues for a fleet with increased EV market shares and an equivalently sized fleet composed of advanced ICE vehicles only. Expected fuel tax revenue in 2030 from the EV mixed fleet is $13.7 billion compared to expected revenue from an equivalently sized fleet composed of ICE vehicles only with advanced fuel economies, which would have $13.8 billion in expected revenue. Funding from the EV mixed fleet would be equivalent to 99% of the expected revenue from the advanced ICE fleet and 60% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

In 2050, expected revenue from the EV mixed fleet would be $15.1 billion and $16.8 billion for the advanced ICE fleet. Funding from the EV mixed fleet would be equivalent to 90% of the expected revenue from the advanced ICE fleet and 51% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

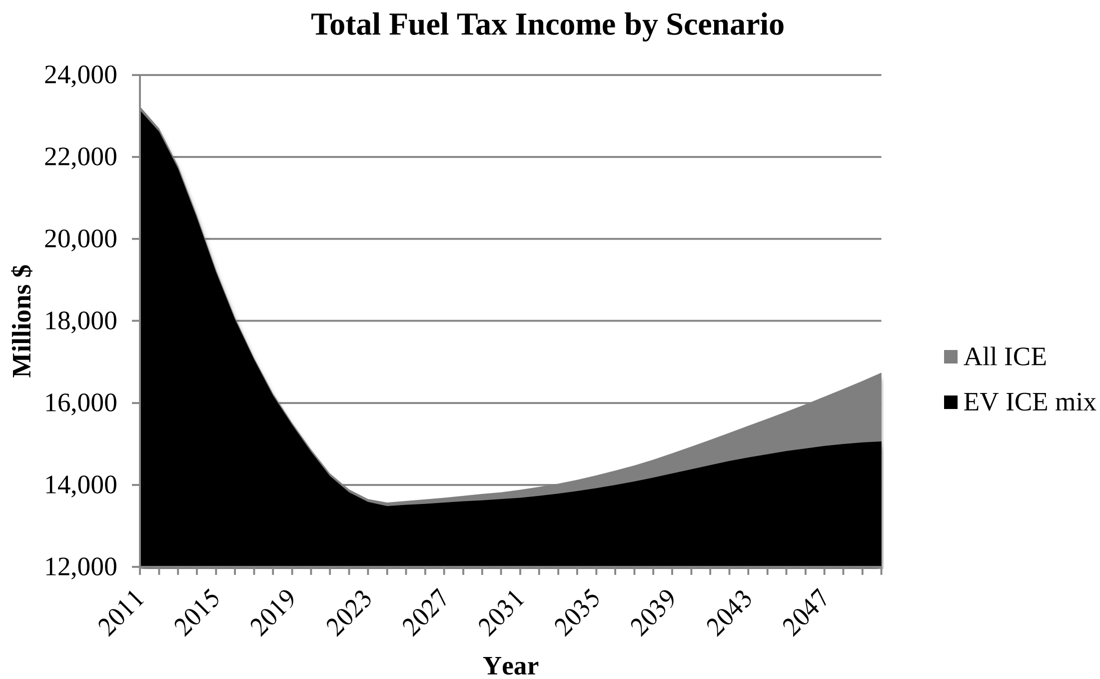


**Figure 22: Total fuel tax revenue (2011–2050), NA 1**

### 6.3.2. Scenario 6: NA 2

Figure 23 shows a comparison of total expected fuel tax revenues for a fleet with increased EV market shares and an equivalently sized fleet composed of advanced ICE vehicles only. Expected fuel tax revenue in 2030 from the EV mixed fleet is $13.0 billion, compared to expected revenue from an equivalently sized fleet composed of ICE vehicles only with advanced fuel economies, which would have $13.8 billion in expected revenue. Funding from the EV mixed fleet would be equivalent to 94% of the expected revenue from the advanced ICE fleet and 57% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

