**U.S. Vehicle Electrification** 

# An Analysis of Automobile CO<sub>2</sub> Reduction Programs to Mitigate Climate Change

By Pat Murphy, Plan Curtail

April 3, 2018



# Contents

| Introduction  | 1  |
|---|----|
| Determining CO <sub>2</sub> Savings   | 2  |
| The Significance of MPGe Calculations   | 3  |
| Reviewing Conventional Hybrid Sales 2000–2017                                 | 5  |
| Reviewing Most Successful Hybrids 2000–2017                                   | 7  |
| Reviewing Least Successful Hybrids 2000–2017                                  | 8  |
| Hybrid Sales and Trends by Manufacturer                                       | 9  |
| Hybrid Market – Manufacturer Trends in the U.S.                               | 16 |
| Plug-In (PHEV and BEV) Sales Summary – US                                     | 17 |
| Manufacturer Analysis – BEV   | 19 |
| Manufacturer Analysis – PHEV  | 20 |
| What's the Near Term Plug-in Future?  | 21 |
| Hybrids or Plug-ins – MPG, MPG <sub>e</sub> , MPG <sub>ghg</sub> Implications | 24 |
| Conclusions   | 26 |

## Introduction

The nation's plug-in car program has been underway for more than two decades, beginning with the delivery of GM's EV1 (Electric Vehicle 1) in 1996. The EV1 along with 10 other cars from six manufacturers delivered about 6,000 Battery Electric Vehicle (BEV) cars from 1996-2002.<sup>1</sup> The second phase of plug-in cars began with the formation of Tesla Motor Company in 2003 and the delivery of the high-end Tesla Roadster in 2008. Another reference point in this second phase is represented by the introduction of GM's Volt Concept car in early 2007. The first two production plug-in cars of this second phase were the Chevrolet Volt Pluggable Hybrid Electric Vehicle (PHEV) and the Nissan Leaf BEV, both shipped in December 2010. A key third production plug-in car was the Tesla Model S BEV, first shipped in 2012. Today there are approximately 43 plug-in car models available in the U.S. About 750,000 plug-in vehicles (BEV and PHEV) have been delivered from January 2011 through December 2017 in the U.S.<sup>2</sup>

Electrification of transport became a national goal on August 4, 2008, when presidential candidate Barack Obama gave a talk in Lansing, MI, saying, "We must end the age of oil in our time." Obama described his New Energy for America plan including the elimination of U.S. dependence on Middle Eastern oil within ten years. In this talk he committed to getting one million 150 mile-per-gallon plug-in hybrid vehicles (PHEVs) on America's roads by the end of 2015. His program offered a \$7,000 tax credit, later changed to a higher purchase rebate. It also provided for more than \$4 billion in loans and tax credits to American auto plants and manufacturers to re-tool their factories to build electric cars. Obama also set a goal of increasing fuel economy standards by four percent each year, more than twice the long-term rate of Miles per Gallon (MPG) improvement of the auto industry.<sup>3</sup> The 150-MPG PHEV (in reality PHEVs are closer to 50 MPG) was not met. Nor was the goal of 1 million PHEV vehicles sold. The number of PHEVs sold by the end of 2017 was 357,000 – slightly less than half of the 750,000 plug-ins sold in the same period). Nonetheless, an electric car industry was born.

The term "Electrified Vehicles" in Table 1 below includes standard hybrid cars (HEVs). A full understanding of the market requires evaluation of the three vehicle types together – standard hybrids (HEVs), Battery Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs). Table 1 shows the sales of "electrified" vehicles for the period 2011–2017.

| Analysis of Electrified Vehicles 2011 - 2017 (In 1000s) Table 1 |                                 |         |         |         |         |         |         |         |  |  |  |  |  |
|---|---------------------------------|---------|---------|---------|---------|---------|---------|---------|--|--|--|--|--|
|   | 2011 2012 2013 2014 2015 2016 2 |         |         |         |         |         |         |         |  |  |  |  |  |
| All Vehicles in Use (Vehicle Fleet)                             | 248,932                         | 251,497 | 252,715 | 258,027 | 261,000 | 265,000 | 268,000 |         |  |  |  |  |  |
| Total Yearly Vehicle Sales                                      | 12,734                          | 14,440  | 15,532  | 16,435  | 17,386  | 17,465  | 17,135  | 111,127 |  |  |  |  |  |
| HEV Sales per year  | 269                             | 434     | 496     | 452     | 384     | 347     | 364     | 2,747   |  |  |  |  |  |
| BEV Sales per year  | 10                              | 14      | 48      | 63      | 71      | 84      | 104     | 395     |  |  |  |  |  |
| PHEV Sales per year   | 8                               | 39      | 49      | 55      | 43      | 73      | 90      | 357     |  |  |  |  |  |
| BEV+PHEV Sales per year   | 18                              | 53      | 97      | 119     | 114     | 157     | 194     | 752     |  |  |  |  |  |
| HEV+BEV+PHEV Sales per year                                     | 287                             | 487     | 592     | 571     | 499     | 504     | 559     | 3,498   |  |  |  |  |  |
| HEV % of Vehicles Sales   | 2.1%                            | 3.0%    | 3.2%    | 2.8%    | 2.2%    | 2.0%    | 2.1%    | 2.5%    |  |  |  |  |  |
| BEV+PHEV % of Vehicles Sales                                    | 0.1%                            | 0.4%    | 0.6%    | 0.7%    | 0.7%    | 0.9%    | 1.1%    | 0.7%    |  |  |  |  |  |
| HEV+BEV+PHEV % of Vehicles Sales                                | 2.3%                            | 3.4%    | 3.8%    | 3.5%    | 2.9%    | 2.9%    | 3.3%    | 3.1%    |  |  |  |  |  |

Table 1: U.S. Shipments of Hybrid and Plug-in Cars 2011–2017

The production of more than 750,000 plug-in cars (BEV and PHEV) through 2017 is an impressive accomplishment. Not to be overlooked is that the reliability and longevity of plug-in cars is no longer a major concern. Plug-ins work and they work well.

# **Determining CO<sub>2</sub> Savings**

Climate change is the main justification for the electrification of transportation. However, the total  $CO_2$  reductions achieved through electrification, which includes standard hybrids and plugins, are not often clear.  $CO_2$  savings from electrified vehicles are shown in Table 2 below, which shows that to date  $CO_2$  reductions have been quite small when contrasted with total automobile emissions. Overconfidence in the growth rate of plug-in (BEV and PHEV) cars may have created an overly optimistic assessment of  $CO_2$  cuts.

| Percent of Vehicle Sales and Vehicle Inventory CO <sub>2</sub> Reductions 2011-2017 (in 1000s) Table 2 |         |         |         |         |         |         |         |         |  |  |  |  |  |
|--|---------|---------|---------|---------|---------|---------|---------|---------|--|--|--|--|--|
|  | 2011    | 2012    | 2013    | 2014    | 2015    | 2016    | 2017    | Total   |  |  |  |  |  |
| All Vehicles in Use (Vehicle Fleet)  | 248,932 | 251,497 | 252,715 | 258,027 | 261,000 | 265,000 | 268,000 |         |  |  |  |  |  |
| Total Yearly Vehicle Sales   | 12,734  | 14,440  | 15,532  | 16,435  | 17,386  | 17,465  | 17,135  | 111,127 |  |  |  |  |  |
| HEV+BEV+PHEV Sales per year  | 287     | 487     | 592     | 571     | 499     | 504     | 559     | 3,498   |  |  |  |  |  |
| % CO <sub>2</sub> Reductions - Yearly Vehicles Sales   | 1.1%    | 1.7%    | 1.9%    | 1.7%    | 1.4%    | 1.4%    | 1.6%    | 1.6%    |  |  |  |  |  |
| % CO <sub>2</sub> Reductions - All Vehicles in Use   | 0.1%    | 0.1%    | 0.1%    | 0.1%    | 0.1%    | 0.1%    | 0.1%    | TBD     |  |  |  |  |  |

Some explanation of Table 2 may be useful. Rows "All Vehicles in Use," "Total Yearly Vehicle Sales," and "HEV+BEV+PHEV Sales" come from Table 1. The rows with % CO<sub>2</sub> Reductions are calculated by using the CO<sub>2</sub> values per car type from the "Emissions from Hybrid and Plug-In Electric Vehicles" section of the Alternative Fuels Data Center's (AFDC) web site.<sup>4</sup> (The AFDC is a resource of the U.S. Department of Energy's Vehicle Technologies Office.) The CO<sub>2</sub> measure is in pounds generated per year per car for each of the four vehicle types listed below:

| CO <sub>2</sub> from Conventional | Vehicles11,435 lbs. per year |
|-----------------------------------|------------------------------|
| CO <sub>2</sub> from PHEVs        | 6,337 lbs. per year          |
| CO <sub>2</sub> from HEVs         | 6,258 lbs. per year          |
| CO <sub>2</sub> from BEVs         | 4,816 lbs. per year          |

A quick calculation using these values shows that, compared to Conventional Vehicles:

PHEVs generate 44.6% less CO<sub>2</sub> than a conventional vehicle, HEVs generate 45.3% less CO<sub>2</sub> and BEVs generate 57.0% less CO<sub>2</sub>.

On average the reduction is 49% less than a conventional vehicle. A weighted average of the three types of electrified cars over the period 2011-2017 shows an average  $CO_2$  reduction of 43% over conventional vehicles. For ease of calculation 50% is used instead of 43% in Table 2, even though this favors electrified cars.

Using 50% as the CO<sub>2</sub> reduction makes calculations in Table 2 straightforward. The "% CO<sub>2</sub> Reductions – Yearly Vehicles Sales" is calculated by dividing the total of the "HEV+BEV+PHEV Sales" by the "Total Yearly Vehicle Sales" and then multiplying the result by 50%. This gives the percent of CO<sub>2</sub> reduction for new vehicles that is contributed by sales of electrified cars. To calculate the savings on a total vehicle fleet basis, "% CO<sub>2</sub> Reductions – All Vehicles in Use (Fleet)," the sum of the "HEV+BEV+PHEV Sales" is first divided by "All Vehicles in Use," and the result is then multiplied by 50%. This shows the CO<sub>2</sub> reduction from electrified cars to the total existing vehicle fleet.

The total CO<sub>2</sub> savings over the last seven years from electrified car sales are minimal, averaging about a 1.5% reduction of Yearly Vehicle Sales and less than 0.1% for the existing vehicle fleet. This might be surprising to many based on the optimistic treatment of plug-in vehicles in the national media. Unfortunately, any success in plug-ins sales has been offset by a reduction in sales of standard hybrid (HEV) cars, coupled with the plateauing of fuel economy at 25 MPG for conventional vehicles. A trend toward increasing sales of SUVs and CUVS as compared to sedans, compacts, and subcompacts, has contributed to this fuel economy plateau.<sup>5</sup>

### The Significance of MPGe Calculations

The 2007 Energy Independence and Security Act required that the EPA design new car window stickers, to become mandatory in 2013, which would show both miles per gallon and  $CO_2$  emissions per mile. The new law also required that electric cars show the number of kilowatt hours consumed to drive 100 miles. Since electric cars don't use gasoline, the window stickers included a new term, Miles-per-Gallon Equivalent (MPGe) to be displayed on electric car window stickers. However, despite the high MPGe numbers on the window stickers, typically more than 100 MPG<sub>e</sub>,  $CO_2$  emissions from the most popular electric cars are about the same as those from a 2017 Toyota Prius Eco, rated at 56-MPG. This is because the window stickers on BEV and PHEV cars do not show the  $CO_2$  generated by the burning of fossil fuels to create electricity to charge the car. This has allowed car companies to use misleading marketing of plug-in cars that may have resulted in false confidence in the  $CO_2$  reduction contribution of such vehicles.

In September 2010, the EPA proposed alternate ways of measuring car  $CO_2$  in a 130-page proposal document that formed the basis for a series of meetings with consumers, nonprofits, auto companies, fuel suppliers, and private individuals. 6,000 comments were submitted. In May 2011 the EPA published a 367 page response to reviewers of the September 2010 document. Many of the responses were critical of the EPA's decision to ignore the emissions generated by power plants. The terminology used in this report to describe the emissions associated with electricity generation and transmission was "upstream emissions."

