Total Cost of Ownership: A Diesel Versus Gasoline Comparison (2012-2013)

by

Bruce M. Belzowski
Managing Director
Automotive Futures

June, 2015

University of Michigan Transportation Research Institute

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Abstract

There are dramatic changes taking place in the U.S. automotive industry as it moves to meet stringent government mandated Corporate Average Fuel Efficiency (CAFE) requirements. Clean diesel engine technology represents one of the technologies companies are using to improve fuel economy. This report not only compares the fuel efficiency of clean diesel vehicles to comparable gasoline versions of the same vehicle (sold at auction during the 2012-2013 timeframe), but it also compares the total cost of ownership (TCO) between the two types of technologies. The report is a followup to our previous work on the total cost of ownership comparison of vehicles sold at auction during the 2010 and 2011 timeframe. The TCO model is built by developing three- and five-year cost estimates of depreciation by modeling used-vehicle auction data, as well as developing estimates for fuel costs by modeling government data. This report differs from the previous report in that it controls for the trim levels of the different vehicles. The depreciation and fuel cost estimates are added to three- and five-year estimates for repairs, fees and taxes, insurance, and maintenance from an outside data source. The results show that clean diesel vehicles provide a return on investment in both the three- and five-year timeframes, though there are differences in the amounts of return among mass market vehicles, medium duty pickup trucks, and luxury vehicles, as well as passenger cars, sport utility vehicles (SUVs), and medium duty pickup trucks.

Keywords: total cost of ownership, clean diesel vehicle, fuel economy, auction, used vehicles

Acknowledgements

We would like to acknowledge the work of two of our UMTRI colleagues, Paul E. Green and Kara Alkire, for their contributions in data analysis and coding. We would also like to thank our sponsor, Bosch Corporation (Robert Bosch LLC), for their support for this project, particularly Bernd Boisten, Andreas Sambel, and Christiane Planche. We also acknowledge the data provided by Mannheim Auctions, Vincentric, and Blackbook, as well as a variety of government data made available from the Environmental Protection Agency, the National Highway Traffic Safety Administration, the Bureau of Labor Statistics, the Energy Information Administration, and the Federal Highway Administration.

Total Cost of Ownership: A Diesel Versus Gasoline Comparison (2012-2013)

Alternative powertrains, specifically clean diesels, hybrids, compressed natural gas, and pure electrics, offer the automotive industry its main opportunity for a sustainable future. All four of these powertrains are currently in the U.S. marketplace, providing an opportunity to measure their value to consumers.

In terms of sales, Table 1 shows that in 2014, sales of vehicles with alternative powertrains in light-duty vehicles was a mix of increases and decreases over 2013 sales. While alternative powertrains still represent a small percentage of market share compared to gasoline engines, clean diesels saw a 10 percent increase in 2014 sales over 2013 sales, while hybrids saw a 10 percent decrease, pure electrics saw a 20 percent increase and compressed natural gas saw a 33 percent decrease.

2013	Percent of Sales		2014	Percent of Sales
Clean Diesels	2.83%		Clean Diesels	3.10%
Hybrids	3.38%		Hybrids	3.05%
Pure Electrics	0.32%		Pure Electrics	0.38%
Compressed Natural Gas (CNG)	0.03%		Compressed Natural Gas (CNG)	0.02%

Source: Polk (2015)

Table 1: Percentage of Sales of Specific Powertrains in Light Duty Vehicles in 2013 and 2014

One issue that has changed significantly over the past few years is the increase in the number of alternative powertrain offerings in the U.S. marketplace. For example, our analysis of the number of models available in the U.S. market in 2014 showed that of the 381 models available, 124 models (33 percent) offered alternative powertrains. This is a significant increase over the 11 percent reported for 2011. So, the potential buyer has a much larger number of vehicles with alternative powertrains available to choose from, relative to the total number of models. Whether these models are on the showroom floor and actively sold by dealers is uncertain.

Also, for similar or identical pairs of vehicles that offer an alternative powertrain and a gasoline powertrain, one can measure the "take rate"[1] of each vehicle based on its powertrain. For example, for clean diesel powertrains, the average take rate compared to that of gasoline competitors is shown for 2008 to 2014 in Table 2 (Polk, 2015). The range of light duty vehicles with clean diesel powertrains has fluctuated between 2008 and 2014, while the range of medium duty pickup trucks with clean diesel engines has been relatively consistent. Some of this

[1] The total number of diesel vehicles sold divided by the sum of the total number of gas and diesel vehicles sold.

inconsistency can be explained by limited production volume available for vehicles with a diesel option.

Model Year	Light Duty Vehicles	Medium Duty Pickup trucks
2008	10%	63%
2009	22%	59%
2010	30%	59%
2011	30%	62%
2012	30%	62%
2013	23%	62%
2014	19%	63%

Source: Polk (2015)

Table 2: Average Take Rate for Clean Diesel Vehicles for Light Duty Vehicles and Medium duty pickup trucks for 2008 to 2014

One can also measure the intentions of buyers who are considering purchasing a new vehicle to see how alternative powertrains fit into their potential purchase. Morpace Research has performed consumer powertrain studies for a number of years and have measured the familiarity of consumers with alternative powertrains, their intentions in purchasing one of these powertrains in their next purchase, while ranking the technologies as a first, second, or third choice. Morpace also measures "true intenders" based on consumers who are very interested in a type of powertrain and chose that type of powertrain as their first or second future choice. In the results from the 2014 purchase intention study results, clean diesels ranked second (19 percent) to hybrids (49 percent) for consumers who considered these alternative powertrains as their first or second choices in their next purchase (Morpace, 2014). As shown in the sales data, these high purchase intentions have not translated to actual sales.

In the Morpace study consumers consider the strengths of clean diesel as its fuel economy, environmental friendliness, innovative technology, and dependability and reliability. They think clean diesel's weaknesses to be upfront cost, cost to repair, and the time it takes to recoup the cost of the technology. This perception of a longer time to recoup the initial cost of clean diesel technology has been the key reason for this study of the total cost of ownership that compares near identical gasoline and clean diesel versions of the same vehicle by combining an UMTRI estimate of resale value and depreciation, and an UMTRI cost estimate for fuel, with costs for insurance, repairs, maintenance, and taxes and fees (from Vincentric) over a three- and five-year time period.

Others have written about the total cost of ownership related to information technology, supply chain (including purchasing and logistics), energy such as lighting, and manufacturing related to quality. These articles mostly focus on TCO from a business perspective rather than a consumer perspective. One article looks at the total lifecycle cost of hybrid vehicles, which includes manufacturing and ownership (Lipman, 2006). Many vehicle-related TCO articles focus on electric cars (Vliet, 2011), (Hensley, 2009), (Gao, 2008), (Dickerman, 2010), (Becker, 2010), (Plotz, 2012), (LeBeau, 2013), (Conti, 2015), (Wu, 2015), and (Tamor, 2015). Other articles look at TCO for hybrid vehicles (Ernst, 2011), plug-in hybrid vehicles (Van Vliet, 2010), (Michalek, 2011), (Santini, 2013), and (Neubauer, 2013), as well as fuel cell vehicles (Van Vliet, 2010), (Dusterwald, 2007), and (Greene, 2013). TCO is also discussed in terms of energy policy scenarios for future vehicle options (Thiel, 2010) and an optimal vehicle maintenance schedule (Lad, 2008). There has also been some recent work on the potential advantage of TCO for consumer choice (Redelbach, 2013) and (Dumortier, 2015). The only similar analysis to this TCO analysis of gasoline and diesel vehicles comes from the work of Gilmore, 2013.

Total cost of ownership is also a term used by the major automotive consumer websites such as Edmunds.com, Kelley Blue Book (kbb.com), Vincentric.com, National Automobile Dealer Association Guides (nadaguides.com), Driverside.com, Cars.com, Intellichoice.com, and Consumer Reports (consumerreports.org) to help consumers compare the cost of ownership between pairs of vehicles. Even the U.S. Department of Energy (http://www.afdc.energy.gov/calc/) has a site where consumers can see the long-term financial effects of vehicle ownership based on one's individual driving habits. Each site uses its own proprietary models for estimating/forecasting the costs of depreciation, fuel, insurance, repairs, maintenance, and fees and taxes, while also offering estimated/forecasted costs associated with loans and what is called opportunity costs. This report does not estimate loan costs because of the wide variety of methods and rates that buyers use to purchase vehicles. It also does not use a version of opportunity costs because it is not clear how these costs are estimated and consequently the value of these costs in a TCO model.

Method

Despite the current low levels of sales of vehicles with alternative powertrains, there are now enough clean diesel powertrains in the U.S. fleet to measure their value in the resale market. The resale market is interesting because it has a formal auction process where dealers bid on used/pre-owned vehicles to sell in the used-vehicle business. As independent businesses, automotive dealers carefully manage their used/pre-owned inventory to maximize their profits. As such, they generally do not take chances by paying more for a vehicle than they can sell it for in the marketplace.

Using the resale value from the auction of vehicles with alternative powertrains compared to near identical gasoline versions of these vehicles thus becomes a way of measuring the success of alternative powertrains in the marketplace. This analysis provides a real-world test of whether the current vehicles with alternative powertrains hold their value in the resale market.

The method to measure the differences between clean diesel and gasoline versions of the same vehicle is based on gathering information from government sources including

- Federal Highway Administration (FHWA): average numbers of vehicle miles driven
- Energy Information Administration (EIA): historical average annual fuel prices
- Bureau of Labor Statistics (BLS): consumer price index for new and used vehicles
- National Highway Traffic Safety Administration (NHTSA): average annual vehicle miles travelled and vehicle survivability
- Environmental Protection Agency (EPA): average miles per gallon

Exclusive data was also used from

- Mannheim auction system: vehicle auction prices and mileage
- Blackbook: original manufacturer's suggested retail price (MSRP) and vehicle trim level. Edmunds.com, cars.com, and Kelley Blue Book were used to verify some MSRP's and trim levels.
- Vincentric : insurance, repairs, maintenance, fees, and tax estimates/forecasts for three and five years

The TCO model for three and five years of ownership consists of

- Depreciation based on
    - UMTRI's resale model
    - original MSRP (Blackbook, with verification from Edmunds.com, cars.com, and Kelley Blue Book)
- Fuel cost based on UMTRI's fuel cost model that includes
    - vehicle model year (Mannheim)
    - vehicle miles per gallon (EPA) and (J.D. Power and Associates)
    - annual average cost of fuel per gallon (EIA)
    - the average number of miles driven for passenger cars, sport utility vehicles, and pickup trucks, as well as vehicle survivability (NHTSA)
- Repairs (Vincentric)
- Insurance (Vincentric)
- Maintenance (Vincentric)
- Fees and taxes (Vincentric)

The method for comparing vehicle prices from different timeframes, for example a vehicle purchased in 2002 and sold at auction in 2012 versus a vehicle purchased in 2009 and sold at auction in 2013, is to adjust all prices to 2013 dollars using the Consumer Price Index (CPI) estimates for new and used vehicles provided by the BLS. Thus, a vehicle's original MSRP, its price at auction, the average cost of fuel in any particular year, and its estimates for insurance, repairs, maintenance, and fees and taxes are all adjusted to make them equal to 2013 dollars using the CPI.

Sample

The sample of 28,239 used vehicles from Mannheim auctions that were sold during 2012 and 2013 form the basis for the resale model used in the TCO model. Twelve hundred vehicles were requested for each gasoline and diesel version of the same vehicle from the Mannheim database. Vehicles with more than 1200 vehicles represented were sampled across all twelve months of each year in order to eliminate any bias related to the time of year a vehicle was sold.