In 2050, expected revenue from the EV mixed fleet would be $13.0 billion and $16.8 billion for the advanced ICE fleet. Funding from the EV mixed fleet would be equivalent to 78% of the expected revenue from the advanced ICE fleet and 44% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

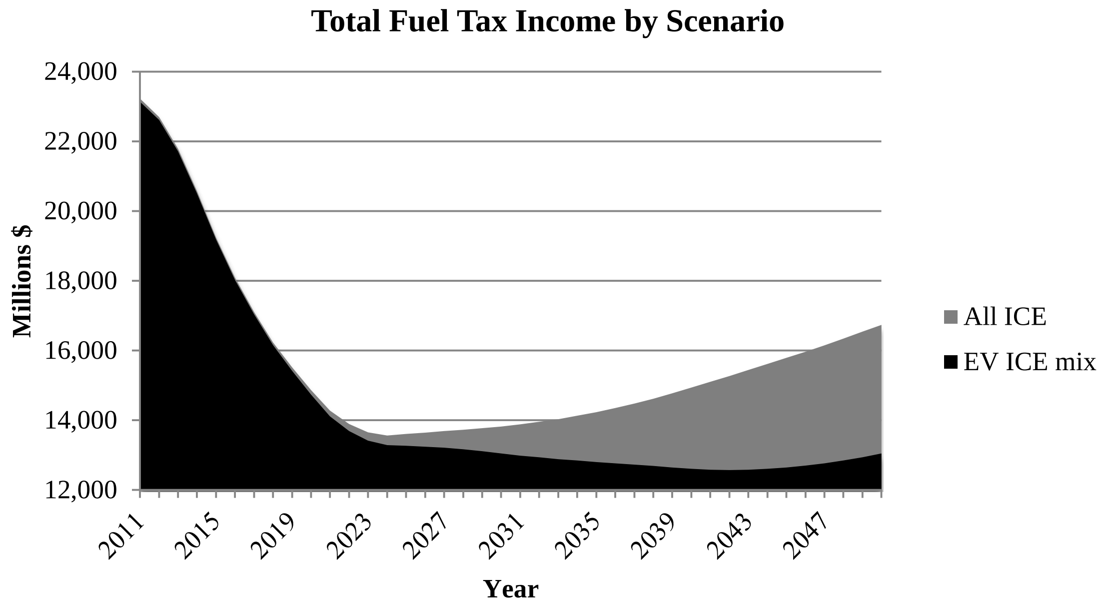


**Figure 23: Total fuel tax revenue (2011–2050), NA 2**

## 6.4. COMBINED SCENARIO

Expected fuel tax revenues from the combined scenario, which is a blend of all three studies, is presented in the next section.

### 6.4.1. Scenario 7: Combined

Figure 24 shows a comparison of total expected fuel tax revenues for a fleet with increased EV market shares and an equivalently sized fleet composed of advanced ICE vehicles only. Expected fuel tax revenue in 2030 from the EV mixed fleet is $13.1 billion, compared to expected revenue from an equivalently sized fleet composed of ICE vehicles only with advanced fuel economies, which would have $13.8 billion in expected revenue. Funding from the EV mixed fleet would be equivalent to 95% of the expected revenue from the advanced ICE fleet and 57% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

In 2050, expected revenue from the EV mixed fleet would be $14.7 billion and $16.8 billion for the advanced ICE fleet. Funding from the EV mixed fleet would be equivalent to 88% of the expected revenue from the advanced ICE fleet and 50% of expected funding from an equivalent size fleet composed of ICE vehicles only with no fuel economy improvements.