The Union of Concerned Scientists (UCS), one of the many reputable non-profit organizations that spoke out for having the information included on the window sticker, said that:

"The failure to incorporate upstream emissions in the data on the label could lead consumers who are concerned about emissions to make adverse decisions due to the lack of all the relevant information at hand".

Commenting on the possible inclusion of such information on window stickers, the Alliance of Automobile Manufacturers stated:

"...such a policy could discourage future sales of plug-in electric vehicles; once upstream emissions are added in, the greenhouse gas emissions for electric vehicles are only marginally lower than other, less expensive technologies..."

The Electric Drive Transportation Association stated:

"Attempting to include upstream emissions on the label would confuse, not inform, the consumers..."

Although the EPA choose a methodology that ignored the emissions from the power plant on the window sticker, it did provide options on the fueleconomy.com website that would allow a prospective car purchaser to determine all related  $CO_2$  emissions. The Union of Concerned Scientists (UCS) developed another method with MPG based on greenhouse gas emissions, labeled MPG<sub>ghg</sub>. The UCS published a report in the spring of 2012, which provided very different, and much lower, MPG values than those of the EPA.<sup>6</sup> A description of the different methods used by the EPA, the Department of Energy (DOE), and the UCS to calculate MPG equivalence can be found on www.plancurtail.org.<sup>7</sup>

The important thing to understand is that this lack of clarity about CO<sub>2</sub> emissions on the window sticker of cars has most likely led to expectations of greenhouse gas emissions reductions that cannot be realized by plug-in cars. The points made in this paper, which provide the method of determining the values in Table 2, add clarity to the debates about the future of plug-ins and also explain why many companies, particularly Toyota, continue making major investments in HEV (standard hybrid) technology. Their underlying assumption is that BEVs and PHEVs are not guaranteed to be the technologies that will free us from worrying about transportation emissions in the future.

# Reviewing Conventional Hybrid (HEV) Sales 2000–2017

Table 3 (below) provides a visual reference of historical first shipment and customer sales of standard hybrid models in the U.S., beginning in 2000. The different models are ordered from top to bottom, first by year of introduction and second by sales volume. The first appearance of a sales number in a row represents the year of first shipment of the model. There are 68 different hybrid cars in this table.

The right-most column shows the total cars sold over a model's lifetime (through 2017) and allows comparisons of the sales of different models. For example, the table shows that total Prius lifetime sales were about 1.8 million cars over 17 years, while the total Chrysler Aspen lifetime sales were only 46 cars over its first 10 years of sales. The bottom row shows the annual sales of all hybrids from 2000 through 2017.

More than half of the entrants into the hybrid market did not succeed. These include the socalled mild hybrids made by GM (Saturn Aura, Saturn Vue, Chevrolet Malibu, Chevrolet Tahoe, and GMC Yukon), because they do not fit in the high-mileage hybrid architecture. Thus, of the 68 models listed in Table 3, 40 of them fit in the categories of low sales, canceled models, or are not really hybrids but "mild" hybrids. This is a relatively high number of unsuccessful models for a new drive train concept but it may be typical of a new technology introduction. These are designated as Least Successful Hybrids and marked with an asterisk in Table 3.

The "Vehicle (mpg)" column includes the miles per gallon in parenthesis next to the name of each car. An example from the Vehicle (MPG) column is the two-seater Honda Insight. There were both standard and automatic models and the MPG was excellent for both models. However, Honda's sales of the car did not warrant it being continued. Its entry is written as Honda Insight 1(53)\*. An asterisk identifies cars that were the least popular models. They are summarized in Table 5 as Least Successful Hybrids. The Most Successful Hybrids are summarized first in Table 4.

| U.S. H                 | U.S. Hybrids Sales by Date of Introduction 2000-2017 (in 1,000s) Table 3 |      |      |      |      |      |      |      |      |      |      |      |       |  |
|------------------------|--|------|------|------|------|------|------|------|------|------|------|------|-------|--|
| Vehicle(mpg)           | 2000-<br>2006  | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total |  |
| Toyota Prius(41)       | 335  | 181  | 159  | 140  | 141  | 136  | 148  | 145  | 123  | 114  | 99   | 66   | 1,786 |  |
| Honda Insight 1(53)*   | 14   | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 14    |  |
| Honda Civic(40)*       | 118  | 33   | 31   | 15   | 7    | 5    | 7    | 8    | 5    | 5    | 1    | 0    | 235   |  |
| Ford Escape(27)*       | 42   | 21   | 17   | 15   | 11   | 10   | 1    | 0    | 0    | 0    | 0    | 0    | 118   |  |
| Honda Accord 1(28)*    | 23   | 3    | 0.2  | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 27    |  |
| Lexus RX400/450h(25)   | 41   | 17   | 15   | 14   | 15   | 11   | 12   | 11   | 9    | 8    | 9    | 9    | 171   |  |
| Toyota Highlander(27)  | 49   | 22   | 19   | 11   | 7    | 5    | 6    | 5    | 4    | 4    | 6    | 17   | 155   |  |
| Mercury Mariner(28)*   | 4  | 4    | 2    | 2    | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 13    |  |
| Toyota Camry(34)       | 31   | 54   | 46   | 23   | 15   | 9    | 46   | 44   | 40   | 31   | 22   | 21   | 382   |  |
| Lexus GS 450h(23)*     | 2  | 2    | 1    | 0.5  | 0.3  | 0.3  | 1    | 1    | 0.2  | 0.1  | 0.1  | 0.1  | 7     |  |
| Nissan Altima(34)*     |  | 8    | 9    | 9    | 7    | 3    | 0.1  | 0    | 0    | 0    | 0    | 0    | 37    |  |
| Saturn Vue(26)*        |  | 4    | 3    | 3    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 10    |  |
| Lexus LS600hL(21)*     |  | 1    | 1    | 0.3  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0    | 0    | 0    | 3     |  |
| Saturn Aura(27)*       |  | 1    | 0.3  | 1    | 0.1  | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 2     |  |
| Chevy Malibu(27)*      |  |      | 2    | 4    | 0.4  | 0.02 | 17   | 14   | 1    | 0    | 0    | 0    | 38    |  |
| Chevy Tahoe(21)*       |  |      | 4    | 3    | 1    | 1    | 1    | 0.4  | 0.1  | 0    | 0    | 0    | 10    |  |
| GMC Yukon(21)*         |  |      | 2    | 2    | 1    | 1    | 1    | 0.3  | 0    | 0    | 0    | 0    | 7     |  |
| Cadillac Escalade(20)* |  |      | 1    | 2    | 1    | 1    | 1    | 0.4  | 0    | 0    | 0    | 0    | 6     |  |
| Chrysler Aspen(21)*    |  |      | 0.05 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0.05  |  |
| Ford Fusion(39)        |  |      |      | 16   | 21   | 11   | 14   | 37   | 35   | 25   | 34   | 57   | 250   |  |
| Honda Insight 2(41)*   |  |      |      | 21   | 21   | 16   | 6    | 5    | 4    | 1    | 0    | 0    | 73    |  |
| Lexus 250h(35)*        |  |      |      | 2    | 11   | 3    | 1    | 0.01 | 0    | 0    | 0    | 0    | 16    |  |
| Chevy Silverado(21)*   |  |      |      | 2    | 2    | 1    | 0.5  | 0.1  | 0    | 0    | 0    | 0    | 5     |  |

| Mercury Milan(39)*            |     |     |     | 1   | 1   | 0    | 0   | 0    | 0   | 0   | 0    | 0    | 3     |
|-------------------------------|-----|-----|-----|-----|-----|------|-----|------|-----|-----|------|------|-------|
| Honda CRZ(37)                 |     |     |     |     | 5   | 11   | 4   | 5    | 4   | 3   | 2    | 1    | 35    |
| Lincoln MKZ(39)               |     |     |     |     | 1   | 6    | 6   | 7    | 10  | 8   | 7    | 6    | 52    |
| Porsche Cayenne(21)*          |     |     |     |     | 0.3 | 2    | 1   | 1    | 1   | 0   | 0    | 0    | 4     |
| Mercedes S400HV(21)*          |     |     |     |     | 1   | 0.3  | 0.1 | 0.1  | 0   | 0   | 0    | 0    | 1     |
| Mazda Tribute(32)*            |     |     |     |     | 1   | 0.5  | 0.1 | 0.0  | 0   | 0   | 0    | 0    | 1     |
| GMC Sierra(21)*               |     |     |     |     | 1   | 0.2  | 0.5 | 0.1  | 0   | 0   | 0    | 1    | 2     |
| Mercedes ML450H(22)*          |     |     |     |     | 1   | 0.0  | 0.0 | 0.0  | 0   | 0   | 0    | 0    | 1     |
| BMW X6(18)*                   |     |     |     |     | 0.2 | 0.04 | 0   | 0    | 0   | 0   | 0    | 0    | 0.3   |
| BMW Hybrid 7(20)*             |     |     |     |     | 0.1 | 0.3  | 0.2 | 0.03 | 0   | 0   | 0    | 0    | 1     |
| Toyota Prius v(42)            |     |     |     |     |     | 8    | 41  | 35   | 31  | 28  | 15   | 10   | 168   |
| Hyunda Sonata(36)             |     |     |     |     |     | 20   | 21  | 22   | 21  | 20  | 19   | 8    | 130   |
| Lexus CT200h(42)              |     |     |     |     |     | 14   | 18  | 15   | 18  | 15  | 9    | 5    | 93    |
| Kia Optima(36)                |     |     |     |     |     | 0.40 | 10  | 14   | 14  | 11  | 6    | 6    | 61    |
| Buick Lacrosse(29)*           |     |     |     |     |     | 2    | 12  | 7    | 7   | 4   | 1    | 1    | 34    |
| Buick Regal(29)*              |     |     |     |     |     | 0.12 | 3   | 3    | 1   | 0   | 0    | 0    | 6     |
| infiniti m35h Q70 (29)*       |     |     |     |     |     | 0.38 | 1   | 0.5  | 0.2 | 0   | 0    | 0    | 2     |
| VW Touareg(21)*               |     |     |     |     |     | 0.39 | 0.3 | 0.1  | 0   | 0   | 0    | 0    | 1     |
| Porsche Panamera(25)*         |     |     |     |     |     | 0.05 | 1   | 0.1  | 0   | 0   | 0    | 0    | 1     |
| Toyota Prius c(50)            |     |     |     |     |     |      | 36  | 42   | 41  | 38  | 20   | 12   | 190   |
| Ford C-Max(43)                |     |     |     |     |     |      | 11  | 28   | 19  | 14  | 12   | 10   | 94    |
| Lexus ES 300h(40)             |     |     |     |     |     |      | 7   | 17   | 15  | 11  | 7    | 5    | 63    |
| Toyota Avalon(40)             |     |     |     |     |     |      | 1   | 16   | 17  | 12  | 8    | 5    | 60    |
| VW Jetta(45)*                 |     |     |     |     |     |      | 0.2 | 6    | 2   | 1   | 1    | 0    | 9     |
| Acura ILX(38)*                |     |     |     |     |     |      | 1   | 1    | 0.4 | 0.0 | 0.0  | 0.0  | 3     |
| BMW 335ih(26)*                |     |     |     |     |     |      | 0.4 | 1    | 0.2 | 0   | 0    | 0    | 1     |
| Audi Q5(26)*                  |     |     |     |     |     |      | 0.3 | 1    | 0.3 | 0.1 | 0.0  | 0.0  | 2     |
| BMW 535ih(26)*                |     |     |     |     |     |      | 0.4 | 1    | 0.1 | 0   | 0    | 0    | 1     |
| Honda Accord 2(47)            |     |     |     |     |     |      |     | 1    | 14  | 11  | 9    | 22   | 57    |
| Infiniti QX60(26)             |     |     |     |     |     |      |     | 1    | 2   | 2   | 1    | 0    | 6     |
| Nissan Pathfinder(26)         |     |     |     |     |     |      |     | 0.3  | 2   | 2   | 1    | 0    | 6.3   |
| Infiniti Q50(31)              |     |     |     |     |     |      |     | 0.3  | 3   | 4   | 2    | 1    | 10.6  |
| Mercedes E400H(26)*           |     |     |     |     |     |      |     | 0.3  | 0.2 | 0   | 0    | 0    | 0.5   |
| Chevrolet Impala(29)*         |     |     |     |     |     |      |     | 0.1  | 1   | 0.3 | 0    | 0    | 1     |
| Subaru Crosstrek Hybrid (31)* |     |     |     |     |     |      |     |      | 8   | 6   | 2    | 0    | 15.7  |
| Lexus NX 300hHybrid (33)      |     |     |     |     |     |      |     |      | 0.4 | 2.6 | 2.8  | 3.3  | 9.1   |
| Acura RLX Hybrid (30)*        |     |     |     |     |     |      |     |      | 0.1 | 0.3 | 0.2  | 0.3  | 0.9   |
| Chevrolet Malibu 2(46)        |     |     |     |     |     |      |     |      |     | 0.1 | 4.3  | 4.5  | 8.8   |
| Toyota RAV4(32)               |     |     |     |     |     |      |     |      |     | 1.5 | 45.1 | 50.6 | 97.1  |
| Acura NSX Hybrid(21)          |     |     |     |     |     |      |     |      |     |     | 0.3  | 0.6  | 0.9   |
| GMC Sierra2(21)*              |     |     |     |     |     |      |     |      |     |     |      | 0.9  | 0.9   |
| Kia Niro Hybrid(49)           |     |     |     |     |     |      |     |      |     |     |      | 27.2 | 27.2  |
| Hyundai Ioniq(55)             |     |     |     |     |     |      |     |      |     |     |      | 10.8 | 10.8  |
| Acura MDX Hybrid(27)          |     |     |     |     |     |      |     |      |     |     |      | 1.8  | 1.8   |
| Lexus LC500h(30)              |     |     |     |     |     |      |     |      |     |     |      | 0.1  | 0.1   |
| Total                         | 660 | 352 | 314 | 286 | 275 | 278  | 434 | 496  | 452 | 384 | 347  | 362  | 4,640 |