As can be seen in Figure 1 most of the gasoline versions of vehicles were sampled at the 1200 vehicle level, but there were not enough of many of the diesel versions of the vehicles sold to meet the 1200 vehicle request, except for the medium duty pickup trucks. Despite lower counts of some vehicles, the analyses performed on all the models met the statistical criteria for significance.

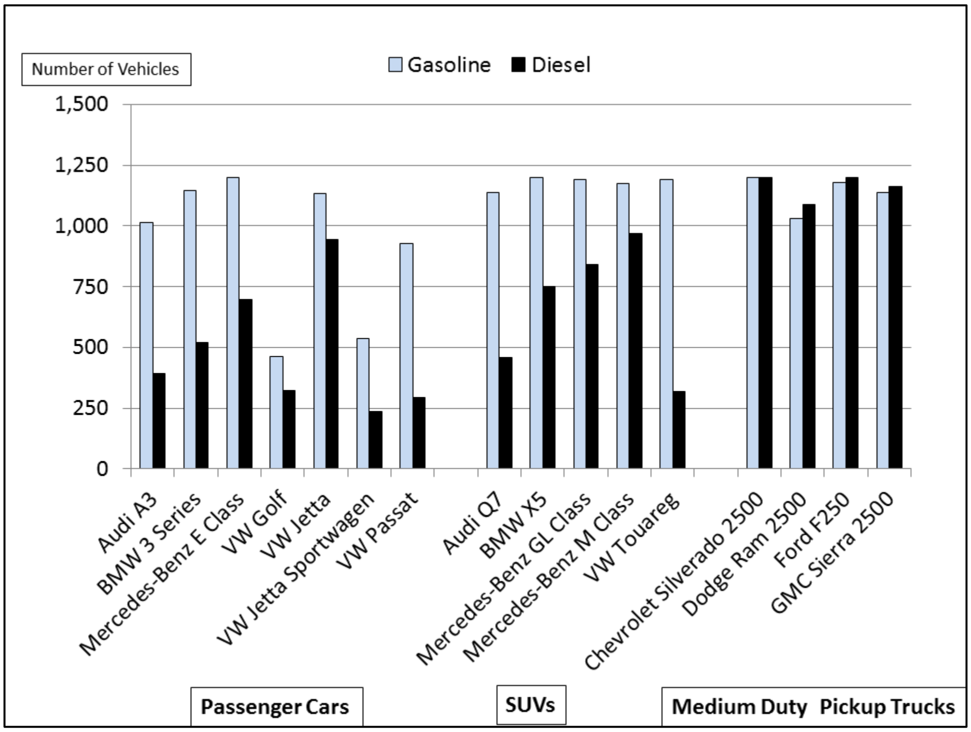

Figure 1: Number of Used Vehicles in Gasoline and Diesel Analyses Provided by Mannheim Auctions

Vehicle Comparisons

This analysis compared gasoline and diesel versions of the same or nearly identical vehicles. Table 3 shows the pairs of vehicles examined in the analyses. It shows the comparison vehicles' miles per gallon[2] and average MSRP for vehicles in the study.

Two interesting effects that are important for this TCO analysis can be seen in this table.

[2] Miles per gallon is measured as a combined city/highway (60%/40%) driving average.

- First, all the diesel vehicles have better miles per gallon than their gasoline counterparts. This will affect the fuel costs that are a part of the TCO formula.
- Second, the difference in average MSRP among groups of vehicles differs significantly.
    - The mass market passenger cars, VW Jetta, VW Jetta Sportwagen, VW Golf, and VW Passat have a variety of gasoline/diesel MSRP differences with the VW Jetta, VW Jetta Sportwagen, and VW Golf having about a $3,500 to $4,700 difference between the gasoline and diesel versions, while the VW Passat has only about a $500 difference.
    - The medium-duty pickup trucks, Chevrolet Silverado 2500, GMC Sierra 2500, Dodge Ram 2500, and Ford F-250 have the largest differences in average MSRPs between the gasoline and diesel versions, ranging from about $8,500 to $11,000.
    - The luxury vehicles, Mercedes E Class, GL Class, M Class, BMW 3-Series and X5, Audi A3 and Q7, and the VW Touareg show a wide range of average differences between the gasoline and diesel versions, ranging from about $300 to $8,000. For three of the vehicles, the Mercedes E Class, the BMW X5, and the Mercedes GL Class the diesel version is *less expensive* than the gasoline version, by about $200 to $5,800.

These MSRP costs are part of the depreciation model, which feeds into the TCO formula, so these differences will have significant effects on the results. They also show some of the strategies of the manufacturers, especially in terms of their pricing of diesel vehicles.

Vehicle	Average MPG Gasoline Vehicles	Average MSRP Gasoline Vehicles	Average MPG Diesel Vehicles	Average MSRP Diesel Vehicles
Passenger Cars				
Audi A3	25	$29,522	34	$31,213
BMW 3 Series	21	$44,922	27	$45,228
Mercedes E Class	20	$53,855	26	$53,642
Volkswagen Golf	26	$19,805	34	$24,529
Volkswagen Jetta	24	$20,923	33	$24,509
Volkswagen Jetta Sportwagen	25	$22,440	33	$26,620
Volkswagen Passat	23	$30,270	34	$30,808
Sport Utility Vehicles (SUVs)				
Audi Q7	16	$51,601	20	$59,790
BMW X5	16	$60,850	22	$54,969
Mercedes GL Class	15	$64,878	19	$61,769
Mercedes M Class	17	$46,219	21	$50,871
Volkswagen Touareg	16	$42,234	22	$50,220
Pickup Trucks				
Chevrolet Silverado 2500	13	$34,278	15	$43,323
Dodge Ram 2500	13	$36,170	15	$44,700
Ford F250	12	$34,132	14	$45,139
GMC Sierra 2500	13	$37,063	15	$46,620

Table 3: Vehicle Type, Average MPG, and Average MSRP for Gasoline and Diesel Vehicles in the TCO Sample

Figure 2 looks at the miles per gallon (MPG) between diesel and gasoline versions of the comparable vehicles that are part of the study, as well as the percentage difference between the two MPGs. As expected, diesel versions of a vehicle have significantly higher MPGs than the gasoline versions, though the medium duty pickup trucks have a much smaller difference between their diesel and gasoline versions. These smaller differences in some cases have to do with different size diesel and gasoline engines available in medium duty pickup trucks. In some cases, the diesel engine will be larger and more powerful than the gasoline engine offered for the same vehicle, yet the diesel engine will still have a slightly higher miles per gallon rating.

In the passenger car segment, the highest percentage difference in miles per gallon of diesel vehicles compared to gasoline vehicles comes from the VW Passat, followed by the VW Jetta and the Audi A3. In the SUV segment, the highest percentage difference in miles per gallon between diesel and gasoline vehicles can be seen in the BMW X5 and the VW Touareg. These differences in fuel economy will have an effect on the fuel costs that are part of the TCO model.

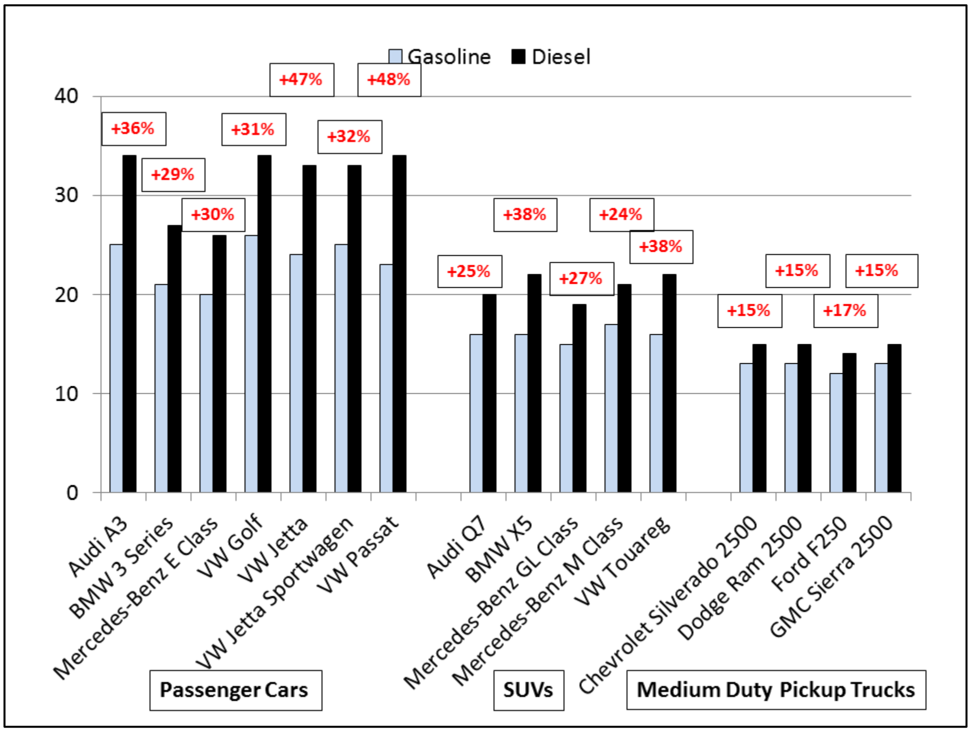

Figure 2: Percentage Differences in Miles per Gallon (MPG) Between Comparable Diesel and Gasoline Vehicle Pairs

Figure 3 shows the percentage differences in manufacturer suggested retail prices (MSRP) between the diesel and gasoline versions of the comparable vehicles in the study. As in all of the analyses for this report, MSRP is adjusted to 2013 dollars.

Historically, manufacturers have always charged more for vehicles with diesel engines than gasoline engines because diesel engines tend to be more expensive to manufacture. In this sample, the same manufacturer can have quite significant differences in MSRPs between diesel and gasoline versions of its vehicles, as noted in Table 3.

One could argue that the European manufacturers may have an advantage in introducing diesel versions of their vehicles because they already have built large numbers of these vehicles in Europe over many years, providing economies of scale for manufacturing diesel engines. They may also have a global scale effect if they sell the same diesel engines in their vehicles in other parts of the world.

In the passenger car segment, there is very little difference among the luxury brands' diesel and gasoline versions of the same vehicle; whereas, with the Volkswagen passenger cars there is about a 20 percent difference between the diesel and gasoline versions of their vehicles. The VW Passat is the only exception to this observation. It is unclear why Volkswagen would price the Passat differently than it does its other passenger cars. Some manufacturers price certain types of vehicles in order to support new technologies. In this case, Volkswagen may be incenting the diesel version of the Passat.

In the SUV segment, there is wide variation in pricing. The Audi Q7, the Mercedes-Benz M Class, and the VW Touareg charge a premium for their diesel versions, while the diesel version of the BMW X5 and the Mercedes-Benz GL Class is less expensive than the gasoline version. The luxury manufacturers may be incenting new diesel technology or possibly supporting their Corporate Average Fuel Economy (CAFE) goal by selling vehicles that have better fuel economy. In the medium duty truck segment, the manufacturers similarly price their diesel versions higher than their gasoline versions.