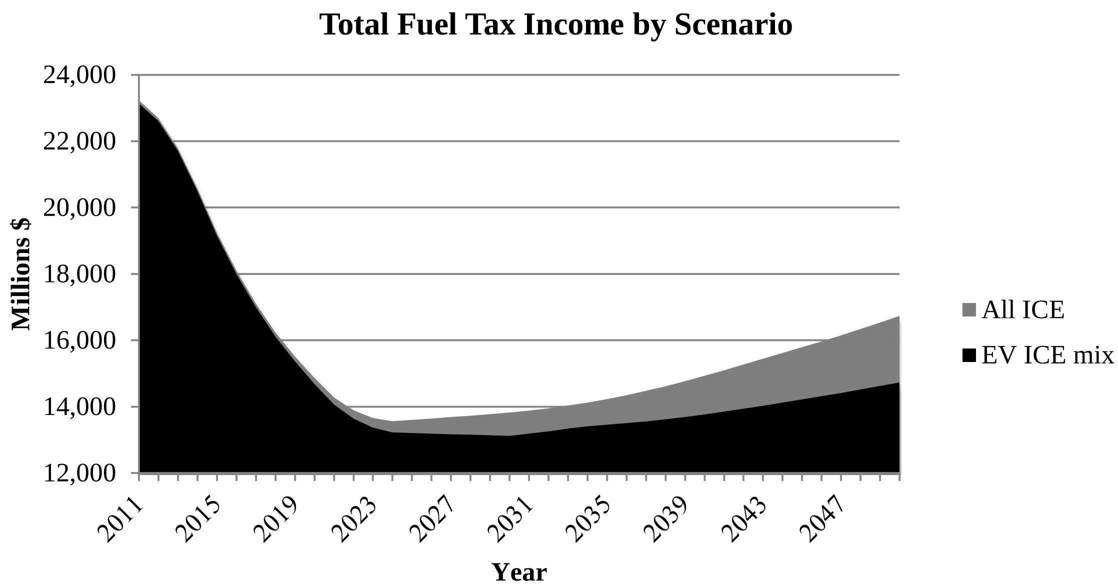


**Figure 24: Total fuel tax revenue (2011–2050), Combined**

### 6.5. Revenue Comparison

A comparison of expected revenue for all seven scenarios for benchmark years 2030 and 2050 is provided in the next section. The following three comparisons were used to frame the impact on fuel tax revenues due to increased shares of EVs, advanced ICE vehicles, or both.

- Comparison of revenues from a light vehicle fleet with increased EVs and advanced ICEs against an all advanced ICE fleet
- Comparison of revenues from a light vehicle fleet with increased EVs and no ICE advances against an all ICE fleet with no fuel economy advances
- Comparison of revenue from a light vehicle fleet with all advanced ICEs against an all ICE fleet with no advances

### 6.5.1. 2030 Revenue Comparisons

Table 7 shows expected fuel tax revenue in year 2030 by market scenario and fleet mix. A comparison of expected funding in year 2030 to other market scenarios and fleet mixes is provided in Table 8. Scenario 3 (CET 3) is expected to have the largest impact on funding and is characterized as having 86% EV sales by 2050. The vehicle fleet mix in in this scenario is expected to generate only 85% of funding that would be expected from a fleet with only advanced ICE vehicles. The fleet mix under Scenario 5 (NA 2) would have smallest impact on fuel tax—this scenario, which is based on the National Academies' "most practical" scenario, would have the highest expected revenue generation of all other scenarios with increased EV shares.

**Table 7: Expected Revenue by Scenario and Fleet Mix in 2030, $millions**

| Scenario | EV Mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 12,529 | 13,823 | 22,903 |
| 2. CET 2 | 11,853 | 13,823 | 22,903 |
| 3. CET 3 | 11,804 | 13,823 | 22,903 |
| 4. MIT1 | 13,347 | 13,823 | 22,903 |
| 5. NA 1 | 13,653 | 13,823 | 22,903 |
| 6. NA 2 | 13,048 | 13,823 | 22,903 |
| 7. Combined | 13,123 | 13,823 | 22,903 |

Table 8 shows expected funding ratios between fleets; these ratios provide an indication of the percentage of funds that are expected to be lost due to EV and ICE increased shares. In 2030, 1.2–14.6% of funds may be lost if increased shares of both EVs and advanced ICEs are realized. In the case that increased shares of EVs are introduced into the light vehicle fleet but no fuel economy advances are realized in ICE vehicles, 40.4–48.5% of fuel tax revenues may be lost. And finally, in the case that no increased shares of EVs are introduced into the fleet, but advances in ICE vehicle fuel economy are realized, roughly 39.6% of fuel tax revenues will be lost.