Table 3: US Hybrid Sales by Year and Totals - 2000–2017

Note that the most productive year of electrified car sales was 2013 with sales of 496,000 hybrid cars. Four years later, in 2017, hybrid sales had declined to 362,000 cars. The top ten models in sales accounted for 97% of total sales of the 68 models.

# **Reviewing the Most Successful Hybrids 2000–2017**

Table 4 is a subset of 28 of the 68 hybrid (HEV) cars listed in Table 3. These are the most successful hybrid cars in terms of sales, or the "hybrid winners" from 2000-2017. Note that the MPG in parenthesis in column one now has two numbers. The first is the MPG value for the first year of introduction while the second number is the MPG value for 2017.

| U.S. Hybrids Sales by Date of Introduction 2000-2017 - Most Successful (in 1000s) Table 4 |       |      |      |      |      |      |      |      |      |      |      |      |       |
|---|-------|------|------|------|------|------|------|------|------|------|------|------|-------|
|   | 2000- |      |      |      |      |      |      |      |      |      |      |      |       |
| Vehicle (mpg)   | 2006  | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total |
| Toyota Prius (41-56)  | 335   | 181  | 159  | 140  | 141  | 136  | 148  | 145  | 123  | 114  | 99   | 66   | 1,786 |
| Lexus RX400/450h (27-30)  | 41    | 17   | 15   | 14   | 15   | 11   | 12   | 11   | 9    | 8    | 9    | 9    | 171   |
| Toyota Highlander (27-29)   | 49    | 22   | 19   | 11   | 7    | 5    | 6    | 5    | 4    | 4    | 6    | 17   | 155   |
| Toyota Camry (34-52)  | 31    | 54   | 46   | 23   | 15   | 9    | 46   | 44   | 40   | 31   | 22   | 21   | 382   |
| Ford Fusion (39-42)   |       |      |      | 16   | 21   | 11   | 14   | 37   | 35   | 25   | 34   | 57   | 250   |
| Honda CRZ (36-36)   |       |      |      |      | 5    | 11   | 4    | 5    | 4    | 3    | 2    | 1    | 35    |
| Lincoln MKZ (38-40)   |       |      |      |      | 1    | 6    | 6    | 7    | 10   | 8    | 7    | 6    | 52    |
| Toyota Prius v (41-56)  |       |      |      |      |      | 8    | 41   | 35   | 31   | 28   | 15   | 10   | 168   |
| Hyundai Sonata (36-40)  |       |      |      |      |      | 20   | 21   | 22   | 21   | 20   | 19   | 10   | 132   |
| Lexus CT200h (42-42)  |       |      |      |      |      | 14   | 18   | 15   | 18   | 15   | 9    | 5    | 93    |
| Kia Optima (36-42)  |       |      |      |      |      | 0.4  | 10   | 14   | 14   | 11   | 6    | 6    | 61    |
| Toyota Prius c (50-46)  |       |      |      |      |      |      | 36   | 42   | 41   | 38   | 20   | 12   | 190   |
| Ford C-Max (40-40)  |       |      |      |      |      |      | 11   | 28   | 19   | 14   | 12   | 10   | 94    |
| Lexus ES 300h (40-40)   |       |      |      |      |      |      | 7    | 17   | 15   | 11   | 7    | 5    | 63    |
| Toyota Avalon (40-40)   |       |      |      |      |      |      | 1    | 16   | 17   | 12   | 8    | 5    | 60    |
| Honda Accord 2 (47-48)  |       |      |      |      |      |      |      | 1    | 14   | 11   | 9    | 22   | 57    |
| Infiniti QX60 (26-26)   |       |      |      |      |      |      |      | 1    | 2    | 2    | 1    | 0    | 6     |
| Nissan Pathfinder (26-26)   |       |      |      |      |      |      |      | 0.3  | 2    | 2    | 1    | 0    | 6     |
| Infiniti Q50 (31-29)  |       |      |      |      |      |      |      | 0.3  | 3    | 4    | 2    | 1    | 11    |
| Lexus NX 300h Hybrid (32-32)  |       |      |      |      |      |      |      |      | 0.4  | 3    | 3    | 3    | 9     |
| Chevrolet Malibu 2 (46-46)  |       |      |      |      |      |      |      |      |      | 2    | 4    | 4    | 9     |
| Toyota RAV4 (32-32)   |       |      |      |      |      |      |      |      |      | 2    | 45   | 51   | 97    |
| Acura NSX Hybrid (21-21)  |       |      |      |      |      |      |      |      |      |      | 0    | 1    | 1     |
| GMC Sierra 1 (20-20)  |       |      |      |      |      |      |      |      |      |      | 0    | 1    | 1     |
| Kia Niro Hybrid (49-49)   |       |      |      |      |      |      |      |      |      |      |      | 27   | 27    |
| Hyundai Ioniq (55-55)   |       |      |      |      |      |      |      |      |      |      |      | 11   | 11    |
| Acura MDX Hybrid (27-27)  |       |      |      |      |      |      |      |      |      |      |      | 2    | 2     |
| Lexus LC500h (30-30)  |       |      |      |      |      |      |      |      |      |      |      | 0.1  | 0.1   |
| Subtotal-28 mdls-88% of sales   | 456   | 275  | 240  | 204  | 205  | 232  | 379  | 446  | 421  | 366  | 342  | 362  | 3,929 |
| Toyota/Lexus Combined Sales   | 456   | 275  | 240  | 188  | 178  | 184  | 313  | 331  | 297  | 265  | 244  | 203  | 3,173 |

Table 4: 28 Most Successful Hybrids (HEV) 2000–2017

The top three models in terms of lifetime sales are the Prius, the Toyota Camry, and the Ford Fusion. The Prius was the first commercial hybrid built and the most popular hybrid in history. Note that its fuel economy increased from 41 MPG in 2000 to 56 MPG in 2017 (first entry in Table 4). This is about a 20% improvement in Toyota's MPG from the first hybrid version to the current 2017 version representing a fuel economy compound growth rate of about 2% per year.

Note that the combination of Toyota and Lexus car sales (Lexus being the luxury car division of Toyota Motor Corporation) represent about 80% of total sales of the 28 cars listed. The Toyota Corporation (including Toyota brands and Lexus brands) has about 70% of total sales of the 68 hybrid models. Most of the unsuccessful cars were not Toyota or Lexus models.

# **Reviewing Least Successful Hybrids 2000–2017**

Table 5 is a list of the least successful hybrid models. There are 40 models included in this category, which includes some mild hybrids. Note that Toyota's market share in this group is only 6% of sales.