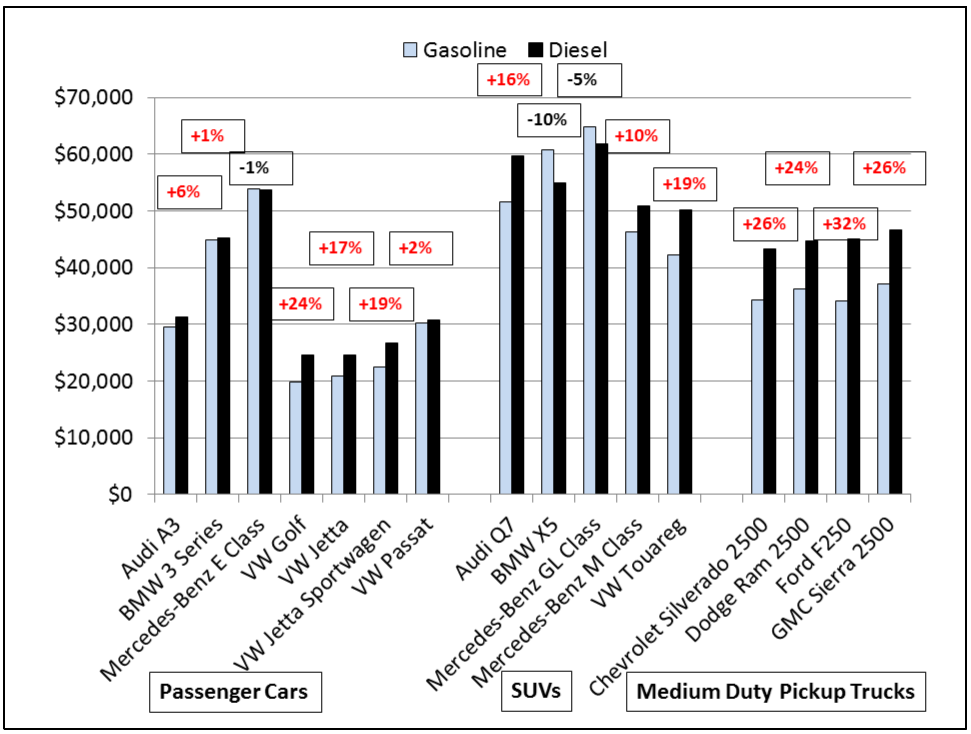

Figure 3: Percentage Differences (Increases) in MSRP between Comparable Diesel and Gasoline Vehicle Pairs

The Resale Model

In order to measure the resale value of the vehicles in the study and generate three- and five-year estimates for sale prices for both gasoline and diesel vehicles, the data provided by Mannheim auctions was used. Mannheim is the world's largest distributor of used/pre-owned vehicles to dealers. The sample of 28,239 auction records comes from auctions that took place in 2012 and 2013.

The main variables in the resale value analysis include the sale price of the vehicle at auction (adjusted to 2013 dollars), the condition of the vehicle, the number of miles driven, and the age of the vehicle. A preliminary correlation analysis showed very high multi-collinearity among these variables. Because of this high multi-collinearity, each variable was examined separately to see which variable was the best predictor of sale price. Based on this examination, the number of miles driven was chosen as the independent variable to explain the variance in sale price.

The LOWESS regression program was used to get the best fit for each distribution. LOWESS differs from the typical regression program in that it creates a smoothed, curved regression line, which sometimes provides a better fit for the distribution. Because the relationship between sale price and the number of miles driven, at times, showed a curved distribution, LOWESS was used to generate both a typical regression line as well as the smoothed, curved regression line.

One of the potential confounding effects in sale prices is the different trim levels available for vehicles. Trim levels are the combination of vehicle accessories that manufacturers use to differentiate their vehicles. For these analyses, three trim levels were coded for each vehicle: high, medium, and low. A high trim level may combine leather seats, sun roof, and navigation system. A medium trim level may combine larger tires and alloy rims, while a low trim level will have only basic tires, interiors, and engines. Each vehicle has its own package of trim levels designed by the manufacturer that may change from year to year and may include different combinations of accessories. Medium duty pickup trucks are some of the most customized vehicles with wide varieties of engine types, numbers of doors, length of beds, and drivelines. Each of the trim levels may have a dramatic effect on the sale price of a vehicle.

For all of the analyses for this study, the LOWESS program was used to estimate the three and five year sale prices for each of the three trim levels. The estimates for each trim level were then weighted by the number of vehicles in that category, creating a weighted average of the combined trim levels. Figure 4 shows this effect for the gasoline version of the GMC Sierra 2500. Note how the higher trim level shows a higher sale price over time, while the medium and low trim levels have lower sale prices at both three and five years. The curved line generated by the LOWESS program provides a better fit for the data, especially for vehicles that are older with higher mileage.

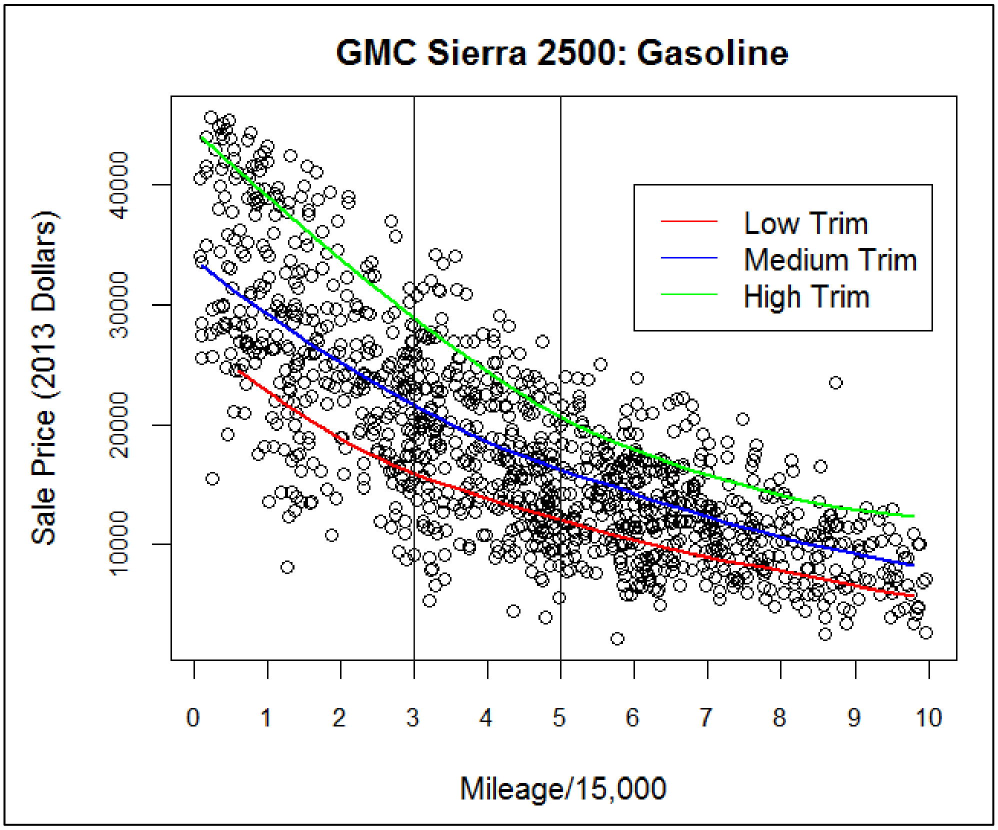

Figure 4: Auction Sale Price by Age of Vehicle and Trim Level for the Gasoline Version of the GMC Sierra 2500

* The age of the vehicle is generated by dividing the actual miles at auction by 15,000, the average number of miles driven by consumers age 20 to 54. (FHWA, http://www.fhwa.dot.gov/ohim/onh00/bar8.htm)

Figure 4 also visually shows how our auction sale-price estimates for three and five years were generated. The three- and five-year estimates of the auction sale price for these vehicles are noted by the points at which the 3-year and 5-year vertical lines intersect the smoothed regression lines. These estimates for each trim level are then weighted by the number of vehicles in each of the trim levels, creating a weighted average across the three levels.

Results

Figure 5 graphically displays the differences in three-year resale estimates for each of the vehicle pairs, where diesel vehicles show distinct advantages in resale values compared to their gasoline counterparts. These resale values control for vehicle miles driven. The percentages shown represent the percentage difference of the diesel powered vehicle compared to the gasoline powered vehicle. In this case, a positive percentage, shown in red, means that the clean diesel vehicle has a higher resale value than the comparable gasoline vehicle.

Except for the Mercedes E Class and the BMW X5 which have a slightly lower resale value for clean diesel vehicles than gasoline vehicles, all the diesel powered vehicles in the study have resale values that are 30 to 50 percent higher than comparable gasoline powered vehicles. In the medium duty truck segment the differences are 60 to 70 percent higher.

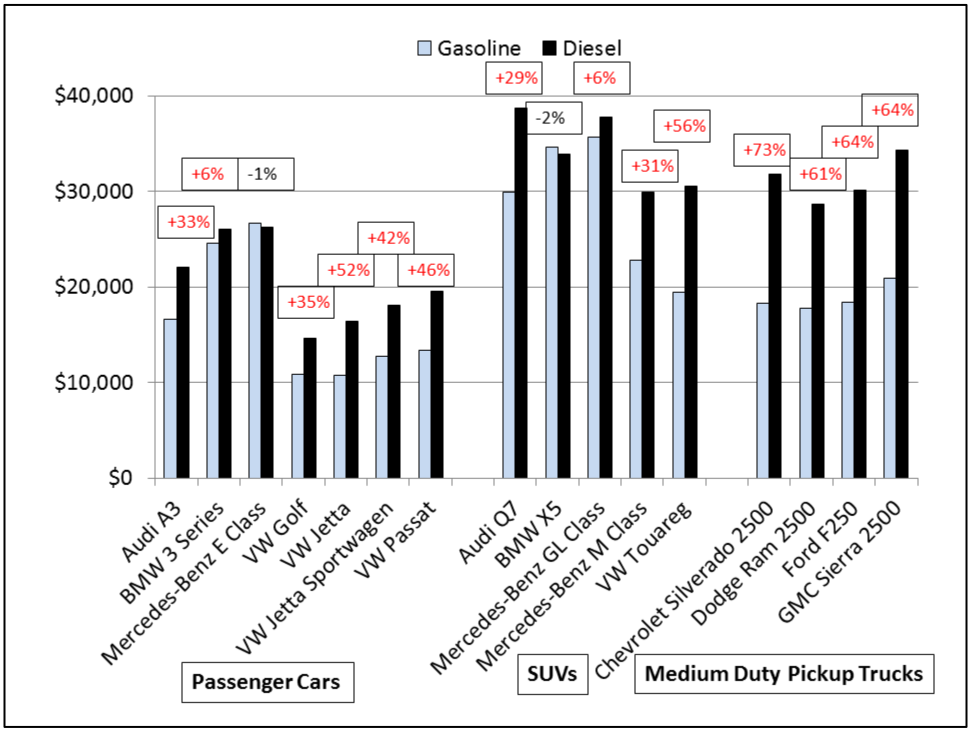

Figure 5: Resale Value of Gasoline and Diesel Vehicles after Three Years of Ownership

Figure 6 shows the estimated resale values of all the vehicle pairs in the study after five years of ownership. All the diesel vehicles show significantly higher resale values while controlling for vehicle miles driven. In the passenger car segment, the average resale price difference range from 9 percent for the Mercedes E Class to 116 percent for the VW Jetta. In the SUV segment, average resale price differences range from 40 percent for the Mercedes M Class to 96 percent for the Volkswagen Touareg. The dramatic price differences seen in the medium duty truck segment at three years also apply to these vehicles in five years with diesel-powered vehicle resale prices differences ranging from 70 to 80 percent higher than similar gasoline powered trucks.