**Table 8: Expected Funding Ratios by Fleet Mix for Comparable Fleet Sizes, 2030**

| Scenario | EV mix/ Advanced ICE | EV mix/ ICE no advances | ICE Advanced/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.906 | 0.547 | 0.604 |
| 2. CET 2 | 0.857 | 0.518 | 0.604 |
| 3. CET 3 | 0.854 | 0.515 | 0.604 |
| 4. MIT 1 | 0.966 | 0.583 | 0.604 |
| 5. NA 1 | 0.988 | 0.596 | 0.604 |
| 6. NA 2 | 0.944 | 0.570 | 0.604 |
| 7. Combined | 0.949 | 0.573 | 0.604 |

### 6.5.2. 2050 Revenue Comparisons

Table 9 shows expected fuel tax revenue in year 2050 by market scenario and fleet mix. A comparison of expected funding in year 2050 to other market scenarios and fleet mixes is provided in Table 10. Scenario 6 (NA 2) is expected to have the largest impact on funding and is characterized as having 96% EV sales by 2050. The vehicle fleet mix in this scenario is expected to generate only 78% of funding that would be expected from a fleet with only advanced ICE vehicles. The fleet mix under Scenario 4 (MIT 1) would have the smallest impact on fuel tax—this scenario, which is based on projections from MIT, suggests light vehicle sales in 2050 would be composed of 40% EVs. In this scenario approximately 92% of funding that would be expected from a fleet with only advanced ICE vehicles would be generated.

**Table 9: Expected Revenue by Scenario and Fleet in 2050, $millions**

| Scenario | EV mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 13,704 | 16,739 | 29,741 |
| 2. CET 2 | 13,242 | 16,739 | 29,741 |
| 3. CET 3 | 13,224 | 16,739 | 29,741 |
| 4. MIT 1 | 15,379 | 16,739 | 29,741 |
| 5. NA 1 | 15,061 | 16,739 | 29,741 |
| 6. NA 2 | 13,047 | 16,739 | 29,741 |
| 7. Combined | 14,730 | 16,739 | 29,741 |

Table 10 shows expected funding ratios between fleets in 2050; these ratios provide an indication of the percentage of funds that are expected to be lost due to increased shares of EVs and ICEs. In 2050, 18.1–22.1% of funds may be lost if both, increased shares of EVs and advanced ICEs, are realized. If increased shares of EVs are introduced into the light vehicle fleet but no fuel economy advances are realized in ICE vehicles, 48.3–56.1% of fuel tax revenues may be lost. And finally, in the case that no increased shares of EVs are introduced into the fleet, but advances in ICE vehicle fuel economy is realized, roughly 43.7% of fuel tax revenues will be lost.

**Table 10: Expected Funding Ratios by Fleet Mix for Comparable Fleet Sizes, 2050**

| Scenario | EV mix/ Advanced ICE | EV mix/ ICE no advances | ICE Advanced/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.819 | 0.461 | 0.563 |
| 2. CET 2 | 0.791 | 0.445 | 0.563 |
| 3. CET 3 | 0.790 | 0.445 | 0.563 |
| 4. MIT 1 | 0.919 | 0.517 | 0.563 |
| 5. NA 1 | 0.900 | 0.506 | 0.563 |
| 6. NA 2 | 0.779 | 0.439 | 0.563 |
| 7. Combined | 0.880 | 0.495 | 0.563 |

### 6.5.3. Cumulative Revenue Comparisons through 2030 and 2050

The following section provides an analysis of the cumulative impact on fuel tax revenue from increased shares of EVs and advanced ICE vehicles in the light vehicle fleet. Cumulative expected revenue impacts are shown for benchmark years 2030 and 2050.