| U.S. Hybrids                  | Sales b       | y Date | of Intro | duction | י 2000-2 | 2017 Le | ast Su | ccessfu | ıl (in 10 | 00s) Ta | ble 5 |      |       |
|-------------------------------|---------------|--------|----------|---------|----------|---------|--------|---------|-----------|---------|-------|------|-------|
| Vehicle (mpg)                 | 2000-<br>2006 | 2007   | 2008     | 2009    | 2010     | 2011    | 2012   | 2013    | 2014      | 2015    | 2016  | 2017 | Total |
| Honda Insight 1 (53)*         | 14            | 0      | 0        | 0       | 0        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 14    |
| Honda Civic (40-45)*          | 118           | 33     | 31       | 15      | 7        | 5       | 7      | 8       | 5         | 5       | 1     | 0.1  | 235   |
| Ford Escape (27)*             | 42            | 21     | 17       | 15      | 11       | 10      | 1      | 0       | 0         | 0       | 0     | 0    | 118   |
| Honda Accord 1 (28)*          | 23            | 3      | 0.2      | 0       | 0        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 27    |
| Mercury Mariner (28)*         | 4             | 4      | 2        | 2       | 1        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 13    |
| Lexus GS 450h (23)*           | 2             | 2      | 1        | 0.5     | 0.3      | 0.3     | 1      | 1       | 0.2       | 0.1     | 0.1   | 0.1  | 7     |
| Nissan Altima (34)*           |               | 8      | 9        | 9       | 7        | 3       | 0      | 0       | 0         | 0       | 0     | 0    | 37    |
| Saturn Vue (26)*              |               | 4      | 3        | 3       | 0        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 10    |
| Lexus LS600hL (21)*           |               | 1      | 1        | 0.3     | 0.1      | 0.1     | 0.1    | 0.1     | 0.1       | 0       | 0     | 0    | 3     |
| Saturn Aura (27)*             |               | 1      | 0.3      | 1       | 0        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 2     |
| Chevy Malibu1 (27)*           |               |        | 2        | 4       | 0        | 0       | 17     | 14      | 1         | 0       | 0     | 0    | 38    |
| Chevy Tahoe (21)*             |               |        | 4        | 3       | 1        | 1       | 1      | 0.4     | 0.1       | 0       | 0     | 0    | 10    |
| GMC Yukon (21)*               |               |        | 2        | 2       | 1        | 1       | 1      | 0.3     | 0         | 0       | 0     | 0    | 7     |
| Cadillac Escalade (20)*       |               |        | 1        | 2       | 1        | 1       | 1      | 0       | 0         | 0       | 0     | 0    | 6     |
| Chrysler Aspen (21)*          |               |        | 0.05     | 0       | 0        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 0.05  |
| Honda Insight 2 (41)*         |               |        |          | 21      | 21       | 16      | 6      | 5       | 4         | 1       | 0     | 0    | 73    |
| Lexus 250h (35)*              |               |        |          | 2       | 11       | 3       | 1      | 0       | 0         | 0       | 0     | 0    | 16    |
| Chevy Silverado (21)*         |               |        |          | 2       | 2        | 1       | 0.5    | 0.1     | 0         | 0       | 0     | 0    | 5     |
| Mercury Milan (39)*           |               |        |          | 1       | 1        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 3     |
| Porsche Cayenne (21)*         |               |        |          |         | 0.3      | 2       | 1      | 1       | 1         | 0       | 0     | 0    | 4     |
| Mercedes S400HV (21)*         |               |        |          |         | 1        | 0       | 0      | 0       | 0         | 0       | 0     | 0    | 1     |
| Mazda Tribute (32)*           |               |        |          |         | 1        | 0.5     | 0.1    | 0       | 0         | 0       | 0     | 0    | 1     |
| GMC Sierra (21)*              |               |        |          |         | 1        | 0.2     | 0.5    | 0.1     | 0         | 0       | 0     | 1    | 2     |
| Mercedes ML450H (22)*         |               |        |          |         | 1        | 0.00    | 0.02   | 0.01    | 0         | 0       | 0     | 0    | 1     |
| BMW X6 (18)*                  |               |        |          |         | 0.25     | 0.04    | 0      | 0       | 0         | 0       | 0     | 0    | 0.3   |
| BMW Hybrid 7 (20)*            |               |        |          |         | 0.10     | 0.34    | 0.23   | 0.03    | 0         | 0       | 0     | 0    | 1     |
| Buick Lacrosse (29)*          |               |        |          |         |          | 2       | 12     | 7       | 7         | 4       | 1     | 1    | 34    |
| Buick Regal (29)*             |               |        |          |         |          | 0.1     | 3      | 3       | 1         | 0       | 0     | 0    | 6     |
| Infiniti m35h Q70 (29)*       |               |        |          |         |          | 0.4     | 1      | 0.5     | 0.2       | 0       | 0     | 0    | 2     |
| VW Touareg (21)*              |               |        |          |         |          | 0.4     | 0.3    | 0.1     | 0         | 0       | 0     | 0    | 1     |
| Porsche Panamera (25)*        |               |        |          |         |          | 0.1     | 0.6    | 0.1     | 0         | 0       | 0     | 0    | 1     |
| VW Jetta (45)*                |               |        |          |         |          |         | 0.2    | 5.7     | 2         | 1       | 1     | 0    | 9     |
| Acura ILX (38)*               |               |        |          |         |          |         | 1      | 1       | 0.4       | 0       | 0     | 0    | 3     |
| BMW 335ih (26)*               |               |        |          |         |          |         | 0.4    | 0.9     | 0.2       | 0       | 0     | 0    | 1     |
| Audi Q5 (26)*                 |               |        |          |         |          |         | 0.3    | 0.9     | 0.3       | 0       | 0     | 0    | 2     |
| BMW 535ih (26)*               |               |        |          |         |          |         | 0.4    | 0.5     | 0.1       | 0       | 0     | 0    | 1     |
| Mercedes E400H (26)*          |               |        |          |         |          |         |        | 0.3     | 0.2       | 0       | 0     | 0    | 0.5   |
| Chevrolet Impala (29)*        |               |        |          |         |          |         |        | 0.1     | 0.6       | 0       | 0     | 0    | 1     |
| Subaru Crosstrek Hybrid (31)* |               |        |          |         |          |         |        |         | 8         | 6       | 2     | 0    | 16    |
| Acura RLX Hybrid (30)*        |               |        |          |         |          |         |        |         | 0.1       | 0.3     | 0.2   | 0.3  | 0.9   |
| Subtotal-40mdls-12% of sales  | 203           | 77     | 75       | 82      | 69       | 45      | 55     | 49      | 31        | 18      | 5     | 2    | 713   |
| Toyota/Lexus Combined Sales   | 4             | 8      | 5        | 25      | 22       | 16      | 6      | 5       | 4         | 1       | 0     | 0    | 96    |
| Toyota/Lexus % of sales       | 0.6%          | 2.3%   | 1.7%     | 8.7%    | 8.0%     | 5.6%    | 1.3%   | 1.0%    | 0.9%      | 0.4%    | 0.0%  | 0    | 2.1%  |
| Grand Total                   | 660           | 352    | 314      | 286     | 275      | 278     | 434    | 496     | 452       | 384     | 347   | 364  | 4.642 |

During the period 2000–2017, 3.9 million hybrids were sold from the most successful hybrid group of 28 cars. During the same period only 0.71 million cars were sold from the 40 least successful hybrid cars. The average sales per model for the 28 successful cars were about 136,000 cars. On average the 40 least successful cars sold about 18,000 per model.

### Hybrid Sales and Trends by Manufacturer

Tables 6 through14 show the record of hybrid car sales by automobile company. Each table shows the number of cars sold yearly for the period 2011–2017. (This information is taken from Table 2). At the bottom of the chart, "Take Rate – Hybrids" is the percent of the total hybrid sales captured by each company. "Take Rate – All Cars" is the percent of all cars sold for each year. The order of the tables is by manufacturer, beginning with hybrid market leader, Toyota. It includes the highest miles per gallon for each model next to the name. The cars are listed from top to bottom covering the last seven-year total for cars sold.

Each table is divided into two sections – "Sustaining/Growing" and "Declining/Disappearing." Some of the models have been withdrawn by the manufacturer – others have been removed based on the author's projections. The Sustaining/Growing category includes the 28 models shown in Table 3. The Declining/Disappearing category consists of the 40 models from Table 4.

#### Toyota

Toyota hybrid cars are available under two different brand names – Toyota and Lexus. Toyota has three other brands that do not include hybrid versions. Table 6 shows the total number of hybrid vehicles Toyota sold in the U.S. in the seven-year period from 2011–2017, slightly more than 1.8 Million.

|                        | Тоу    | γota Hybr | ids (in 10 | 00s) Tabl | e 6    |        |        |             |
|------------------------|--------|-----------|------------|-----------|--------|--------|--------|-------------|
| Year                   | 2011   | 2012      | 2013       | 2014      | 2015   | 2016   | 2017   | 7 yr. Total |
| Sustaining/Growing     |        |           |            |           |        |        |        |             |
| Toyota Prius (50)      | 136    | 148       | 145        | 123       | 114    | 99     | 66     | 830         |
| Toyota Camry(41)       | 9      | 46        | 44         | 40        | 31     | 22     | 21     | 213         |
| Toyota Prius c(50)     |        | 36        | 42         | 41        | 38     | 20     | 12     | 190         |
| Toyota Prius v(42)     | 8      | 41        | 35         | 31        | 28     | 15     | 10     | 168         |
| Toyota Avalon(40)      |        | 1         | 16         | 17        | 12     | 8      | 5      | 60          |
| Lexus CT 200h(42)      | 14     | 18        | 15         | 18        | 15     | 9      | 5      | 93          |
| Lexus RX400/450h(30)   | 11     | 12        | 11         | 9         | 8      | 9      | 9      | 68          |
| Lexus ES 300h(40)      |        | 7         | 17         | 15        | 11     | 7      | 5      | 63          |
| Toyota Highlander(28)  | 5      | 6         | 5          | 4         | 4      | 6      | 17     | 46          |
| Lexus NX 300h (33)     | 0      | 0         | 0          | 0.4       | 3      | 3      | 3      | 9           |
| Toyota RAV4            | 0      | 0         | 0          | 0         | 2      | 45     | 51     | 97          |
| Lexus LC500h           | 0      | 0         | 0          | 0         | 0      | 0      | 0.1    | 0.1         |
| Sub Total              | 184    | 313       | 331        | 297       | 265    | 244    | 203    | 1,836       |
| Declining/Disappearing |        |           |            |           |        |        |        |             |
| Lexus 250H(35)*        | 3      | 1         | 0          | 0         | 0      | 0      | 0      | 4           |
| Lexus GS450H(31)*      | 0      | 1         | 1          | 0         | 0      | 0      | 0      | 2           |
| Lexus LS 600HL(20)*    | 0      | 0         | 0          | 0         | 0      | 0      | 0      | 0           |
| Sub Total              | 3      | 1         | 1          | 0         | 0      | 0      | 0      | 6           |
| Total                  | 187    | 314       | 332        | 297       | 265    | 244    | 203    | 1,842       |
| Take Rate - Hybrids    | 69.56% | 72.38%    | 66.92%     | 65.63%    | 69.11% | 70.24% | 55.82% |             |
| Take Rate - All Cars   | 1.47%  | 2.18%     | 2.14%      | 1.81%     | 1.52%  | 1.40%  | 1.19%  |             |
| All Hybrids            | 269    | 434       | 496        | 452       | 384    | 347    | 364    |             |
| All Vehicles           | 12,734 | 14,442    | 15,532     | 16,435    | 17,386 | 17,465 | 17,135 |             |

Table 6: Toyota/Lexus Hybrid Sales 2011–2017

Toyota has made hybrid cars a corporate priority, even cancelling some plug-in models such as the RAV4 EV to make that point. Toyota is building over one million hybrids yearly spread across several different models. The company has committed to providing a hybrid version of each of its conventional models. Prius sales rates in Japan, a country with a third of the U.S. population, are running at almost three times the U.S., 160,192 units in 2017 in Japan versus 65,631 units in the U.S. Prius c sales in Japan are ten times the Prius c sales in the U.S., 131,165 units in Japan versus 12,415 units in the U.S. in 2017.<sup>8</sup> Combined Prius and Prius c sales in Japan were 6% of the total car sales in Japan in 2017. Prius and Prius c combined sales in 2017 in the U.S. were less than 1% of total car sales.<sup>9</sup> A similar trend can be seen in many other regions of the world, where conventional hybrids are alive and well and remain a viable option to plugin cars.

#### Ford

Ford took U.S. hybrid market-share from Toyota with its original high sales of the Fusion and C-Max models. U.S. sales for these two cars more than doubled from 2012 to 2013. But sales declined for both models from 2013 to 2014 and from 2014 to 2015 reflecting a reduction in those cars' actual MPG (in parenthesis). In the case of Ford (Table 7), two numbers are shown for the first three cars MPG. One represents the original MPG and the second the downgraded numbers. The Ford Fusion MPG was reduced from 47 to 42, the Ford C-max from 47 to 40 and the Lincoln MKX from 45 to 40. Later models (2016 and 2017) captured back some of the lost fuel economy. Note Ford sales were about 370,000 compared to Toyota sales at 1.8 million cars during this seven-year period.

| FORD Hybrids (in 1000s) Table 7 |        |        |        |        |        |        |        |             |  |  |  |  |  |
|---------------------------------|--------|--------|--------|--------|--------|--------|--------|-------------|--|--|--|--|--|
| Year                            | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 7 yr. Total |  |  |  |  |  |
| Sustaining/Growing              |        |        |        |        |        |        |        |             |  |  |  |  |  |
| Ford Fusion(47-42)              | 11     | 14     | 37     | 35     | 25     | 34     | 57     | 214         |  |  |  |  |  |
| Ford C-Max(47-40)               |        | 11     | 28     | 19     | 14     | 12     | 10     | 94          |  |  |  |  |  |
| Lincoln MKZ(45-40)              | 6      | 6      | 7      | 10     | 8      | 7      | 6      | 51          |  |  |  |  |  |
| Subtotal                        | 17     | 31     | 73     | 65     | 47     | 53     | 74     | 359         |  |  |  |  |  |
| Declining/Disappearing          |        |        |        |        |        |        |        |             |  |  |  |  |  |
| Ford Escape(32)*                | 10     | 1      | 0      | 0      | 0      | 0      | 0      | 12          |  |  |  |  |  |
| Mercury Milan(39) *             | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0           |  |  |  |  |  |
| Mercury Mariner(27)*            | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0           |  |  |  |  |  |
| Subtotal                        | 10     | 1      | 0      | 0      | 0      | 0      | 0      | 12          |  |  |  |  |  |
| Total                           | 27     | 33     | 73     | 65     | 47     | 53     | 74     | 371         |  |  |  |  |  |
| Take Rate - Hybrids             | 10.1%  | 7.5%   | 14.7%  | 14.3%  | 12.3%  | 15.2%  | 20.2%  |             |  |  |  |  |  |
| Take Rate - All Cars            | 0.2%   | 0.2%   | 0.5%   | 0.4%   | 0.3%   | 0.3%   | 0.4%   |             |  |  |  |  |  |
| All Hybrids                     | 269    | 434    | 496    | 452    | 384    | 347    | 364    |             |  |  |  |  |  |
| All Vehicles                    | 12,734 | 14,442 | 15,532 | 16,435 | 17,386 | 17,465 | 17,135 |             |  |  |  |  |  |

Table 7: Ford Family Hybrid Sales - 2011–2017

Ford has a long history in standard hybrids; having successfully developed and marketed the Ford Escape Hybrid with more than 22,000 sold from 2004 through 2012, mostly prior to the period covered in this table). The Ford Fusion Hybrid and the C-Max Hybrid are the company's major hybrid offerings. The Fusion Hybrid has been particularly successful in the last two years while the C-Max Hybrid has languished somewhat. Ford has announced that the C-Max Hybrid will be withdrawn from the market in the near future.