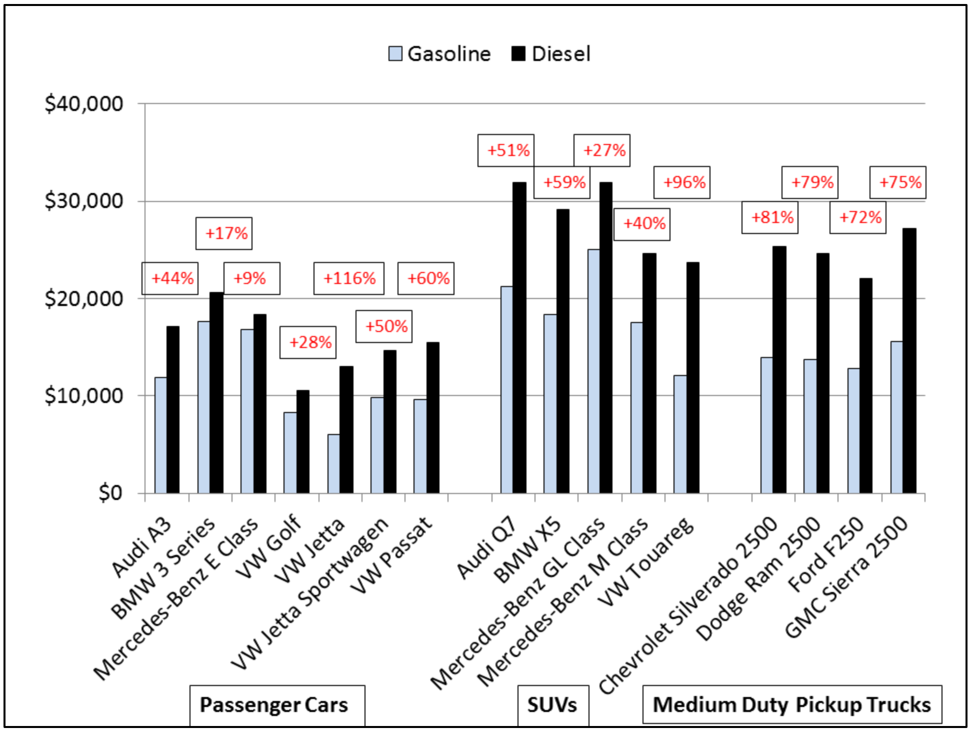

Figure 6: Resale Value Comparisons for Gasoline and Diesel Vehicles after Five Years of Ownership

The Depreciation Model

The depreciation model that feeds into the TCO model is based on subtracting the estimated resale value for three and five years (adjusted to 2013 dollars) from the average MSRP (adjusted for 2013 dollars) for comparable diesel and gasoline powered vehicles.

Results

Figure 7 displays the three-year depreciation (in 2013 dollars) for the diesel and gasoline versions of comparable vehicles in the study, as well as the percentage difference between the diesel and gasoline versions. In this figure, a negative percentage difference means that the diesel powered vehicle has depreciated less than the comparable gasoline powered vehicle.

Fourteen of the sixteen diesel vehicles hold their value better than comparable gasoline powered vehicles over the three-year timeframe, but there is a wide variance in the percentage of savings. In the passenger car segment, two of the vehicles, the Mercedes E Class and the Volkswagen Golf gasoline versions, depreciate less than the diesel versions, while the five other vehicles' diesel versions depreciate less than the gasoline versions. The five vehicles where the diesel versions show less depreciation range from 6 percent to 33 percent, with four of the five vehicles reporting double digit savings.

In the SUV segment, all of the diesel powered vehicles report lower depreciation over three years, with four of the five reporting double digit savings. In the medium duty truck segment, all four diesel versions of the trucks report lower depreciation than the gasoline powered versions, with three of the four trucks reporting double digit savings.

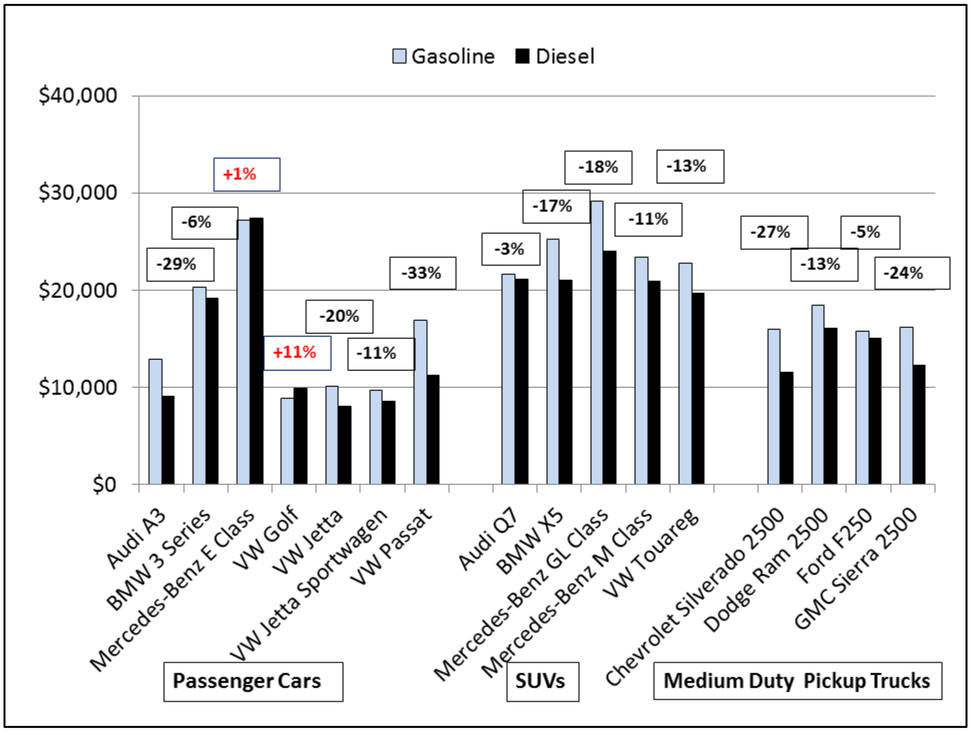

Figure 7: Depreciation Comparisons in Price and Percent Difference for Diesel and Gasoline Vehicles after Three Years of Ownership

Figure 8 displays the five-year depreciation for the diesel and gasoline versions of comparable vehicles in the study, as well as the percentage difference between the diesel and gasoline versions.

Similar to the three year analysis, fourteen of the sixteen diesel vehicles hold their value better than comparable gasoline vehicles over the five-year timeframe, but there is a wide variance in the percentage of savings. In the passenger car segment, six of the seven cars in this group show lower depreciation for the diesel version, ranging from 5 to 26 percent savings. Only the gasoline version of the Volkswagen Golf depreciates less than its diesel version.

All the diesel SUVs depreciate less than the gasoline versions of the vehicles. Two of the diesel SUVs, the BMW X5 (39 percent) and the Mercedes GL Class (25 percent), depreciate much less than the gasoline versions of those SUVs. In the medium duty truck segment, three of the four diesel powered trucks depreciate less than the gasoline powered versions, reporting modest 8 to 11 percent savings. Only the Ford F250 gasoline version depreciates less than its diesel version.

This result may be a holdover from a reputation problem due to a number of years where the quality of its diesel engine was suspect. This issue would lower the resale value of the F250 diesel and allow the gasoline version to better hold its value.

This analysis displays a point that will occur in the TCO analysis as well: the gap in depreciation between the gasoline and diesel versions of the same vehicle tends to decrease as a vehicle ages for some vehicles and for others it increases. When the gap decreases, it means that the difference in depreciation between the diesel and gasoline versions begins to narrow. This is the case for the three and five year depreciation for the Audi A3 (29 percent difference in favor of the diesel powered vehicle in 3 years, but only a 20 percent difference in five years), the Volkswage Golf (-11 percent to -20 percent), the Volkswagen Sportwagen (11 percent to 5 percent), the Volkswagen Passat (33 percent to 26 percent), the Mercedes M Class (11 percent to 8 percent), the Volkswagen Touareg (13 percent to 12 percent), and all four medium duty pickup trucks, the Chevrolet Silverado 2500 (27 percent to 11 percent), the Dodge Ram 2500 (13 percent to 8 percent), the Ford F250 (5 percent to -3 percent), and the GMC Sierra 2500 (24 percent to 10 percent).

The gap in depreciation for three and five years increases for some of the other vehicles, meaning that the diesel vehicles' depreciation is less in year five than in year three. This effect can be seen in the BMW 3 Series (6 percent difference in favor of the diesel powered vehicle in 3 years, but a 10 percent difference in five years), the Mercedes E Class (-1 percent to 5 percent), the Volkswagen Jetta (20 percent to 22 percent), the Audi A7 (3 percent to 8 percent), BMW X5 (17 percent to 39 percent), and the Mercedes GL Class (18 percent to 25 percent). These shifts in differences are most likely the effect of the unique characteristics of a vehicle's engine or a vehicle's quality and reliability as well as the overall desirability of a vehicle over time that provide a better or worse reputation for these vehicles in the eyes of buyers. And these differences will affect not only the depreciation but also the TCO for a vehicle.

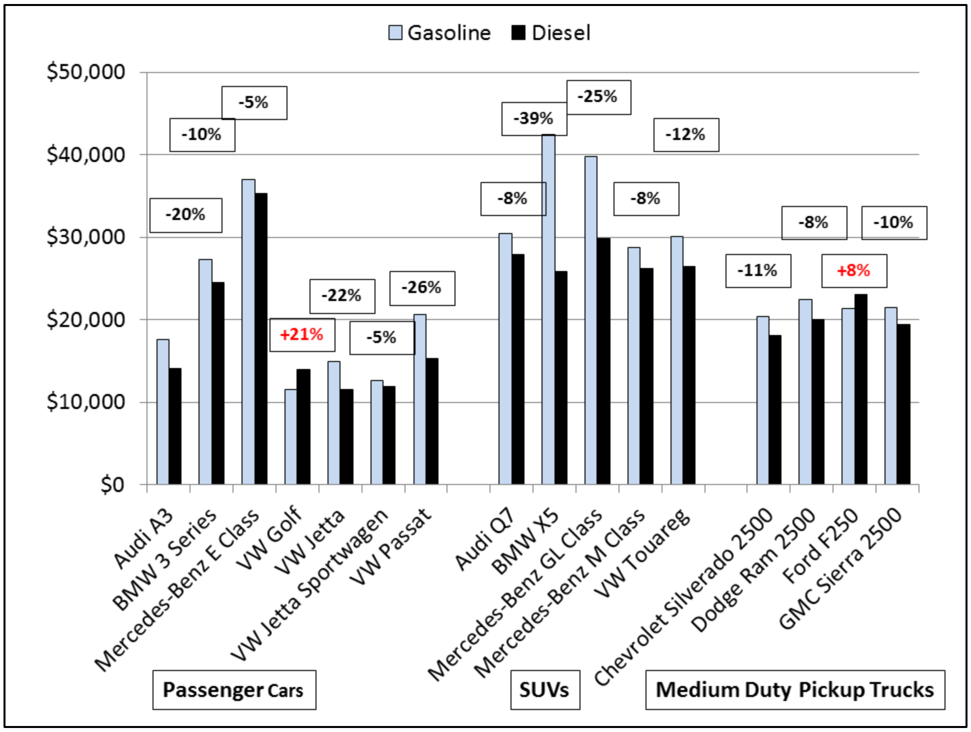

Figure 8: Depreciation Comparisons for Diesel and Gasoline Vehicles after Five Years of Ownership

Fuel Cost Model

A fuel cost model was developed with three- and five-year estimates using the combination of the model year of the vehicle from Mannheim, average annual gasoline and diesel fuel prices from the EIA, the number of annual miles driven based on the type of vehicle (passenger car, SUV, and pickup truck) and vehicle survival analyses from NHTSA, and vehicle miles per gallon from the EPA. Fuel prices were also adjusted to 2013 dollars using the CPI.

Results

Figure 9 shows the estimated diesel and gasoline fuel cost comparisons for three years of ownership, as well as the percentage difference between the diesel and gasoline versions. As expected, all diesel vehicles show lower fuel costs than all the gasoline versions of comparable vehicles, with twelve of the sixteen vehicles showing double-digit reductions in fuel costs, ranging from 12 to 27 percent. All four fuel cost estimates for the medium duty pickup trucks are below 10 percent: Chevrolet Silverado 2500 (7 percent), Dodge Ram 2500 (8 percent), Ford F250 (8 percent), and GMC Sierra 2500 (4 percent).