**6.5.3.1 2030 Cumulative Revenue Comparisons.** Table 11 shows cumulative expected fuel tax revenues by scenario for benchmark years 2030 and 2050. Cumulative fuel tax revenues by 2030 are expected to be between $312 billion and $325 billion if increased shares of EVs and advances in ICE fuel economy are realized. If no increases in EV shares occur, less than $327 billion in revenue would be generated from fuel taxes from 2011 through 2050. Finally, in the case of no increases in EV shares and no increases in ICE fuel economy, roughly $422 billion in fuel tax revenue would be generated from 2011 through 2050.

**Table 11: Cumulative Fuel Tax Revenue by Scenario in 2030, $millions**

| Scenario | EV mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 318,431 | 326,991 | 422,334 |
| 2. CET 2 | 312,598 | 326,991 | 422,334 |
| 3. CET 3 | 312,266 | 326,991 | 422,334 |
| 4. MIT 1 | 322,980 | 326,991 | 422,334 |
| 5. NA 1 | 325,355 | 326,991 | 422,334 |
| 6. NA 2 | 322,080 | 326,991 | 422,334 |
| 7. Combined | 321,539 | 326,992 | 422,334 |

Table 12 shows cumulative expected fuel tax revenue losses for years 2011 through 2030. For all scenarios that model increased EV shares, Scenario 3 (CET 3) is expected to have the biggest impact on revenue with $14.4 billion in losses through 2030 (when compared to a fleet of all ICEs with advanced fuel economy). When comparing the impacts that increased fuel economy may have on funding, the difference in two fleets with ICE vehicles only—one with advanced ICEs and one without—nearly $95 billion in cumulative fuel tax revenue losses could be expected from 2011 through 2050.

**Table 12: Cumulative Fuel Tax Revenue Losses by Scenario in 2030, $millions**

| Scenario | EV mix/ Advanced ICE | EV mix/ICE no advances | Advanced ICE/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 8,560 | 103,902 | 95,342 |
| 2. CET 2 | 14,393 | 109,735 | 95,342 |
| 3. CET 3 | 14,725 | 110,067 | 95,342 |
| 4. MIT 1 | 4,011 | 99,353 | 95,342 |
| 5. NA 1 | 1,636 | 96,978 | 95,342 |
| 6. NA 2 | 4,911 | 100,253 | 95,342 |
| 7. Combined | 5,453 | 100,795 | 95,342 |

Finally, cumulative funding ratios are show in Table 13. Fleets with EV share increased will generate 95.5–99.5% of the funding that would be expected from an all advanced ICE fleet for years 2011 through 2050. These percentages drop to 73.9–77.0% when comparing fleets with increased EV fleets to an equivalently sized fleet with all ICE vehicles that do not have increased fuel economy. Lastly, a light vehicle fleet with all advanced ICEs will generate 77.4% of the fuel tax revenues that would be expected from a fleet with all ICE vehicles with no fuel economy gains.

**Table 13: Expected Cumulative Funding Ratios 2011–2030, $millions**

| Scenario | EV mix/ Advanced ICE | EV mix/ ICE no advances | ICE Advanced/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.974 | 0.754 | 0.774 |
| 2. CET 2 | 0.956 | 0.740 | 0.774 |
| 3. CET 3 | 0.955 | 0.739 | 0.774 |
| 4. MIT 1 | 0.988 | 0.765 | 0.774 |
| 5. NA 1 | 0.995 | 0.770 | 0.774 |
| 6. NA 2 | 0.985 | 0.763 | 0.774 |
| 7. Combined | 0.983 | 0.761 | 0.774 |

**6.5.3.2 2050 Cumulative Revenue Comparisons.** Table 14 shows cumulative expected fuel tax revenues by scenario for benchmark year 2050. Cumulative fuel tax revenues by 2050 are expected to be between $574 billion and $3,614 billion if those increased shares of EVs and advances in ICE fuel economy are realized. In the case of no increases in EV shares, less than $630 billion in revenue would be generated from fuel taxes from 2011 through 2050. Finally, in the case of no increases in EV shares and no increases in ICE fuel economy, roughly $949 billion in fuel tax revenue would be generated from 2011 through 2050.