In October 2014, the company changed its ads for the C-Max from "high MPG performance" to "fun to drive."<sup>10</sup> In March of 2015, Raj Nair, Ford group vice president of Global Product Development announced that the company is "very well established" with its hybrid and electric-drive technology, so well established that it's now time for Ford to turn its attention to performance, meaning acceleration not miles per gallon. Nair noted that sales of performance vehicles are up 70% in the US since 2009, Nair said that the high performance vehicles draw customers that in general are younger and better educated.<sup>11</sup> Ford will continue to have some moderate success with its hybrids but not based on exceptional mileage performance.

#### Honda

Honda was the second manufacturer in the world to develop hybrid cars and for years was second to Toyota. Its hybrid cars were eventually outclassed by Toyota and its hybrid sales have declined steadily (Table 9). Sales of the Insight (1 and 2) declined to the extent that both models were discontinued in 2006. The Honda Civic hybrid (one of the very first hybrids made) was very successful from 2000 through 2009 but sales fell off after that and the model was discontinued in 2016. Honda sold an Accord Hybrid from 2005 – 2007 but withdrew it from the market after low sales. The newer Honda Accord model, introduced in 2013, has a much more efficient hybrid drive train and Honda may be able to make a comeback with this better more efficient drive train technology.

| Honda 2011-2017 (in 1000s) Table 8 |        |        |        |        |        |        |        |             |  |  |  |  |
|------------------------------------|--------|--------|--------|--------|--------|--------|--------|-------------|--|--|--|--|
| Year                               | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 7 yr. Total |  |  |  |  |
| Sustaining/Growing                 |        |        |        |        |        |        |        |             |  |  |  |  |
| Honda Accord 2(42)                 |        |        | 1      | 14     | 11     | 9      | 22     | 57          |  |  |  |  |
| Honda CRZ(37)                      | 11     | 4      | 5      | 4      | 3      | 2      | 1      | 30          |  |  |  |  |
| Acura NSX(21)                      | 0      | 0      | 0      | 0      | 0      | 0      | 1      | 1           |  |  |  |  |
| Acura MDX(27)                      | 0      | 0      | 0      | 0      | 0      | 0      | 2      | 2           |  |  |  |  |
| Subtotal                           | 11     | 4      | 6      | 18     | 14     | 12     | 25     | 87          |  |  |  |  |
| Declining/Disappearing             |        |        |        |        |        |        |        |             |  |  |  |  |
| Honda Accord 1(28)                 |        |        |        |        |        |        |        |             |  |  |  |  |
| Honda Civic(44)                    | 5      | 7      | 8      | 5      | 5      | 1      | 0      | 31          |  |  |  |  |
| Honda Insight 1 (53)*              | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0           |  |  |  |  |
| Honda Insight 2 (42)*              | 16     | 6      | 5      | 4      | 1      | 0      | 0      | 32          |  |  |  |  |
| Acura ILX(38)*                     | 0      | 1      | 1      | 0      | 0      | 0      | 0      | 3           |  |  |  |  |
| Acura RLX(34)                      | 0      | 0      | 0      | 0.1    | 0.3    | 0.2    | 0.3    | 1           |  |  |  |  |
| Subtotal                           | 20     | 14     | 14     | 10     | 7      | 1      | 0      | 66          |  |  |  |  |
| Total                              | 32     | 18     | 20     | 27     | 21     | 13     | 25     | 153         |  |  |  |  |
| Take Rate - Hybrids                | 11.7%  | 4.2%   | 3.9%   | 6.0%   | 5.4%   | 3.8%   | 7.0%   |             |  |  |  |  |
| Take Rate - All Cars               | 0.2%   | 0.1%   | 0.1%   | 0.2%   | 0.1%   | 0.1%   | 0.1%   |             |  |  |  |  |
| All Hybrids                        | 269    | 434    | 496    | 452    | 384    | 347    | 364    |             |  |  |  |  |
| All Vehicles                       | 12,734 | 14,442 | 15,532 | 16,435 | 17,386 | 17,465 | 17,135 |             |  |  |  |  |

Table 8: Honda and Acura Hybrid Sales - 2011–2017

Beginning in the late 1990s, with the birth of the hybrid, Honda sold about 2/3rds as many hybrids as Toyota. But since 2005, Toyota has increased its hybrid market share significantly relative to Honda due to much better technology.

# Hyundai/Kia

These two Korean manufacturers share common drive trains. The Kia Optima is a version of the Hyundai Sonata and Hyundai holds a significant stock position in Kia. Both companies have admitted to overstating MPG ratings for several models in the past and paid significant penalties.<sup>12</sup> Their earlier hybrid car's fuel economy is lower than their main competitors, including Toyota and Ford. However, the recently delivered Kia Niro and Hyundai loniq have impressive MPG ratings, 49 and 58 MPG respectively. First years sales were high. Note that the company currently has about an 8-9% market share, third after Toyota and Ford. They are a strong competitor in the hybrid market.

|                      | HYUN   | IDIA/KIA | Hybrids ( | (in 1000s) | Table 9 |        |        |             |
|----------------------|--------|----------|-----------|------------|---------|--------|--------|-------------|
| Year                 | 2011   | 2012     | 2013      | 2014       | 2015    | 2016   | 2017   | 7 yr. Total |
| Sustaining/Growing   |        |          |           |            |         |        |        |             |
| Hyundai Sonata(40)   | 20     | 21       | 22        | 21         | 20      | 19     | 10     | 132         |
| Kia Optima(42)       | 0.4    | 10       | 14        | 14         | 11      | 6      | 6      | 61          |
| Kia Niro(49)         |        |          |           |            |         |        | 27     | 27          |
| Hyundai Ioniq(58)    |        |          |           |            |         |        | 11     | 11          |
| Total                | 20     | 31       | 36        | 35         | 31      | 25     | 53     | 231         |
| Take Rate - Hybrids  | 7.5%   | 7.1%     | 7.2%      | 7.7%       | 8.2%    | 7.2%   | 14.6%  |             |
| Take Rate - All Cars | 0.2%   | 0.2%     | 0.2%      | 0.2%       | 0.2%    | 0.2%   | 0.2%   |             |
| All Hybrids          | 269    | 434      | 496       | 452        | 384     | 347    | 364    |             |
| All Vehicles         | 12,734 | 14,442   | 15,532    | 16,435     | 17,386  | 17,465 | 17,135 |             |

Table 9: Hyundai/Kia Hybrid Sales - 2011–2017

### General Motors (GM)

GM conventional hybrid sales have declined steadily, as shown in Table 10. This is not surprising since GM made a strategic decision to focus on plug-in hybrids like the Volt and battery electric cars such as the Spark and later the Bolt and did not emphasize conventional hybrid models. The company earlier attempted to enhance its hybrid position by offering what is called a Mild Hybrid. A mild hybrid is a conventional car that turns off its engine at a traffic light or stop sign and automatically turns on again when the gas petal is pressed. These cars provide one or two of the functions of a high fuel economy hybrid, but not the impressive MPG of a full hybrid car. It is not expected that mild hybrids will affect hybrid sales since they represent only a tiny part (less than 2%) of the hybrid market. They include versions of the Chevy Malibu, Buick Lacrosse and Buick Regal – GM's top sellers. GM began selling a 47 MPG hybrid Malibu in 2016. This is a big step up in fuel economy from the company's mild hybrids, which ranged from 21 to 29 MPG. This may imply a strategic shift for the company, although its continued focus on PHEVs and BEVs could mean a move away from HEVs.<sup>13</sup>

| GM (in 1000s) Table 10 |        |        |        |        |        |        |        |             |  |  |  |  |
|------------------------|--------|--------|--------|--------|--------|--------|--------|-------------|--|--|--|--|
| Year                   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 7 yr. Total |  |  |  |  |
| Sustaining/Growing     |        |        |        |        |        |        |        |             |  |  |  |  |
| Chevy Malibu 2(46)     |        |        |        |        | 0.06   | 4      | 4      | 9           |  |  |  |  |
| GMC Sierra 2(21)       |        |        |        |        |        |        | 1      | 1           |  |  |  |  |
| Subtotal               |        |        |        |        | 0.06   | 4      | 5      | 10          |  |  |  |  |
| Declining/Disappearing |        |        |        |        |        |        |        |             |  |  |  |  |
| Buick Lacrosse(29)*    | 2      | 12     | 7      | 7      | 4      | 1      | 1      | 34          |  |  |  |  |
| Chevy Malibu 1(29)*    | 0      | 17     | 14     | 1      | 0      | 0      | 0      | 31          |  |  |  |  |
| Buick Regal(29)*       | 0      | 3      | 3      | 1      | 0      | 0      | 0      | 6           |  |  |  |  |
| Cadillac Escalade(21)* | 1      | 1      | 0      | 0      | 0      | 0      | 0      | 2           |  |  |  |  |
| Chevy Silverado(21)*   | 1      | 0      | 0      | 0      | 0      | 0      | 0      | 2           |  |  |  |  |
| Chevy Tahoe(21)*       | 1      | 1      | 0      | 0      | 0      | 0      | 0      | 2           |  |  |  |  |
| GMC Yukon(21)*         | 1      | 1      | 0      | 0      | 0      | 0      | 0      | 1           |  |  |  |  |
| Chevy Impala(29)*      | 0      | 0      | 0      | 1      | 0      | 0      | 0      | 1           |  |  |  |  |
| GMC Sierra 1(21)*      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 1           |  |  |  |  |
| Saturn Aura(27)*       | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0           |  |  |  |  |
| Saturn Vue(26)*        | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0           |  |  |  |  |
| Sub Total              | 5      | 34     | 25     | 10     | 5      | 1      | 1      | 80          |  |  |  |  |
| Total                  | 5      | 34     | 25     | 10     | 5      | 5      | 6      | 90          |  |  |  |  |
| Take Rate - Hybrids    | 1.9%   | 7.8%   | 5.1%   | 2.2%   | 1.2%   | 1.5%   | 1.6%   |             |  |  |  |  |
| Take Rate - All Cars   | 0.0%   | 0.2%   | 0.2%   | 0.1%   | 0.0%   | 0.0%   | 0.0%   |             |  |  |  |  |
| All Hybrids            | 269    | 434    | 496    | 452    | 384    | 347    | 364    |             |  |  |  |  |
| All Vehicles           | 12,734 | 14,442 | 15,532 | 16,435 | 17,386 | 17,465 | 17,135 |             |  |  |  |  |

Table 10: GM Hybrid Sales 2011-2017

#### Nissan

Nissan hybrid sales are shown in Table 11. Prior to 2011 Ford and Nissan hybrids used technology from the Toyota Prius under a licensing agreement, including technology for the transmission, power inverter, battery, and charging control unit. Nissan's early hybrid, the Altima sold 36,613 units from 2007-2012; Nissan withdrew it from the market in 2013. Nissan made a major successful strategic decision to compete in the battery electric (BEV) car market with its Leaf just as GM did for the plug-in hybrid market with its Volt PHEV, sacrificing an opportunity to compete in the standard hybrid market. A newer Nissan hybrid drive train option is used on the 2014 Pathfinder, but sales have been low. Nissan has focused so long on the Leaf BEV that it is unlikely the company can compete effectively with a standard hybrid in the near future.