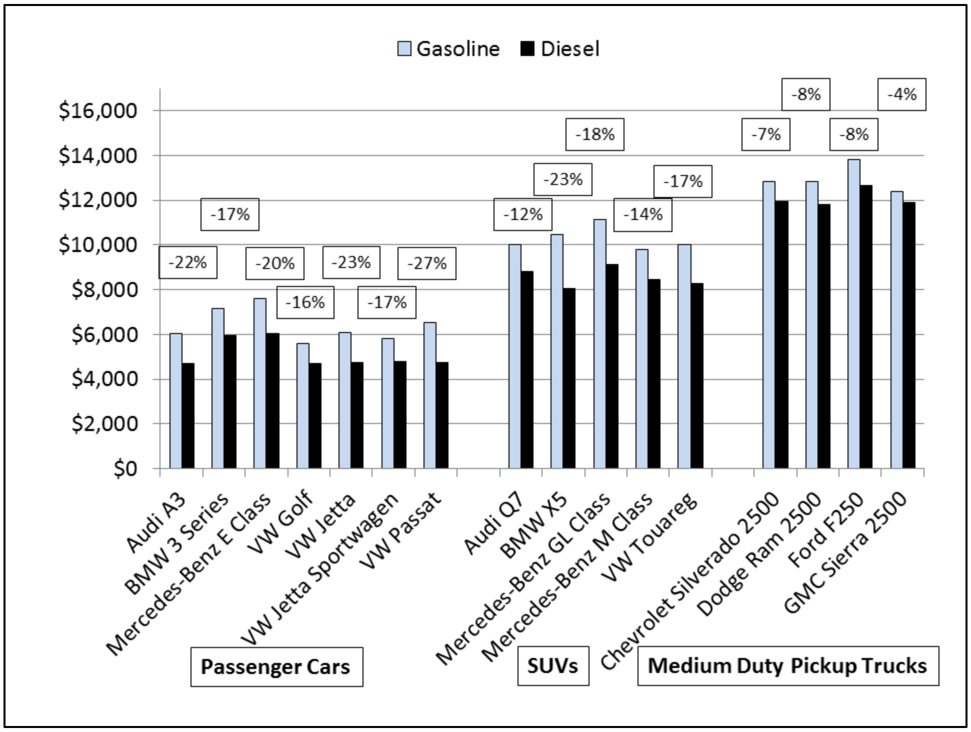

Figure 9: Fuel Cost Comparisons for Diesel and Gasoline Vehicles after Three Years of Ownership

Figure 10 displays the estimated diesel and gasoline fuel cost comparisons for five years of ownership. Similar to the three-year comparisons, five-year estimated fuel costs for diesel vehicles are less than those of comparable gasoline versions. Also similar to the three-year comparisons are the percentage differences in terms of the reduction from gasoline to diesel costs with double digit differences ranging from 12 to 27 percent for twelve of the sixteen vehicles in the study. Also similar to the three year comparisons, all four fuel cost estimates for the medium duty pickup trucks are below 10 percent: Chevrolet Silverado 2500 (6 percent), Dodge Ram 2500 (8 percent), Ford F250 (8 percent), and GMC Sierra 2500 (4 percent).

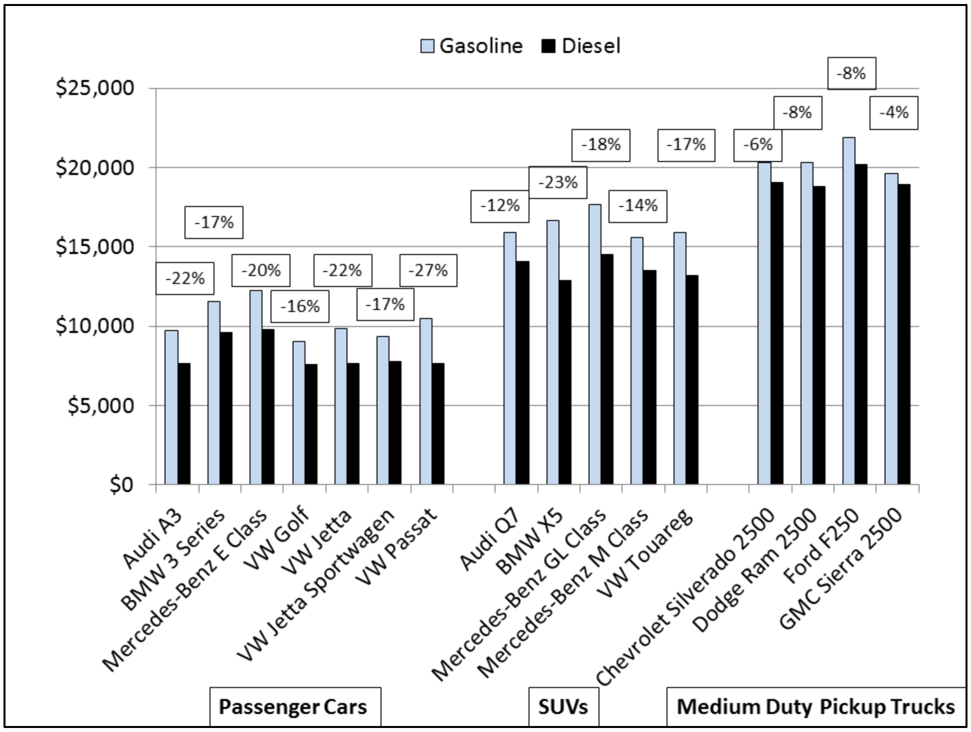

Figure 10: Fuel Costs Comparisons for Gasoline and Diesel Vehicles After 5 Years of Ownership

The Insurance, Repairs, Maintenance, and Fees and Taxes Model

Data for insurance, repairs, maintenance, and fees and taxes was provided by Vincentric, U.S. company specializing in estimating this data. The combined costs estimates are for vehicles for model year 2013, so the values are in 2013 dollars, as are all the other data in the total cost of ownership model. Estimates for vehicles with two different drivelines were averaged to create one estimate.

Results

Figure 11 shows dollar estimates for the combination of four major post purchase costs for comparable 2013 diesel and gasoline vehicles for three years of ownership, as well as the percentage difference between the diesel and gasoline versions. Only one vehicle comparison (Mercedes GL Class) shows the gasoline version of a vehicle with a cost estimate greater than the diesel version. Ten of the other fifteen vehicle comparisons show single digit cost estimates that are higher for the diesel version than the gasoline version, while five of the fifteen vehicle comparisons show double digit cost estimates, including the Volkswagen Golf, Volkswagen Jetta, the Chevrolet Silverado 2500, the Dodge Ram 2500, and the GMC Sierra 2500.

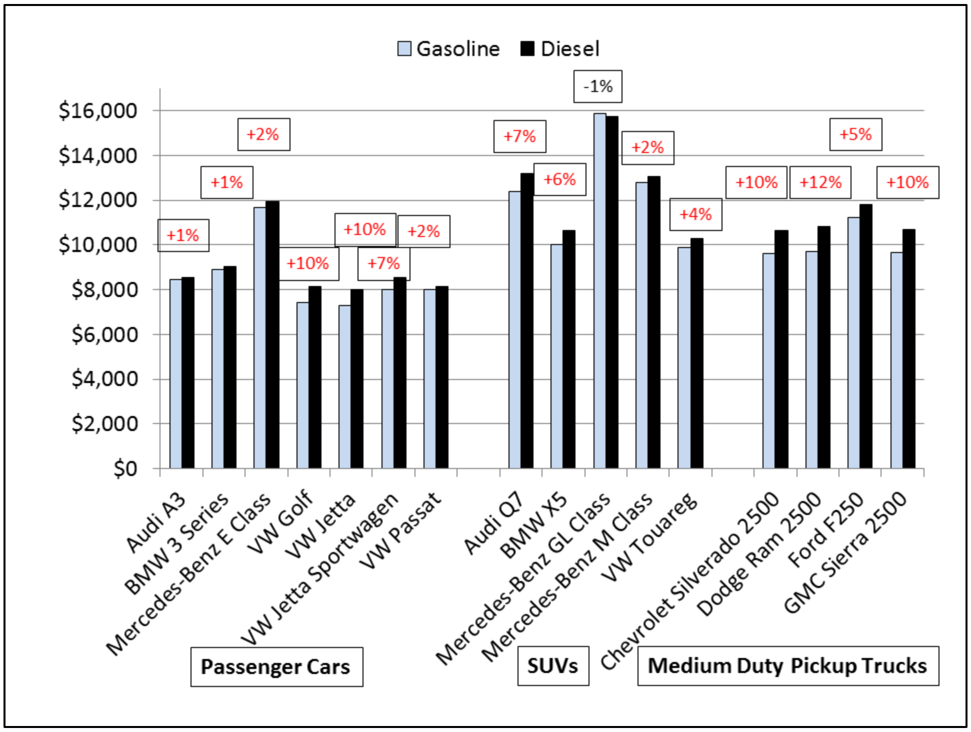

Figure 11: Vincentric Estimated Costs for Insurance, Repairs, Maintenance, and Fees and Taxes for 2013 Gasoline and Diesel Vehicles Over 3 Years

Figure 12 shows dollar estimates for the combination of four major post purchase costs for comparable 2013 diesel and gasoline vehicles over five years of ownership, as well as the percentage difference between the diesel and gasoline versions. Only two vehicle comparisons (Audi A3 and Mercedes GL Class) show the gasoline version of a vehicle with a cost estimate greater than the diesel version. Nine of the other fifteen vehicle comparisons show single digit cost estimates that are higher for the diesel version than the gasoline version, while five of the fifteen vehicle comparisons show double digit cost estimates, including the Volkswagen Jetta, Volkswagen Sportwagen, the Chevrolet Silverado 2500, the Dodge Ram 2500, and the GMC Sierra 2500.

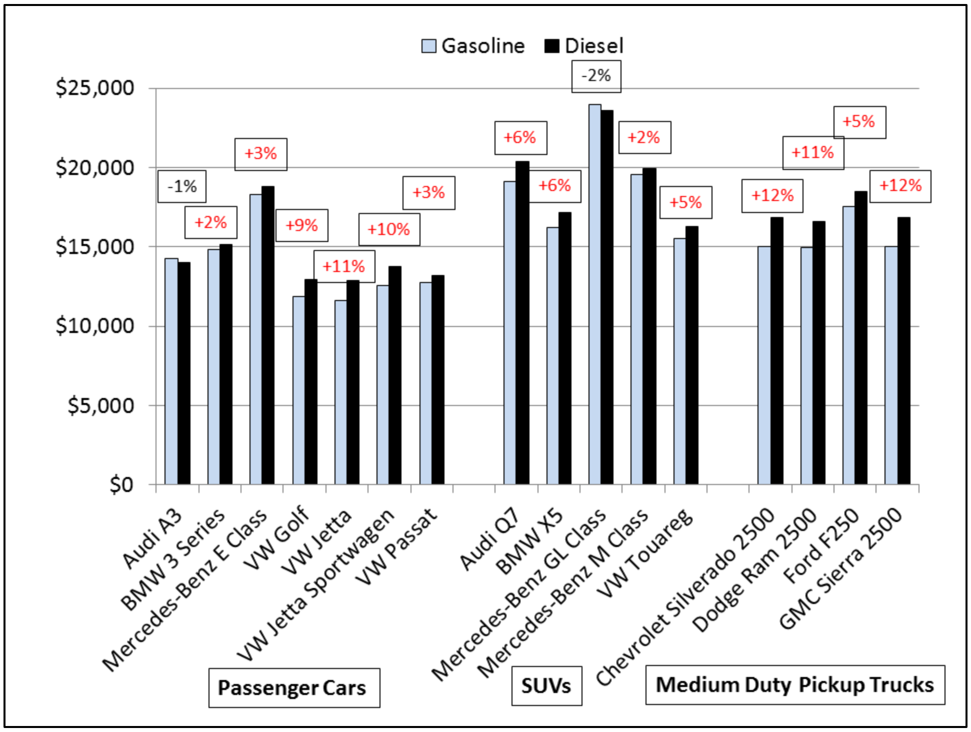

Figure 12: Vincentric Estimated Costs for Insurance, Repairs, Maintenance, and Fees and Taxes for Gasoline and Diesel Vehicles Over 5 Years

Total Cost of Ownership Model

Comparing the total cost of ownership of gasoline and diesel versions of the same model continues to be challenging. By developing a resale model based on the actual prices paid at auction (Mannheim auction data), by developing separate resale estimates based on specific vehicle trim levels, and by developing a fuel cost model based on actual fuel prices (EIA, FHWA, and EPA data) for a sample of 28,239 vehicles sold at auction in 2012 and 2013, the major pieces of the total cost of ownership model are in place. Models based on 2013 dollars with Vincentric's three- and five-year estimates for repairs, maintenance, insurance, and fees and taxes for the same types of vehicles, also in 2013 dollars, combined to develop good estimates for the total cost of ownership of gasoline and diesel versions of the same vehicles over both three- and five-year ownership periods.