**Table 14: Cumulative Fuel Tax Revenue by Scenario in 2050, $millions**

| Scenario | EV mixed | Advanced ICE | ICE no advances |
|---|---|---|---|
| 1. CET 1 | 574,138 | 629,307 | 949,227 |
| 2. CET 2 | 556,083 | 629,307 | 949,227 |
| 3. CET 3 | 555,161 | 629,307 | 949,227 |
| 4. MIT 1 | 607,197 | 629,307 | 949,227 |
| 5. NA 1 | 613,512 | 629,307 | 949,227 |
| 6. NA 2 | 577,245 | 629,307 | 949,227 |
| 7. Combined | 599,093 | 629,307 | 949,227 |

Table 15 shows cumulative expected fuel tax revenue losses for years 2011 through 2030. For all scenarios that model increased EV shares, Scenario 3 (CET 3) is expected to have the biggest impact on revenue with $74.1 billion in losses through 2050 (when compared to a fleet of all ICEs with advanced fuel economy). When comparing the impacts that increased fuel economy may have on funding, the difference in two fleets with ICE vehicles only—one with advanced ICEs and one without—nearly $319 billion in cumulative fuel tax revenue losses could be expected from 2011 through 2050.

**Table 15: Cumulative Fuel Tax Revenue Losses by Scenario in 2050, $millions**

| Scenario | EV mix/ Advanced ICE | EV mix/ICE no advances | Advanced ICE/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 55,169 | 375,090 | 319,920 |
| 2. CET 2 | 73,224 | 393,144 | 319,920 |
| 3. CET 3 | 74,146 | 394,067 | 319,920 |
| 4. MIT 1 | 22,110 | 342,030 | 319,920 |
| 5. NA 1 | 15,795 | 335,715 | 319,920 |
| 6. NA 2 | 52,062 | 371,982 | 319,920 |
| 7. Combined | 30,214 | 350,134 | 319,920 |

Finally, cumulative funding ratios are show in Table 16. Fleets with EV share increased will generate 88.2–97.5% of the funding that would be expected from an all advanced ICE fleet for years 2011 through 2050. These percentages drop to 58.5–64.6% when comparing fleets with increased EV fleets to an equivalently sized fleet with all ICE vehicles that do not have increased fuel economy. Lastly, a light vehicle fleet with all advanced ICEs will generate 66.3% of the fuel tax revenues that would be expected from a fleet with all ICE vehicles with no fuel economy gains.

**Table 16: Expected Cumulative Funding Ratios 2011–2050, $millions**

| Scenario | EV mix/ Advanced ICE | EV mix/ ICE no advances | ICE Advanced/ ICE no advances |
|---|---|---|---|
| 1. CET 1 | 0.912 | 0.605 | 0.663 |
| 2. CET 2 | 0.884 | 0.586 | 0.663 |
| 3. CET 3 | 0.882 | 0.585 | 0.663 |
| 4. MIT 1 | 0.965 | 0.640 | 0.663 |
| 5. NA 1 | 0.975 | 0.646 | 0.663 |
| 6. NA 2 | 0.917 | 0.608 | 0.663 |
| 7. Combined | 0.952 | 0.631 | 0.663 |

### 6.6 SUMMARY

The total impact that EVs and advanced ICEs will have on fuel tax funding varies according to the light vehicle fleet mix and is relative to expected funding from an all ICE fleet with no fuel efficiency gains. Regardless of increased EV sales (which are likely), fuel tax revenues will decline due to fuel economy increases alone, and the inclusion of EVs only increases the losses.

# CHAPTER 7. ALTERNATIVE FUNDING MECHANISMS

The following section provides an overview of three alternative funding solutions that states within the U.S. have considered or implemented in order to partially or wholly fill the funding gap left by fuel taxes. The three alternative funding solutions are described as 1) additional vehicle registration fees, 2) indexed fuel taxes, and 3) the vehicle-miles traveled (VMT) tax.