| NISSAN Hybrids (in 1000s) Table 11 |        |        |        |        |        |        |        |             |  |  |  |  |
|------------------------------------|--------|--------|--------|--------|--------|--------|--------|-------------|--|--|--|--|
| Year                               | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 7 yr. Total |  |  |  |  |
| Sustaining/Growing                 |        |        |        |        |        |        |        |             |  |  |  |  |
| Infinita Q50(30)                   |        |        | 0.3    | 3.5    | 4.0    | 2.0    | 0.9    | 10.6        |  |  |  |  |
| Nissan Pathfinder(26)              |        |        | 0.3    | 2.5    | 2.2    | 0.8    | 0.4    | 6.3         |  |  |  |  |
| Infinita QX60(26)                  |        |        | 0.7    | 1.7    | 2.4    | 1.1    | 0.3    | 6.1         |  |  |  |  |
| Subtotal                           |        |        | 1.3    | 7.6    | 8.6    | 3.9    | 1.6    | 23.0        |  |  |  |  |
| Declining/Disappearing             |        |        |        |        |        |        |        |             |  |  |  |  |
| Altima(33)*                        | 3.2    | 0.1    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 3.3         |  |  |  |  |
| Infiniti Q70(29)                   | 0.4    | 0.7    | 0.5    | 0.2    | 0.2    | 0.1    | 0.1    | 2.1         |  |  |  |  |
| Subtotal                           | 3.6    | 0.8    | 0.5    | 0.2    | 0.2    | 0.1    | 0.1    | 5.4         |  |  |  |  |
| Total                              | 3.6    | 0.8    | 1.8    | 7.8    | 8.8    | 4.0    | 1.6    | 28.4        |  |  |  |  |
| Take Rate - Hybrids                | 1.34%  | 0.18%  | 0.36%  | 1.72%  | 2.29%  | 1.17%  | 0.44%  |             |  |  |  |  |
| Take Rate - All Cars               | 0.03%  | 0.01%  | 0.01%  | 0.05%  | 0.05%  | 0.02%  | 0.01%  |             |  |  |  |  |
| All Hybrids                        | 269    | 434    | 496    | 452    | 384    | 347    | 364    |             |  |  |  |  |
| All Vehicles                       | 12,734 | 14,442 | 15,532 | 16,435 | 17,386 | 17,465 | 17,135 |             |  |  |  |  |

Table 11: Nissan and Infiniti Hybrid Sales 2011–2017

# BMW

BMW has only a token position in the standard hybrid market. (Table 11) Their current commitment is to plug-in electric cars with the "i" series.

|                        |        | BMW Hyl | brids (in 1 | 000s) Tab | le 12  |        |        |             |
|------------------------|--------|---------|-------------|-----------|--------|--------|--------|-------------|
| Year                   | 2011   | 2012    | 2013        | 2014      | 2015   | 2016   | 2017   | 7 yr. Total |
| Declining/Disappearing |        |         |             |           |        |        |        |             |
| BMW Hybrid 7(20)*      | 0.3    | 0.2     | 0           | 0         | 0      | 0      | 0      | 1           |
| BMW 335ih(26)*         | 0      | 0.4     | 0.9         | 0.2       | 0      | 0      | 0      | 1           |
| BMW 535ih(26)*         | 0      | 0.4     | 0.5         | 0         | 0      | 0      | 0      | 1           |
| BMW X6(18)*            | 0.04   | 0       | 0           | 0         | 0      | 0      | 0      | 0           |
| Subtotal               | 0      | 1       | 1           | 0         | 0      | 0      | 0      | 3           |
| Total                  | 0      | 1       | 1           | 0         | 0      | 0      | 0      | 3           |
| Take Rate - Hybrids    | 0.1%   | 0.2%    | 0.3%        | 0.1%      | 0.0%   | 0.0%   | 0.0%   |             |
| Take Rate - All Cars   | 0.0%   | 0.0%    | 0.0%        | 0.0%      | 0.0%   | 0.0%   | 0.0%   |             |
| All Hybrids            | 269    | 434     | 496         | 452       | 384    | 347    | 364    |             |
| All Vehicles           | 12,734 | 14,442  | 15,532      | 16,435    | 17,386 | 17,465 | 17,135 |             |

Table 12: BMW Hybrid Sales - 2011–2017

### VW/Porsche

Hybrid Porsches, Audis, and early VWs have not been successful. Surprisingly VW's Jetta Hybrid, with good MPG, is in decline. VW is committed to plug-ins at this point and is dropping its Porsche hybrid models, replacing them with plug-in versions. See Table 13.

|                        | v      | W/PORS | CHE (in 1 | 000s) Tab | ole 13 |        |        |             |
|------------------------|--------|--------|-----------|-----------|--------|--------|--------|-------------|
| Year                   | 2011   | 2012   | 2013      | 2014      | 2015   | 2016   | 2017   | 7 yr. Total |
| Declining/Disappearing |        |        |           |           |        |        |        |             |
| VW Jetta Hybrid(45)*   | 0      | 0      | 6         | 2         | 1      | 1      | 0      | 9           |
| Porsche Cayenne(21)*   | 2      | 1      | 1         | 1         | 0      | 0      | 0      | 4           |
| Audi Q5 Hybrid(26)*    | 0      | 0.3    | 0.9       | 0.3       | 0      | 0      | 0      | 2           |
| VW Touareg Hybrid(21)* | 0.4    | 0.3    | 0.1       | 0         | 0      | 0      | 0      | 1           |
| Porsche Panamera(25)*  | 0      | 0.6    | 0.1       | 0         | 0      | 0      | 0      | 1           |
| Subtotal               | 2      | 2      | 7         | 3         | 1      | 1      | 0      | 16          |
| Total                  | 2      | 2      | 7         | 3         | 1      | 1      | 0      | 16          |
| Take Rate - Hybrids    | 0.7%   | 0.6%   | 1.5%      | 0.6%      | 0.2%   | 0.2%   | 0.2%   |             |
| Take Rate - All Cars   | 0.0%   | 0.0%   | 0.0%      | 0.0%      | 0.0%   | 0.0%   | 0.0%   |             |
| All Hybrids            | 269    | 434    | 496       | 452       | 384    | 347    | 364    |             |
| All Vehicles           | 12,734 | 14,442 | 15,532    | 16,435    | 17,386 | 17,465 | 17,135 |             |

### Mercedes

Mercedes does not offer a good hybrid contender and may have chosen not to compete in the hybrid market but focus on plug-ins. Table 14 shows this direction.

|                        | MERCEDES (in 1000s) Table 14 |        |        |        |        |        |        |             |  |  |  |  |  |  |
|------------------------|------------------------------|--------|--------|--------|--------|--------|--------|-------------|--|--|--|--|--|--|
| Year                   | 2011                         | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 7 yr. Total |  |  |  |  |  |  |
| Declining/Disappearing | 0                            | 0      | 0      | 0      | 0      | 0      | 0      | 0           |  |  |  |  |  |  |
| Mercedes S400hv(21)*   | 0.3                          | 0.1    | 0.1    | 0.0    | 0.0    | 0.0    | 0.0    | 1           |  |  |  |  |  |  |
| Mercedes E400H(26)*    | 0.0                          | 0.0    | 0.3    | 0.2    | 0.1    | 0.0    | 0.0    | 1           |  |  |  |  |  |  |
| Mercedes ML450h(22)*   | 0.0                          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0           |  |  |  |  |  |  |
| Subtotal               | 0.3                          | 0.1    | 0.4    | 0.2    | 0.1    | 0.0    | 0.0    | 1           |  |  |  |  |  |  |
| Total                  | 0.3                          | 0.1    | 0.4    | 0.2    | 0.1    | 0.0    | 0.0    | 1           |  |  |  |  |  |  |
| Take Rate - Hybrids    | 0.1%                         | 0.0%   | 0.1%   | 0.0%   | 0.0%   | 0.0%   | 0.0%   |             |  |  |  |  |  |  |
| Take Rate - All Cars   | 0.0%                         | 0.0%   | 0.0%   | 0.0%   | 0.0%   | 0.0%   | 0.0%   |             |  |  |  |  |  |  |
| All Hybrids            | 269                          | 434    | 496    | 452    | 384    | 347    | 364    |             |  |  |  |  |  |  |
| All Vehicles           | 12,734                       | 14,442 | 15,532 | 16,435 | 17,386 | 17,465 | 17,135 |             |  |  |  |  |  |  |

Table 14: Mercedes Hybrid Sales 2011–2017

### Subaru, Chrysler, and Mazda

Information is not provided on Subaru, who entered the market in 2014. They have a very small share and are not analyzed further here. Chrysler and Mazda were even smaller and are ignored in this analysis.

# Hybrid Market – Manufacturer Trends in the U.S.

The most successful companies in the U.S. hybrid market are Toyota, Ford, and Hyundai/Kia with a combined 90% of 2017 standard hybrid sales. Even though Honda's Insight and Civic hybrids were initially well received they eventually were removed from the market.

|             | Hybrid Ma | rket Trends | s - % of Sal | es - by Man | ufacturer T | able 15 |         |
|-------------|-----------|-------------|--------------|-------------|-------------|---------|---------|
|             | 2011      | 2012        | 2013         | 2014        | 2015        | 2016    | 2017    |
| Company     | % sales   | % sales     | % sales      | % sales     | % sales     | % sales | % sales |
| Toyota      | 69.6      | 72.4        | 66.9         | 65.6        | 69.1        | 70.2    | 55.8    |
| Ford        | 10.1      | 7.5         | 14.7         | 14.3        | 12.3        | 15.2    | 20.2    |
| Honda       | 11.7      | 4.2         | 3.9          | 6.0         | 5.4         | 3.8     | 7.0     |
| Hyundai/Kia | 7.5       | 7.1         | 7.2          | 7.7         | 8.2         | 7.2     | 14.6    |
| GM          | 1.9       | 7.8         | 5.1          | 2.2         | 1.5         | 1.5     | 1.6     |
| Nissan      | 1.3       | 0.2         | 0.4          | 1.7         | 2.3         | 1.2     | 1.6     |
| BMW         | 0.1       | 0.2         | 0.3          | 0.1         | 0.0         | 0.0     | 0.0     |
| VW          | 0.7       | 0.6         | 1.5          | 0.6         | 0.2         | 0.2     | 0.2     |
| Mercedes    | 0.1       | 0.1         | 0.0          | 0.1         | 0.0         | 0.0     | 0.0     |

Table 15: Hybrid Share of Market Trends 2011–2017

As noted earlier, hybrid growth in the U.S. is low compared to growth in other parts of the world, such as Japan, where it is high. Standard hybrid gasoline car engines are exceeding 40% efficiency. But sales of these much more efficient cars are being negatively affected by the U.S. consumer's recent trend of purchasing CUVs. A crossover utility vehicle (CUV) is a vehicle typically built on a unibody car platform combining features of a sport utility vehicle (SUV) with those of a passenger vehicle.

Hyundai/Kia has replaced Honda as the third ranking hybrid manufacturer and seems to be targeting the smaller car market. Hyundai/Kia are also becoming direct competitors to Toyota's Prius models. Ford is withdrawing the C-max Hybrid from the market. The sharp drop in Toyota's market share in 2017 is reflected by a corresponding increase in sales of Ford, Hyundai/Kai, and Honda HEVs.

The race between plug-ins and conventional hybrids is on, but plug-in cars are not yet dominating the market. They remain heavily subsidized and when the subsidies are eventually removed, the HEV may represent a much less expensive technology that does almost as well as PHEV and BEVs in terms of  $CO_2$  reductions.

# Plug-In (BEV and PHEV) Sales Summary – U.S.

Tesla Motors was formed in 2003 to build a battery electric car using lithium-ion batteries. The company introduced its first product, the Roadster, in 2006 and shipped its first production version of that model in 2008. (Tesla delivered about 2,800 Roadsters and discontinued the product when Model S production began in 2012.) GM began its plug-in hybrid Volt effort in 2006, demonstrated a concept vehicle in January 2007, introduced the production version in September 2008, and shipped the first production cars in December 2010.<sup>14</sup> A rough total development time estimate based on this data is five years to first shipment (2006-2010) followed by seven full years of production (2011-2017); thus modern plug-ins today represent the result of a ten year development program.