The basic equation is:

Depreciation (Original MSRP-Resale Value) + Fuel Costs + Repairs + Insurance + Maintenance + Fees and Taxes

Results

Figures 13 through 17 show the dollar amounts that each of the parts of the TCO represents in the three- year timeframe, as well as the combined amount for all the parts of the TCO model.

They also show the amount saved or lost by driving a diesel rather than a gasoline version of the same vehicle over the three year timeframe. Finally, all of the vehicles are organized by type of vehicle: passenger cars, SUVs, and medium duty pickup trucks.

In terms of the level of importance of each of the parts of the TCO model in the three year timeframe, depreciation tends to be the main factor followed by fuel costs, insurance, maintenance, fees and taxes, and repairs.

In the three-year timeframe, all the diesel vehicles in the study, except for the Volkswagen Golf, are estimated to have a lower TCO than similar gasoline versions of the same vehicles, with savings ranging from $949 to $7,319. This means that owners of diesel vehicles recoup and exceed their initial higher investment in diesel vehicles within the first three years of ownership.

Figures 13 and 14 show that in the passenger segment, with the exception of the Volkswagen Golf, diesel vehicles provide a wide range of savings. At the lower end, the Mercedes E Class saves owners $1,091 over three years of ownership, and the Volkswagen Sportwagen saves $1,583. The vehicles with a mid-range of savings include the BMW 3 Series ($2,287) and the Volkswagen Jetta ($2,687), and vehicles at the higher end of savings include the Audi A3 ($4,977), and the Volkswagen Passat ($7,289). Both the Audi A3 and Volkswagen Passat gasoline versions suffer from much higher depreciation compared to the diesel versions.

In the SUV segment shown in Figures 15 and 16, the low end of savings is represented by the diesel version of the Audi Q7 that saves owners $929 over three years of ownership. The other four diesel SUVs offer owners much higher savings and include the Mercedes M Class, ($3,525), the Volkswagen Touareg ($4,358), the BMW X5 ($6,023), and the Mercedes GL Class ($7,319). The main factors in the higher savings group are the lower depreciation and lower fuel costs of the diesel versions of the vehicles.

The medium duty truck segment, as shown in Figure 17, also provides a range of savings for owners of the diesel versions of these vehicles. The diesel version of the Ford F250 saves owners $1,319, and the Dodge Ram 2500 saves owners $2,281. Higher savings are seen in the GMC Sierra 2500 ($3,378) and the Chevrolet Silverado 2500 ($4,250).

The general trend is positive for diesel versions of the same gasoline-powered vehicles, but a number of factors can affect the actual amount of money saved.

- Depreciation plays a large role in a vehicle’s TCO analysis, and things that affect it such as a poor reputation in the marketplace can decrease its price when it comes to market for resale.
- Manufacturers also sometimes charge higher prices for very new vehicles in order to recoup their R&D expenses. This higher price may not hold up in the resale market, thus making the TCO higher for a vehicle with new technology.

- Manufacturers can also support particular technologies by making them less expensive than their competitors. Luxury manufacturers may have more room to influence prices because they generally have a larger profit margin on their vehicles than do mass market manufacturers. They may also provide incentives to purchase a particular fuel saving technology in order to help meet their Corporate Average Fuel Economy (CAFE) goals.
- Finally, fuel costs are the second largest contributor to TCO, and higher diesel prices can also have a negative effect on TCO if the gap between the price of gasoline and diesel fuel is wide.

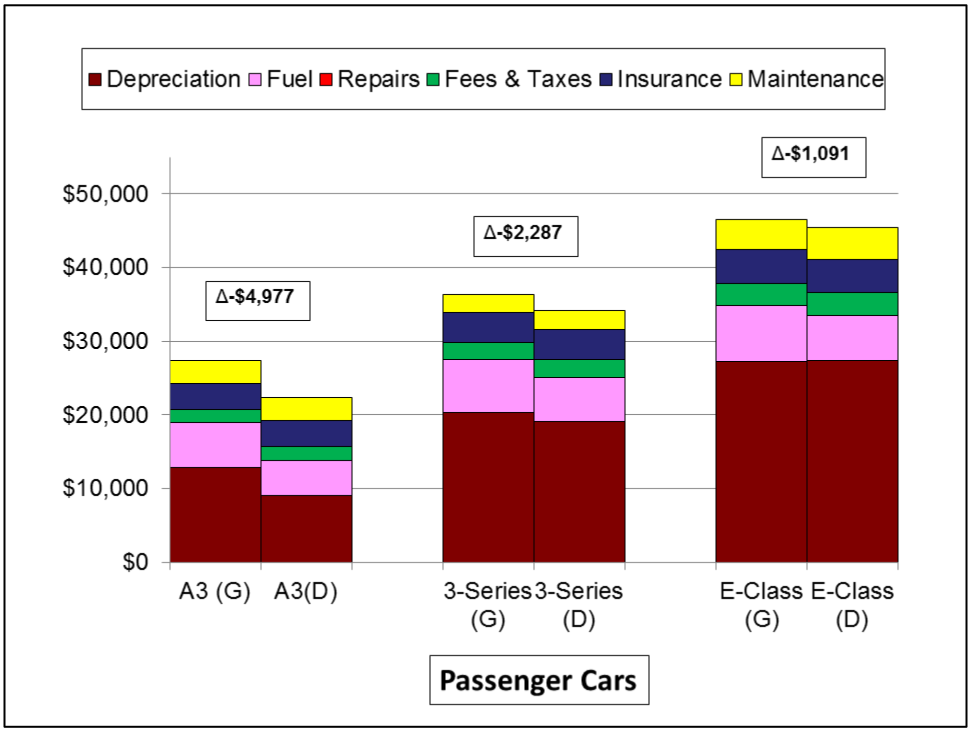

Figure 13: The Total Cost of Ownership for Selected Gasoline and Diesel Passenger Cars Over a 3 Year Timeframe

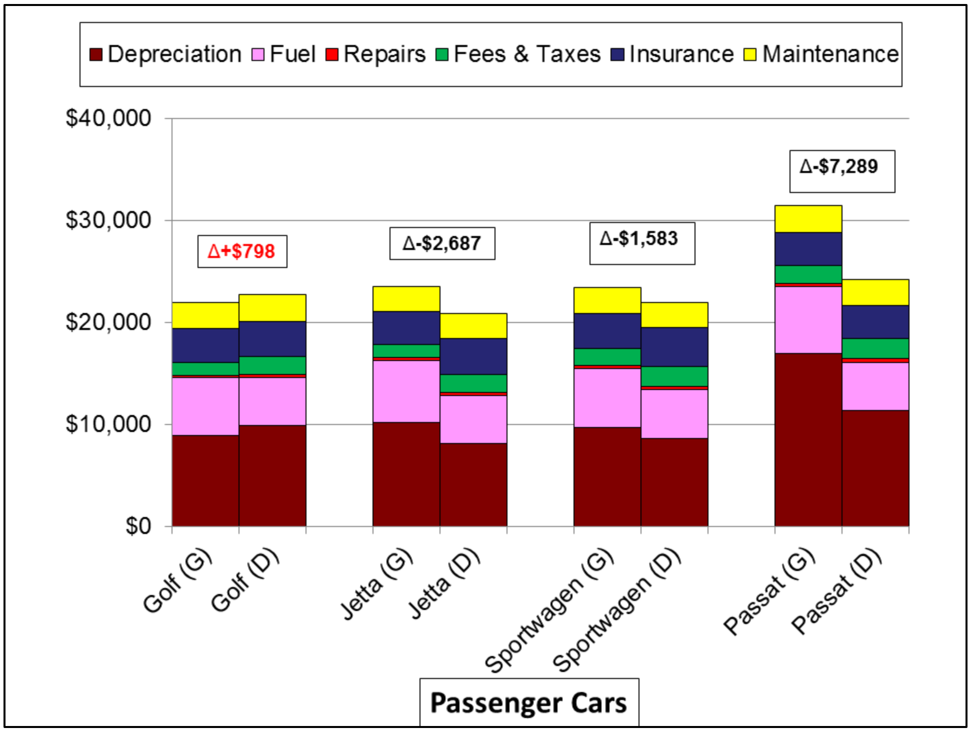

Figure 14: The Total Cost of Ownership for Selected Gasoline and Diesel Passenger Cars Over a 3 Year Timeframe

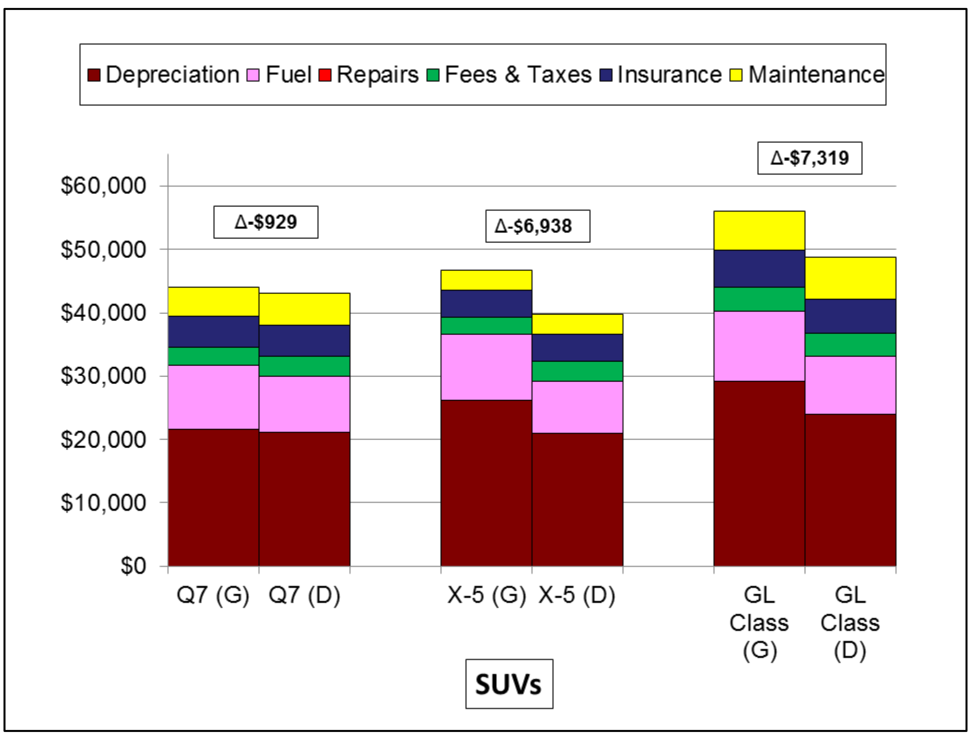

Figure 15: The Total Cost of Ownership for Selected Gasoline and Diesel SUVs Over a 3 Year Timeframe