## 7.1 Additional Vehicle Registration Fee

Washington State has begun charging EV owners annually a $100 fee to supplement roadway funding that is traditionally obtained through the state's gas tax. In the state of Washington, the current gas tax is set at 37.5¢ per gallon and is the largest source of transportation revenue. At 37.5¢ per gallon for a vehicle owner who drives an average of 12,000 miles with a fuel economy of 23–25 MPG, the total expected tax to be paid annually would be equal to $180–$200.

Under Washington State House Bill 2660, which was passed by a vote of 56 to 42 on March 8, 2012, and went into effect February 1, 2013, drivers of EVs will pay $100 more for their annual vehicle registration *(23)*. It is important to note that this charge applies only to those with fully electric vehicles. Those with hybrid EVs, who do use gasoline partially, are not subject to this fee. One other exemption on EVs was written into this bill: all-electric vehicles that do not exceed 35 MPH are not required to pay this fee. However, in Washington's neighboring state, Oregon, state law has been passed that requires both hybrid and fully electric vehicles to pay a 4-year or 2-year registration fee of $172 or $86 respectively.

The new registration fee has been met with multiple arguments, which are summarized below.

> ***i.*** Those that support the law believe that while the EVs are good for the environment, they do still cause the same amount of wear and tear on infrastructure as non-EVs; therefore, they should still be paying *(24)*. While the upfront cost of the registration may be a shock to vehicle owners at first, over the life of the vehicle, owners should still see savings due to gasoline cost savings and in some instances the fee is more than offset by available state and federal tax breaks and incentives.

***ii.*** Some opponents argue that the fee may be discouraging to early adopters of EVs and discourage cleaner fuels while other opponents point out that they are already paying taxes on the electricity used to charge the vehicles *(24).*

Language from State House Bill 2660 regarding special provisions regarding the use and distribution of funds under this law is provided here *(23).*

*(a) The fee under this section is imposed to provide funds to mitigate the impact of vehicles on state roads and highways and for the purpose of evaluating the feasibility of transitioning from a revenue collection system based on fuel taxes to a road user assessment system, and is separate and distinct from other vehicle license fees. Proceeds from the fee must be used for highway purposes, and must be deposited in the motor vehicle fund created in RCW 46.68.070, subject to (b) of 2 this subsection.*

*(b) If in any year the amount of proceeds from the fee collected under this section exceeds one million dollars, the excess amount over one million dollars must be deposited as follows:*

*(i) Seventy percent to the motor vehicle fund created in RCW 46.68.070;*
*(ii) Fifteen percent to the transportation improvement account created in RCW 47.26.084; and*
*(iii) Fifteen percent to the rural arterial trust account created in RCW 36.79.020.*

The passage above shows the provisions, which state that revenue beyond the first $1 million collected from the EV fee should be divided into three accounts: seventy percent goes to the motor vehicle fund, 15% goes to the transportation improvement account, and the remaining 15% goes into the rural trust account.

According to the Department of Licensing in Washington, in 2012 there were roughly only 1600 all-electric vehicles registered in the state, which would mean that during its first year only $160,000 will be collected—meaning that the $1 million provision may not kick in for multiple years into the future *(24).* One last noteworthy element of the bill was that was written so that the fee will automatically expire on the effective date of any passed legislation that imposes a VMT fee or tax, indicating that might be a real possibility for the state *(23).*

### 7.2 Indexed Fuel Tax

Virginia has taken a different approach to the fuel tax through the passage of Senate Bill 639, which indexes the fuel tax to fuel price and includes the following provisions (which also relate to sales taxes in an effort to keep pace with inflation) *(25):*

- Implements a 3.5% tax on wholesale gasoline and 6.0% tax on wholesale diesel
- Raises vehicle sales taxes from 3% to 4.3%
- Implements a $100 tax for electric *and* hybrid vehicles at the time of their purchase

Some have pointed out that this method may be good for discouraging the use of vehicles with poor fuel economy since those who consume more fuel will be paying more, but it may have adverse effects on lower-income individuals who cannot afford to purchase more fuel-efficient cars.