Table 16 shows sales of Battery Electric Vehicles (BEVs) and Table 17 represents Pluggable Electric Hybrid Vehicles (PHEVs) sales. Table 18 is the total sales of both combined. There are currently 18 BEV and 26 PHEV models. Of the 18 BEV models the Nissan Leaf, Tesla Model S, Tesla Model X, BMW i3, and Chevrolet Bolt have 83% of this market.

| BEV Sales 2011-2017 (in 1000s) Table 16 |            |      |      |      |      |      |      |      |       |         |  |  |
|---|------------|------|------|------|------|------|------|------|-------|---------|--|--|
| Manufacturer                            | Model      | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total | % Sales |  |  |
| Nissan                                  | Leaf       | 10   | 10   | 23   | 30   | 17   | 14   | 11   | 115   | 29.1%   |  |  |
| Mercedes                                | Smart EV   | 0.4  | 0.1  | 1    | 3    | 1    | 1    | 1    | 7     | 1.7%    |  |  |
| Mitsubishi                              | i-MIEV     | 0.1  | 1    | 1    | 0    | 0    | 0    | 0    | 2     | 0.5%    |  |  |
| Tesla                                   | Model S    |      | 2    | 19   | 17   | 25   | 29   | 27   | 118   | 30.0%   |  |  |
| Ford                                    | Focus      |      | 1    | 2    | 2    | 2    | 1    | 2    | 9     | 2.2%    |  |  |
| Toyota                                  | RAV4 EV    |      | 0.2  | 1    | 1    | 0    | 0    | 0    | 2     | 0.6%    |  |  |
| Honda                                   | Fit EV     |      | 0.1  | 1    | 0    | 0    | 0    | 0    | 1     | 0.3%    |  |  |
| Chevrolet                               | Spark      |      |      | 1    | 1    | 3    | 3    | 0    | 7     | 1.9%    |  |  |
| Fiat                                    | 500e       |      |      | 0.4  | 2    | 5    | 4    | 3    | 14    | 3.5%    |  |  |
| BMW                                     | i3         |      |      |      | 6    | 11   | 8    | 6    | 31    | 7.9%    |  |  |
| Mercedes                                | B250e      |      |      |      | 1    | 2    | 1    | 1    | 4     | 1.0%    |  |  |
| Kia                                     | Soul EV    |      |      |      | 0.4  | 1    | 2    | 2    | 5     | 1.3%    |  |  |
| VW                                      | e-Golf     |      |      |      | 0.4  | 4    | 4    | 4    | 12    | 3.1%    |  |  |
| Tesla                                   | Model X    |      |      |      |      | 0.2  | 18   | 22   | 40    | 10.1%   |  |  |
| Chevrolet                               | Bolt       |      |      |      |      |      | 1    | 23   | 24    | 6.0%    |  |  |
| Hyundai                                 | Ioniq EV   |      |      |      |      |      |      | 0.4  | 0.4   | 0.1%    |  |  |
| Tesla                                   | Model 3    |      |      |      |      |      |      | 1.8  | 1.8   | 0.4%    |  |  |
| Honda                                   | Clarity EV |      |      |      |      |      |      | 1.1  | 1.1   | 0.3%    |  |  |
| Total                                   |            | 10   | 14   | 48   | 63   | 71   | 84   | 104  | 395   | 100.0%  |  |  |

Table 16: BEV Sales - 2011–2017

The Nissan Leaf and Tesla S each have about 30% cumulative BEV market share. The Tesla S and Tesla X combined have a 40% BEV market share. The Leaf and Tesla S are also the leading models on the world market. Nissan has sold 300,000 Leafs worldwide as of the end of 2017 with Tesla sales slightly less. Leaf sales lagged in 2017, waiting for the new 2018 model which is now shipping. 2017 Bolt sales were impressive.

2018 will be a key year because of three new very competitive mass-market BEV vehicles, the GM Bolt, Leaf 2, and Tesla 3. This market had previously been dominated by the Leaf. Tesla will continue to dominate the luxury market with the Tesla S and Tesla X.

The PHEVs shown in Table 17 include 26 models. The top four models in sales are the Chevrolet Volt, the Prius Prime, the Ford Fusion Energi, and the Ford C-max Energi. These four models have 66% of the 2017 U.S. PHEV market and 83% of the U.S. cumulative market.

| PHEV SALES: 2011-2017 (in 1000s) Table 17 |                |      |      |      |      |      |      |      |       |         |  |  |
|---|----------------|------|------|------|------|------|------|------|-------|---------|--|--|
| Manufacturer                              | Model          | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total | % Sales |  |  |
| Chevrolet                                 | Volt           | 8    | 23   | 23   | 19   | 15   | 25   | 20   | 134   | 37.4%   |  |  |
| Toyota                                    | Prius Prime    |      | 13   | 12   | 13   | 4    | 2    | 21   | 66    | 18.4%   |  |  |
| Ford                                      | C-Max Energi   |      | 2    | 7    | 8    | 8    | 8    | 8    | 42    | 11.7%   |  |  |
| Ford                                      | Fusion Energi  |      |      | 6    | 12   | 10   | 16   | 10   | 53    | 14.8%   |  |  |
| Honda                                     | Accord Plug-in |      |      | 1    | 0    | 0    | 0    | 0    | 1     | 0.3%    |  |  |
| Porsche                                   | Panamera Ehyb  |      |      | 0    | 1    | 0    | 0    | 0    | 2     | 0.5%    |  |  |
| Cadillac                                  | ELR            |      |      | 0    | 1    | 1    | 1    | 0    | 3     | 0.8%    |  |  |
| BMW                                       | i8             |      |      |      | 1    | 2    | 2    | 0    | 5     | 1.4%    |  |  |
| Porsche                                   | Cayenne Ehyb   |      |      |      | 0.1  | 1    | 2    | 2    | 5     | 1.4%    |  |  |
| BMW                                       | X5 xDr40e      |      |      |      |      | 1    | 6    | 5    | 12    | 3.4%    |  |  |
| Mercedes                                  | S 550e         |      |      |      |      | 0.1  | 1    | 1    | 1     | 0.4%    |  |  |
| Hyundai                                   | Sonata Plug-in |      |      |      |      | 0.2  | 3    | 1    | 4     | 1.2%    |  |  |
| Audi                                      | A3 Plugin      |      |      |      |      | 0.0  | 4    | 3    | 7     | 2.0%    |  |  |
| Volvo                                     | XC90           |      |      |      |      | 0.1  | 2    | 2    | 4     | 1.2%    |  |  |
| BMW                                       | 330e           |      |      |      |      |      | 1    | 4    | 5     | 1.4%    |  |  |
| Mercedes                                  | GLE 550e       |      |      |      |      |      | 0.2  | 0    | 1     | 0.2%    |  |  |
| Mercedes                                  | C350e          |      |      |      |      |      | 0.2  | 1    | 1     | 0.3%    |  |  |
| BMW                                       | 740e           |      |      |      |      |      | 0.1  | 1    | 1     | 0.2%    |  |  |
| Chrysler                                  | Pacifica       |      |      |      |      |      |      | 3    | 3     | 0.8%    |  |  |
| BMW                                       | 530e           |      |      |      |      |      |      | 4    | 4     | 1.1%    |  |  |
| Kia                                       | Optima PlugIn  |      |      |      |      |      |      | 2    | 2     | 0.4%    |  |  |
| Mini                                      | Countryman PI  |      |      |      |      |      |      | 0.5  | 0.5   | 0.1%    |  |  |
| Cadillac                                  | CT6            |      |      |      |      |      |      | 0.2  | 0.2   | 0.1%    |  |  |
| Volvo                                     | XC60           |      |      |      |      |      |      | 0.5  | 0.5   | 0.1%    |  |  |
| Honda                                     | Clarity PlugIn |      |      |      |      |      |      | 0.0  | 0.9   | 0.0%    |  |  |
| Volvo                                     | S90 PlugIn     |      |      |      |      |      |      | 0.0  | 0.1   | 0.0%    |  |  |
| Total                                     |                | 8    | 39   | 49   | 55   | 43   | 73   | 89   | 357   | 99.7%   |  |  |

Table 17: PHEV Sales - 2011–2017

Note in Table 18 that distribution is skewed between BEV and PHEV. There are several more PHEVs than BEVs. Yet the majority of sales have gone to BEVs.

| BEV and PHEV SALES: 2011-2017 (in 1000s) Table 18   |       |    |    |    |     |     |     |     |     |        |  |  |
|---|-------|----|----|----|-----|-----|-----|-----|-----|--------|--|--|
| Manufacturer     Model     2011     2012     2013     2014     2015     2016     2017     Total     % Sales |       |    |    |    |     |     |     |     |     |        |  |  |
| BEV Total   | BEV   | 10 | 14 | 48 | 63  | 71  | 84  | 104 | 395 | 52.5%  |  |  |
| PHEV Total  | PHEV  | 8  | 39 | 49 | 55  | 43  | 73  | 89  | 357 | 47.5%  |  |  |
| Grand Total   | Total | 18 | 53 | 97 | 119 | 114 | 157 | 193 | 752 | 100.0% |  |  |

Table 18: BEV and PHEV Sales 2011–2017

# Manufacturers Analysis – BEV

The BEV market is smaller than the standard hybrid market. For this reason there is less need for specific numbers; rather a general commentary is provided here. For BEVs the most important consideration is that its market is split into a luxury market and a mass-market. Surprisingly the luxury market has much more activity and higher sales volumes than the mass-market. This may change in 2018 with the coming to market of the GM Bolt and Tesla 3.

| BEV Sales 2011-2017 (in 1000s) Table 19 |            |      |      |      |      |      |      |      |       |         |
|---|------------|------|------|------|------|------|------|------|-------|---------|
| Manufacturer                            | Model      | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total | % Sales |
| Luxury                                  |            |      |      |      |      |      |      |      |       |         |
| Tesla                                   | Model S    |      | 2    | 19   | 17   | 25   | 29   | 27   | 118   | 30.0%   |
| Tesla                                   | Model X    |      |      |      |      | 0.2  | 18   | 22   | 40    | 10.1%   |
| BMW                                     | i3         |      |      |      | 6    | 11   | 8    | 6    | 31    | 7.9%    |
| Tesla                                   | Model 3    |      |      |      |      |      |      | 2    | 2     | 0.4%    |
| Mercedes                                | B250e      |      |      | 0    | 1    | 2    | 1    | 1    | 4     | 1.0%    |
| Subtotal                                |            |      | 2    | 19   | 23   | 38   | 55   | 57   | 195   | 49.5%   |
| Mass-Market                             |            |      |      |      |      |      |      |      |       |         |
| Nissan                                  | Leaf       | 10   | 10   | 23   | 30   | 17   | 14   | 11   | 115   | 29.1%   |
| VW                                      | e-Golf     | 0    | 0    | 0    | 0.4  | 4    | 4    | 4    | 12    | 3.1%    |
| Chevrolet                               | Bolt       |      |      |      |      |      | 1    | 23   | 24    | 6.0%    |
| Fiat                                    | 500e       |      |      | 0.4  | 2    | 5    | 4    | 3    | 14    | 3.5%    |
| Kia                                     | Soul EV    |      |      | 0.0  | 0    | 1    | 2    | 2    | 5     | 1.3%    |
| Hyundai                                 | Ioniq EV   |      |      | 0.0  | 0    | 0    | 0    | 0    | 0     | 0.1%    |
| Honda                                   | Clarity EV |      |      | 0.0  | 0    | 0    | 0    | 1    | 1     | 0.3%    |
| Subtotal                                |            | 10   | 10   | 23   | 32   | 27   | 24   | 45   | 171   | 43.4%   |
| Disappearing                            |            |      |      |      |      |      |      |      |       |         |
| Mercedes                                | Smart EV   | 0.4  | 0    | 1    | 3    | 1    | 1    | 1    | 7     | 1.7%    |
| Mitsubishi                              | i-MIEV     | 0.1  | 1    | 1    | 0.2  | 0    | 0    | 0    | 2     | 0.5%    |
| Ford                                    | Focus      |      | 1    | 2    | 2    | 2    | 1    | 2    | 9     | 2.2%    |
| Toyota                                  | RAV4 EV    |      | 0.2  | 1    | 1    | 0    | 0    | 0    | 2     | 0.6%    |
| Honda                                   | Fit EV     |      | 0.1  | 1    | 0    | 0    | 0    | 0    | 1     | 0.3%    |
| Chevrolet                               | Spark      |      |      | 1    | 1    | 3    | 3    | 0    | 7     | 1.9%    |
| Subtotal                                |            | 0.5  | 2    | 6    | 7    | 6    | 5    | 2    | 28    | 7.2%    |
| Total                                   |            | 10.1 | 14   | 48   | 63   | 71   | 84   | 104  | 395   |         |

Table 19: BEV Luxury vs. Mass-Market Sales - 2011–2017 (in 1000s)

To some extent the BEV history has been the Nissan Leaf and the Tesla Models S and X. In the BEV Luxury Market, Tesla dominates with BMW second. BMW and Mercedes are threatened by the success of Tesla and are responding. In the Mass-Market, Nissan is without compare. Its new Leaf model is now available and in 2018 the transition will take place. VW is committed to electric vehicles because of the "dieselgate" scandal, which implies a reduction in their diesel car sales in the future. GM's Bolt was well received during 2017. The big question for 2018 is sales of the Bolt and Tesla 3 as well as how rapidly Nissan can manufacture the new Leaf.