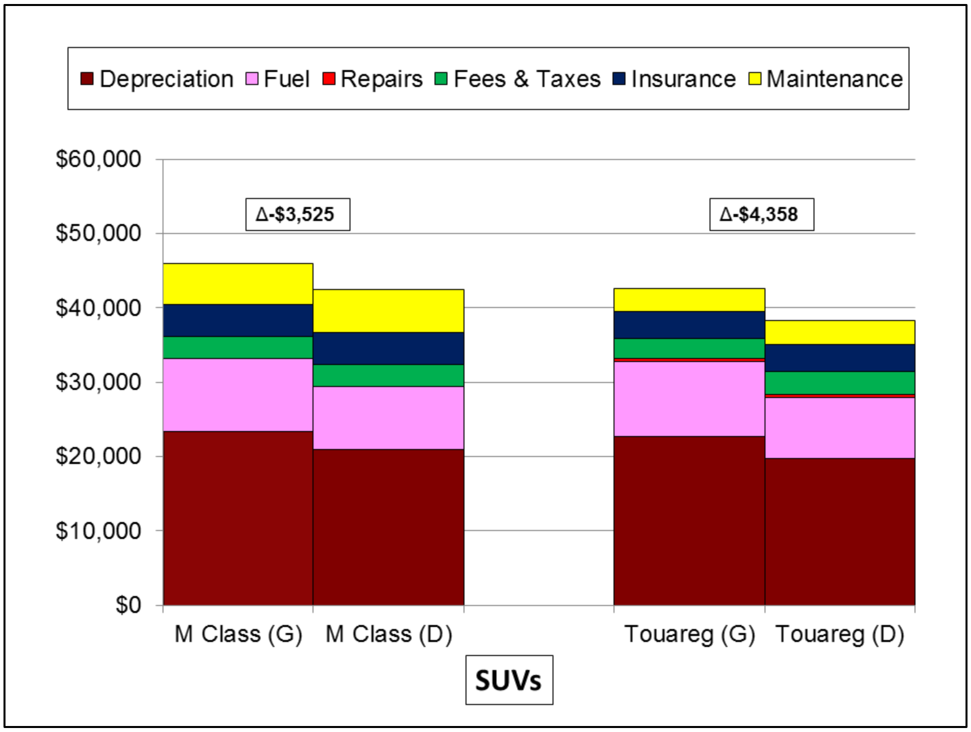

Figure 16: The Total Cost of Ownership for Selected Gasoline and Diesel SUVs Over a 3 Year Timeframe

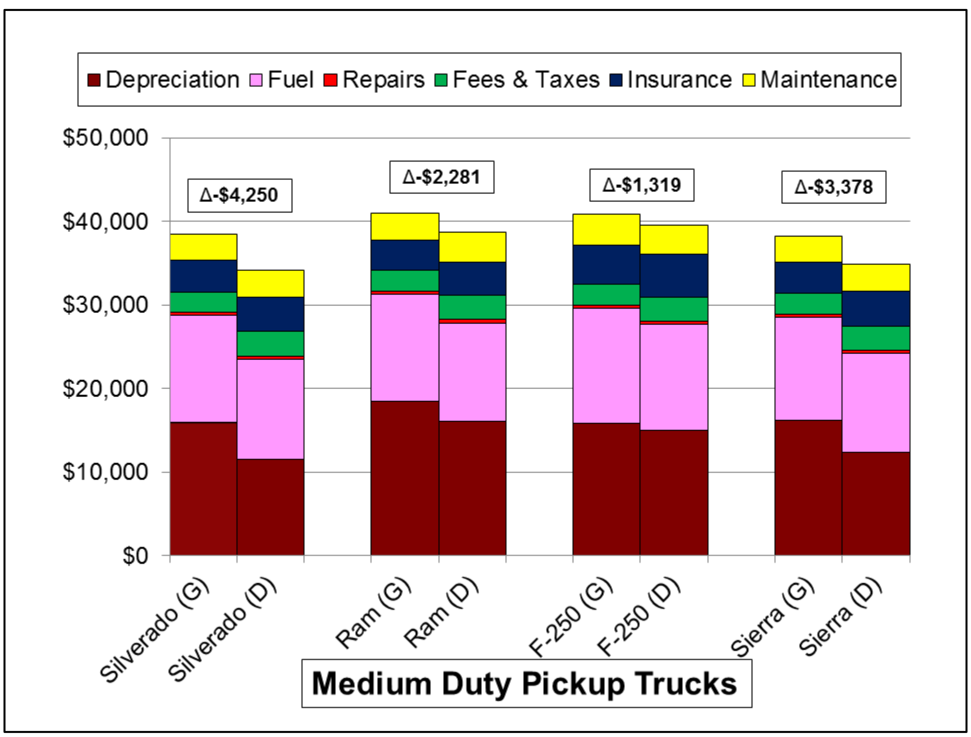

Figure 17: The Total Cost of Ownership for Selected Gasoline and Diesel Medium Duty Pickup Trucks Over a 3 Year Timeframe

Figures 18 to 22 show the dollar amounts that each of the parts of the TCO represents in the five-year timeframe, as well as the combined amount for all the parts of the TCO model. They also show the amount saved or lost by driving a diesel rather than a gasoline version of the same vehicle over the five year timeframe. Finally, all of the vehicles are organized by type of vehicle: passenger cars, SUVs, and medium duty pickup trucks.

In terms of the level of importance of each of the parts of the TCO model in the five year timeframe, depreciation tends to be the main factor followed by fuel costs, insurance, maintenance, fees and taxes, and repairs.

In the three-year timeframe, all the diesel vehicles in the study, except for the Volkswagen Golf and the Ford F250, are estimated to have a lower TCO than similar gasoline versions of the same vehicles, with savings ranging from $1,102 to $19,505. The TCO analysis also shows that all the passenger cars, except for the Volkswagen Sportwagen and Golf, all the SUVs, and the Dodge Ram 2500 exceed the savings gained during the first three years of ownership. This means that 11 of the 16 vehicles in the study continue to accrue savings through the three to five year ownership period.

As noted above, most of the TCO differences between the diesel and gasoline versions of the vehicles are explained through the lower depreciation and lower fuel costs for the diesel versions. It must be mentioned that fuel costs do not seem to have the same effect for the medium duty pickup trucks for both the three and five year TCO models. As shown in Table 3, the differences in fuel economy between the gasoline and diesel versions of the medium duty pickup trucks are not as large as they are for the passenger cars and SUVs. Because these trucks tend to have very large and powerful engines that consume high levels of fuel, their miles per gallon will always tend to be lower. But it must be noted that the diesel versions of these trucks tend to have larger, more powerful engines than the gasoline versions, yet still have a slightly higher miles per gallon rating.

Figures 18 and 19 show that in the passenger segment, diesel vehicles provide a wide range of savings. At the lower end, the Volkswagen Sportwagen saves diesel owners $1,102. The vehicles with a mid-range of savings include the Mercedes E-Class ($3,643), BMW 3 Series ($4,308) and the Volkswagen Jetta ($4,342), and vehicles at the higher end of savings include the Audi A3 ($5,828) and the Volkswagen Passat ($7,688). Both the Audi A3 and Volkswagen Passat gasoline versions suffer from much higher depreciation compared to the diesel versions.

In the SUV segment shown in Figures 20 and 21, the low end of savings is represented by the diesel version of the Audi Q7 that saves owners $3,134 over five years of ownership while the . Mercedes M Class saves $4,153 and the Volkswagen Touareg saves $5,637. Higher levels of saving are seen in the diesel versions of the BMW X5 ($19,505), and the Mercedes GL Class ($12,426). The main factors in the higher savings group are the lower depreciation and lower fuel costs of the diesel versions of the vehicles.

The medium duty truck segment, as shown in Figure 22, also provides a range of savings for owners of the diesel versions of these vehicles, but at a reduced level reported in the three year timeframe. Owners of the diesel version of the Ford F250 actually have a higher TCO than the owners of the gasoline version, losing $943. The Dodge Ram 2500 diesel owners save $2,291, while the Chevrolet Silverado 2500 owners save $1,811 and the GMC Sierra 2500 owners save $3,209.

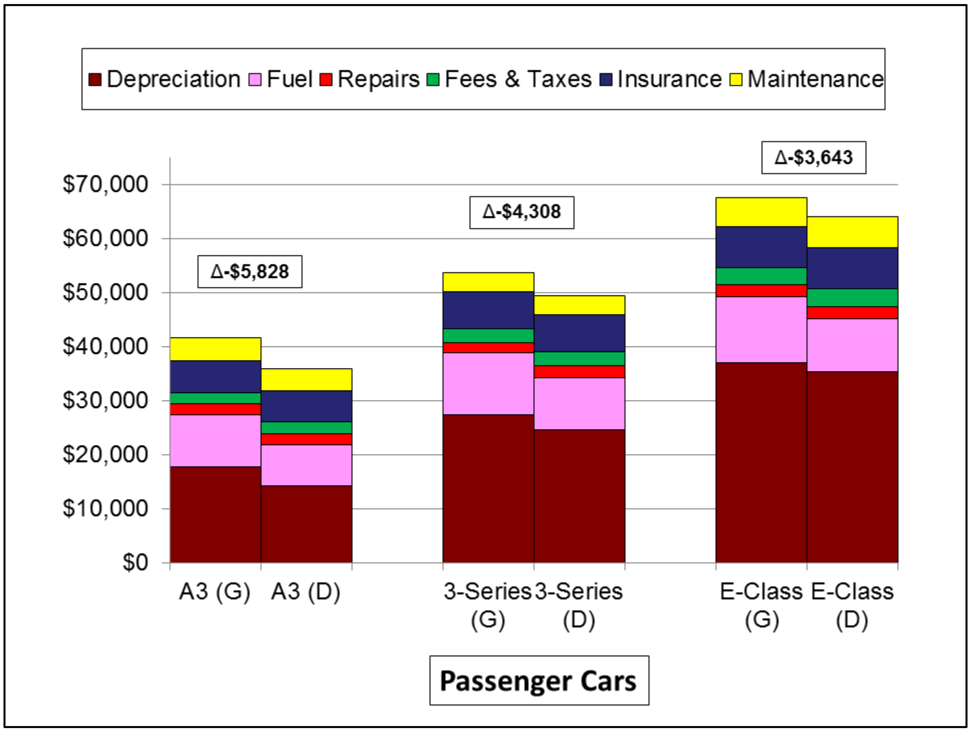

Figure 18: The Total Cost of Ownership for Selected Gasoline and Diesel Passenger Cars Over a 5 Year Timeframe