### 7.3. Vehicle Miles Traveled (VMT) Fee

VMT fees charge drivers a flat rate on the amount of miles that are driven on a system. By taxing every car at the same flat rate (versus a traditional gas tax), VMT fees ensure that drivers pay taxes in an amount proportional to how much they actually drive. Perhaps the state that is furthest ahead in the effort to implement a VMT tax is Oregon, which has not only completed a pilot program but has proposed Senate Bill 810 based on the finding from its pilot. The VMT charge would become effective beginning July 1, 2015, if passed in the Legislature. The new law would impose a flat charge on vehicles at the rate of 1.5¢ per mile instead of the state's 30¢-per-gallon gas tax.

Initially participation in the new VMT program will be capped to slowly build trust and understanding with the public help ease fears about government knowledge of driver miles and location (if GPS is used).

Many aspects of a VMT scheme need to be researched and debated, and issues exist that need to be resolved. Of particular importance is the potential socio-economic effects of VMT. McMullen, et al. completed a study of techniques they deemed appropriate for assessing the socioeconomic impacts of VMT (27). The study, which was completed for the state of Oregon, sought to answer the following questions:

1. Would a VMT fee be regressive by placing disproportionate hardship on those in lower-income groups?

2. Would those in rural areas in Oregon be adversely impacted relative to those urban areas?

3. Would a change to a VMT fee discourage people from acquiring alternative fuel vehicles or more fuel-efficient vehicles and thus run contrary to the state and national priority of reducing fossil fuel use?

The study reported that a VMT may, in fact, be regressive by placing a disproportionate burden on lower-income persons. In addition, it is expected that those in rural areas would be adversely impacted (relative to those in urban areas), and VMT fees will discourage drivers from buying more fuel-efficient vehicles.

# CHAPTER 8. CONCLUSION

It is clear from the results that as more EVs enter the fleet, and as ICE and EV fuel economies advance, revenue from the federal fuel tax will decline; the results of this study suggest that up to 41.5% of federal fuel tax funds may be lost. It is important to note that the rate at which revenue declines depends on many factors, such as the rate of fuel economy gains, timing of fuel economy gains, VMT, and total vehicle fleet size. The relationship among these factors is complex and further investigation is warranted to better understand vehicle fleet mix, fuel economy, and fuel tax revenue. The following factors are identified limitations of this research and future work should address these limitations.

- Fuel economy projections were made based on realistic manufacturer capability and do not account for the influence that politics may have on fleet fuel economy. Future work should assess political will for increasing fuel economy standards, which may be a limiting factor. For hybrid EVs, which are continually developing their technology, fuel economy may indeed differ from the initial estimates used in this study. Also, should the battery capability increase greatly, all-electric vehicles may require no gasoline (or very little gasoline).

- VMT was assumed to be the same for both EV drivers and ICE drivers in this study. It may be a reasonable assumption that EV drivers may differ in the miles traveled compared to ICE driver (due to battery constraints and many other factors), but at the time of this report, no concrete evidence existed to verify this assumption.

- Sales projections for EVs were informed by three academic studies. Market projections for EVs are continually being updated as technology gains are realized and more information becomes available. Fuel tax revenue losses are strongly related to EV sales as EV fuel economies are far greater than those of ICE vehicles. As time goes on, sales are likely to increase, meaning fuel consumption per vehicle will decrease, causing revenue impacts. While shortfall is almost certain, the amount of revenue lost is not.

Finally, if the fuel tax is to remain a source of funding, then transportation officials need to create and implement transportation revenue generation strategies that tie actual roadway use to amount of taxes paid by a driver (and not their gasoline consumption). Already an extensive body of literature exists on the topic of alternative transportation taxation strategies, and this study has been completed to help support and motivate the implementation of such strategies.

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