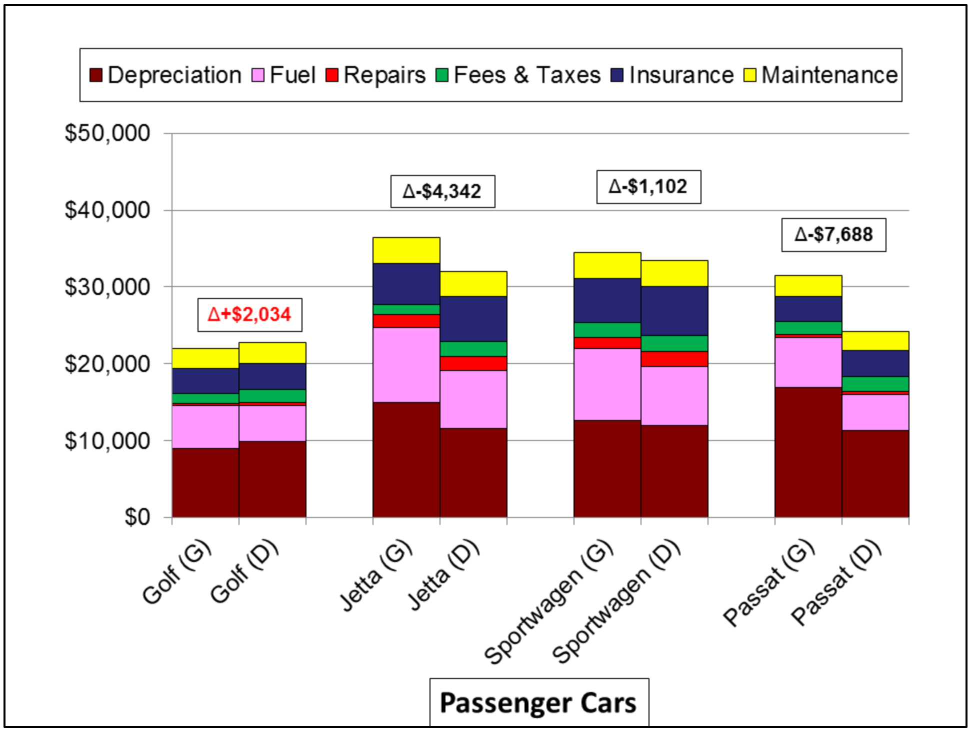

Figure 19: The Total Cost of Ownership for Selected Gasoline and Diesel Passenger Cars Over a 5 Year Timeframe

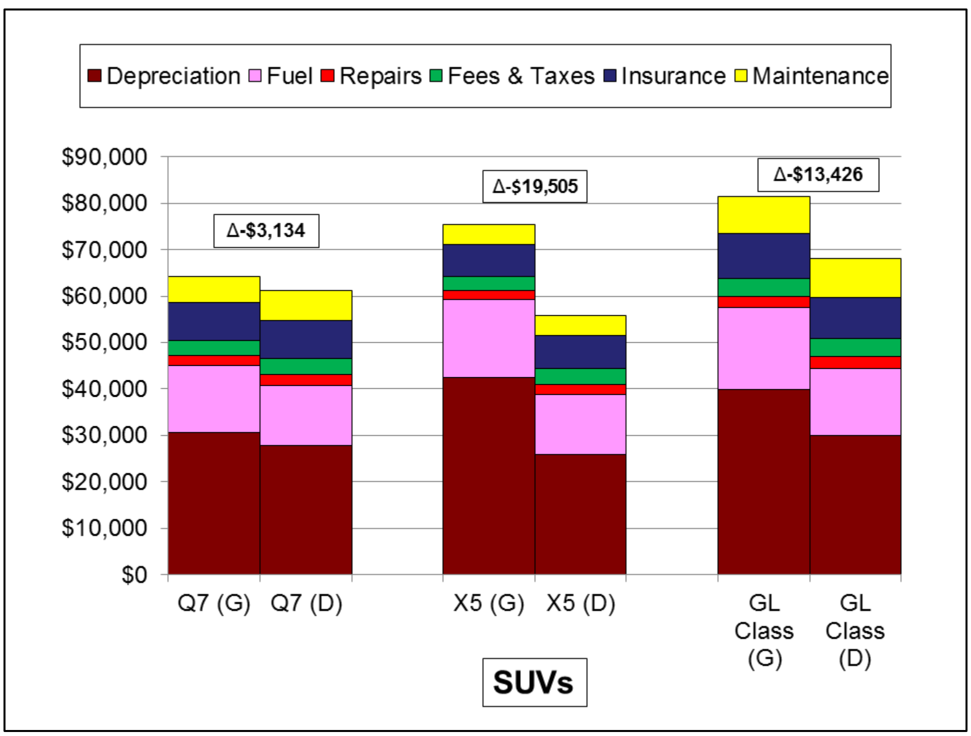

Figure 20: The Total Cost of Ownership for Selected Gasoline and Diesel SUVs Over a 5 Year Timeframe

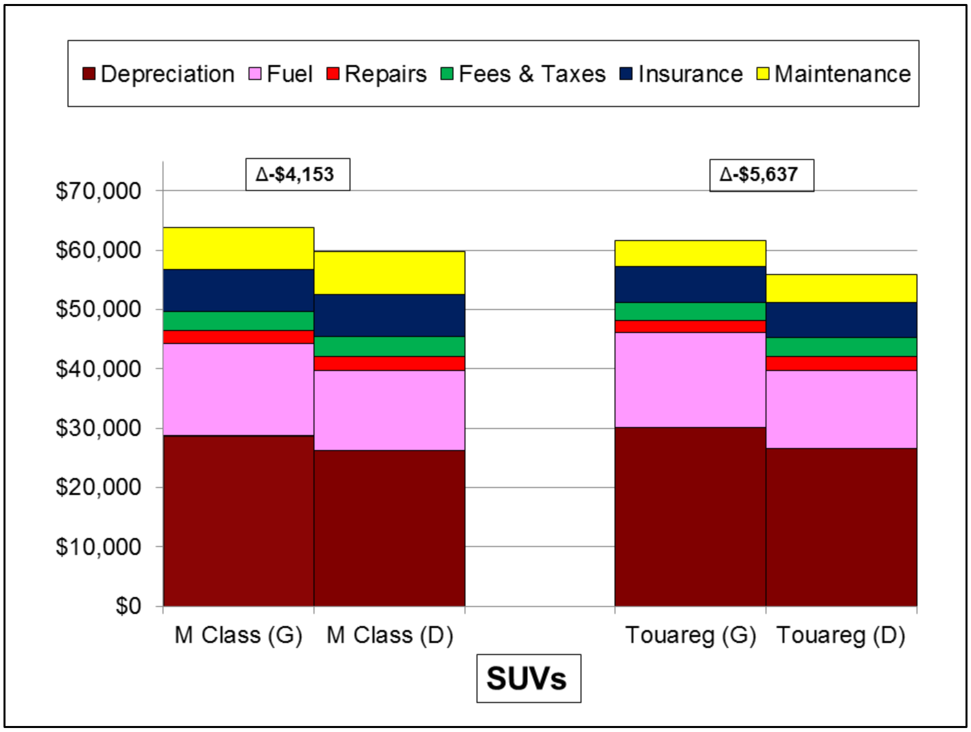

Figure 21: The Total Cost of Ownership for Selected Gasoline and Diesel SUVs Over a 5 Year Timeframe

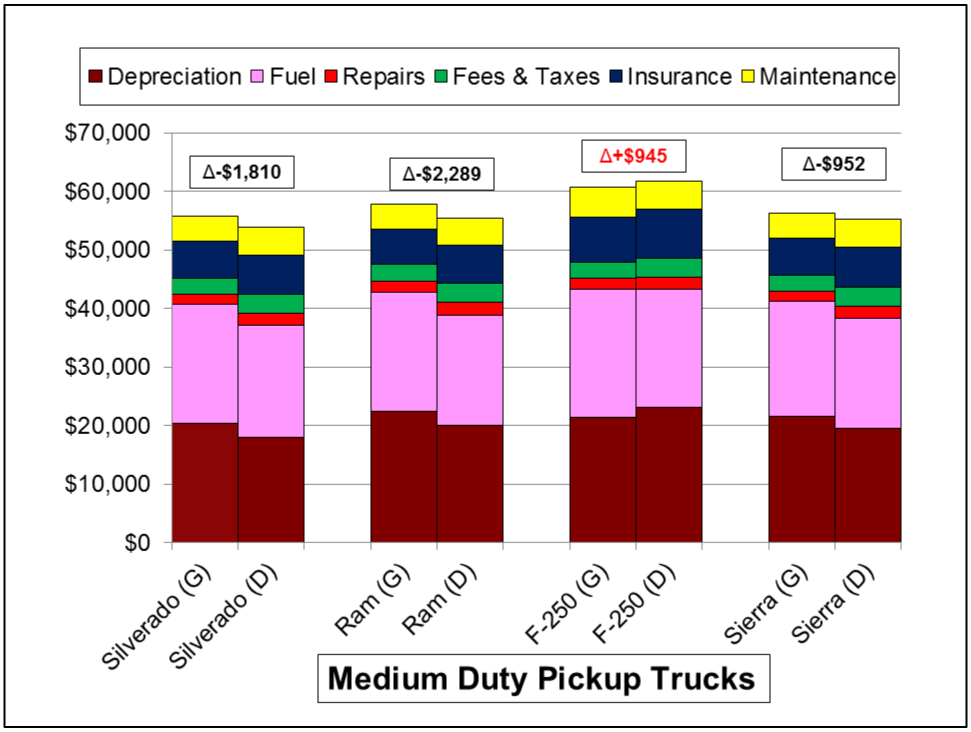

Figure 22: The Total Cost of Ownership for Selected Gasoline and Diesel Medium Duty Pickup Trucks Over a 5 Year Timeframe

Discussion and Conclusions

The results of the 2012-2013 TCO analyses are even more promising than the results of the previous 2010-2011 study. Overall, the results of the TCO analyses show that diesel vehicles provide owners with a TCO that in many cases is much less than that of the gasoline versions of the same vehicles. The estimates of savings for three and five years of ownership vary from a low of $929 in three years to a high of $19,505 in five years, but most of the savings are in the $2,000 to $7,000 range, which also include the extra cost that is usually added to the original price of the diesel version of a vehicle. Though there are some exceptions to these positive results for some of the diesel versions of vehicles from a TCO perspective, the overall direction of the results supports the idea that diesel vehicles compete well within the U.S. market. In particular, the idea that buyers can get a return on their initial higher investment in a diesel vehicle within three years is a very positive sign, considering that new vehicle buyers tend to keep their new vehicles for an average of three to five years.

Some continuing challenges for diesels in the U.S. include the potential increase in the cost of diesel fuel compared to gasoline, and the resulting need for diesels to proportionally improve their fuel economy to maintain a TCO advantage. This is particularly important because both gasoline and diesel powered vehicles must improve their fuel economy as required by Corporate Average Fuel Economy (CAFE) regulations for 2020 and 2025.

Since the previous 2010-2011 study, the market for diesels has grown with the introduction of diesel versions of the Audi A6, A7, A8, and Q5, BMW 3, 5, 7 Series and X3, Chevrolet Cruze, Ford Transit, Jeep Grand Cherokee, Porsche Cayenne, Ram Promaster, Ram 1500, and Volkswagen Beetle. There have also been some recent announcements of diesel versions of the Audi A4, Chevrolet Colorado, GMC Canyon, Mazda 6, Mercedes C-Class, Nissan Titan, Porsche Macan, and the Range Rover. As more of these vehicles enter the auction market, they will add to the number of vehicles that may be part of future TCO studies (though it takes a number of years for these new vehicles to reach the auction market in sufficient numbers to be analyzed).

One effect of the increase in the number of diesel models in the market may be that the sheer number of diesels in the marketplace may decrease the premium diesels now enjoy in the resale market. Another important issue related to the increase in diesel models may be that the increased number of diesel models in the fleet may also bring down the price of diesel-powered vehicles through economies of scale, providing consumers with both price and fuel savings. Though this is not likely in the short term, in the longer term diesel engines may lose some of their resale premium if they become a much larger part of the light duty fleet, particularly if manufacturers see an opportunity to increase their market share in a segment or increase their CAFE rating.

Diesel-powered vehicles are providing significant value to their owners through their TCO advantage over their gasoline-powered counterparts, and they will play an increasingly important role for manufacturers and consumers as fuel economy regulations become increasingly strict.

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