In the Disappearing category, sales volumes have been low. Ford has been successful in standard hybrids with the Fusion and C Max but not with their Focus BEV. With their change of command in 2017, a new strategy is being put in place. The company is far behind GM and Nissan in terms of BEV sales.

# Manufacturers Analysis – PHEV

The analysis of PHEVs differs from the analysis of the BEVs because of the success of Tesla in the BEV luxury market. With PHEVs there are three leaders in the mass-market, Chevrolet, Ford, and Toyota with 86% of the market across four models. The luxury PHEV cars are a mixture, with BMW having five models, Mercedes four models, Cadillac and Porsche with two models each and Audi, Chrysler and Volvo one model each. These seven companies with sixteen models have only 14% of the market.

| PHEV SALES: 2011-2017 (in 1000s) Table 20 |                |      |      |      |      |      |      |      |       |         |
|---|----------------|------|------|------|------|------|------|------|-------|---------|
| Manufacturer                              | Model          | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Total | % Sales |
| Luxury                                    |                |      |      |      |      |      |      |      |       |         |
| Porsche                                   | Panamera Ehyb  |      |      | 0.09 | 1    | 0.4  | 0.4  | 0.02 | 2     | 0.5%    |
| Cadillac                                  | ELR            |      |      | 0.01 | 1    | 1    | 1    | 0.02 | 3     | 0.8%    |
| BMW                                       | i8             |      |      |      | 1    | 2    | 2    | 0.5  | 5     | 1.4%    |
| Porsche                                   | Cayenne Ehyb   |      |      |      | 0.1  | 1    | 2    | 2    | 5     | 1.4%    |
| BMW                                       | X5 xDr40e      |      |      |      |      | 1    | 6    | 5    | 12    | 3.5%    |
| Mercedes                                  | S 550e         |      |      |      |      | 0.1  | 1    | 1    | 1     | 0.4%    |
| Audi                                      | A3 Plugin      |      |      |      |      | 0.0  | 4    | 3    | 3     | 0.8%    |
| Volvo                                     | XC90           |      |      |      |      | 0.1  | 2    | 2    | 4     | 1.2%    |
| BMW                                       | 330e           |      |      |      |      |      | 1    | 4    | 5     | 1.4%    |
| Mercedes                                  | GLE 550e       |      |      |      |      |      | 0.2  | 0    | 1     | 0.2%    |
| Mercedes                                  | C350e          |      |      |      |      |      | 0.2  | 1    | 1     | 0.3%    |
| BMW                                       | 740e           |      |      |      |      |      | 0.1  | 0.7  | 1     | 0.2%    |
| Chrysler                                  | Pacifica       |      |      |      |      |      |      | 3    | 3     | 0.8%    |
| BMW                                       | 530e           |      |      |      |      |      |      | 4    | 4     | 1.1%    |
| Cadillac                                  | CT6            |      |      |      |      |      |      | 0.2  | 0.2   | 0.1%    |
| Volvo                                     | XC60           |      |      |      |      |      |      | 0.5  | 0.5   | 0.2%    |
| Honda                                     | Clarity Plugin |      |      |      |      |      |      | 0.9  | 0.9   | 0.3%    |
| Volvo                                     | S90 Plugin     |      |      |      |      |      |      | 0.1  | 0.1   | 0.0%    |
| Subtotal                                  |                |      |      | 0.09 | 3    | 6    | 19   | 28   | 51    | 14.6%   |
| Mass-Market                               |                |      |      |      |      |      |      |      |       |         |
| Chevrolet                                 | Volt           | 8    | 23   | 23   | 19   | 15   | 25   | 20   | 134   | 37.9%   |
| Toyota                                    | Prius Prime    |      | 13   | 12   | 13   | 4    | 2    | 21   | 66    | 18.6%   |
| Ford                                      | C-Max Energi   |      | 2    | 7    | 8    | 8    | 8    | 8    | 42    | 11.8%   |
| Ford                                      | Fusion Energi  |      |      | 6    | 12   | 10   | 16   | 10   | 53    | 15.0%   |
| Honda                                     | Accord Plug-in |      |      | 0.5  | 0.4  | 0.1  | 0    | 0    | 1     | 0.3%    |
| Hyundai                                   | Sonata Plug-in |      |      |      |      | 0.2  | 3    | 1    | 4     | 1.2%    |
| Kia                                       | Optima PlugIn  |      |      |      |      |      |      | 2    | 2     | 0.4%    |
| BMW Mini                                  | Countryman PI  |      |      |      |      |      |      | 0.5  | 0.5   | 0.1%    |
| Subtotal                                  |                | 8    | 39   | 49   | 53   | 37   | 54   | 62   | 301   | 85.4%   |
| Grand Total                               |                | 8    | 39   | 49   | 55   | 43   | 73   | 90   | 352   | 100.0%  |

Table 20: Luxury and Conventional PHEV Sales 2011-2017 (in 1000s)

#### What's the Near Term Plug-in Future?

Researchers at Carnegie Mellon University (CMU) published two policy briefs in 2015 about the benefits of electrified vehicles and the potential for their adoption in the US. The briefs condense the findings of a number of papers published by the CMU Vehicle Electrification Group led by Professor Jeremy Michalek. The first, *Electric Vehicle Benefits and Costs in the United States*,<sup>15</sup> shows that the benefits of vehicle electrification vary based on vehicle type, driving style, climate, the method of supplying electricity, and time when charging is done. The report suggests that use of HEVs and PHEVs vehicles is most advantageous when adopted by city drivers in mild-climate regions with a "clean" electricity grid, such as San Francisco or Los Angeles. Further, drivers should not be encouraged to charge at night in coal-heavy regions. The second report, *Electric Vehicle Benefits and Costs in the United States*,<sup>16</sup> points out that electric vehicles can only make an impact to the extent that consumers adopt them, which is affected by a variety of factors including cost, consumer preferences, and government policy. One surprising conclusion was that plug-in technology will only be adopted if the price is significantly lower than conventional cars or standard hybrids. Two short videos by Professor Michalek provide an excellent summary of the situation.<sup>17</sup>

A more recent 2018 report by accounting firm KPMG which involved interviews with 953 automobile senior executives, concludes that industry executives have a dim view of electric cars.<sup>18</sup> One of the main conclusions is that electric cars will fail but that the industry will build them anyway because government regulation will require that such cars be provided. Industry executives point out that there is a plethora of electrified cars available, but customers still prefer the current available internal combustion engine vehicles. This is borne out by the statistics in this report.

Car companies go along with government dictates, particularly if the government provides large amounts of funding as was done with plug-ins. Building electrified cars means that auto companies can continue manufacturing the typical mix of gasoline cars and argue that they are becoming "greener," satisfying both the public and the government. Car companies learned not to fight government programs, as they did in California during the first EV effort of the 1990s. They have found that the sales volume of the alternative vehicles has been so small that the costs of developing and manufacturing could easily be spread across the huge volume of gasoline cars. This is substantiated by the U.S. 2017 car sales of 17.1 million cars, which included 559,000 electrified cars or 3.3% of the sales, the majority of which are HEVs rather than plug-ins. Plug-in sales in 2017 were 194,000 cars with a 1.1% market share.

The manufacturers view regarding the disinterest of consumers for low emissions cars is borne out by the low sales numbers. The auto industry's primary R and D emphasis has now moved on to autonomous driving, which will make travel even more convenient leading to more miles driven, which also translates into more car purchases. A recent study suggests that autonomous vehicles might add one trillion more vehicle miles traveled each year by 2050.<sup>19</sup>

The government has taken the responsibility of providing fuel economy information on the window sticker (even if somewhat misleading). If consumers criticize car companies for misrepresenting plug-in MPGe equivalent (as discussed in detail in this document as well as other documents on the Plan Curtail web site), they respond that they are simply following the laws that give the government responsibility for determining the MPGe calculation method.

There is a significant amount of marketing of plug-ins by government at all levels, including local communities. Often local or regional governments will buy a few plug-ins for their use, a strategy also used by some corporations, to promote plug-in cars. Electrification of transportation has become a major "popular" idea for mitigating climate change for all world governments. This focus and the associated intense publicity gives a somewhat false perspective both about the volume of sales (constantly referred to as "exploding") and the depth of the interest by consumers (small). The publicity can serve to assuage the conscience of the average consumer who has little interest in electric cars by assuming someone else is buying them. As long as the sales numbers are ignored, such a "feel-good" strategy will continue to keep the public content.

Another argument used to justify plug-in car sales is that "the grid is growing greener every year!" This holds out hope that at some point in the future all electricity will come from renewables and at that point, plug-in cars will be the standard. But the actual rate of efficiency improvement of the so-called "greening of the grid" is quite low. The recent rapid growth of solar PV gives the impression that the power utilities are achieving record levels of renewable electricity. However, on a worldwide basis, solar PV still provides less than 1% of all energy consumed.

Government subsidies for plug-in cars have been substantial and have played a key role in plug-in car sales. The original Obama program called for subsidizing sales of one million plug-in cars. This subsidy expires once a manufacturer has sold 200,000 of the cars. Unless it is extended, plug-in cars will have to compete on their merits against standard hybrid cars in the near future. An example of this is Georgia's subsidy of electric cars. When it was removed, sales dropped precipitously, some models by more than 90%.<sup>20 21</sup>

It is also important to understand that the financial subsidies for these cars tend to go to high income households.<sup>22</sup> Sixty percent of the \$18 billion in clean-energy tax credits distributed by the Federal government between 2006 and 2012 went to the top income quintile--households making more than \$200,000 per year. Credits for plug-in cars were the single incentive that proved to be most concentrated at the upper end of the income spectrum. Two tax credits aimed at green cars, the Alternative Motor Vehicle Credit (AMVC) and the Qualified Plug-In Electric Drive Motor Vehicle Credit (PEDVC), accounted for \$895 million, or about 5 percent of total clean-energy tax credits awarded during the period studied. The bottom 80 percent of people filing for the PEDVC received little more than 10 percent of the benefits.

Another important factor is the continued increase in the percentage of SUVs sold in the U.S. Figure 1 shows this long-term trend<sup>23</sup> towards larger cars, which is somewhat surprising in light of the increasing concern about climate change.



Figure 1 – Increased Share of Market by Light Trucks (Government name for SUVs)

Average MPG in the U.S. has not increased for some years. More and more consumers prefer SUVs and CUVs over more efficient passenger cars or highly efficient standard hybrids. Thus the move to SUVs and CUVs is canceling out the efficiency improvements of more efficient drive trains – HEV, BEV or PHEV.



Figure 2 – Average MPG for New Automobiles<sup>24</sup>

There are many contradicting trends, which make it difficult to decide if a plug-in future is axiomatic. The percent of the new car market that is electrified has not grown significantly. The emphasis on conventional larger vehicles implies that the average person is not willing to sacrifice comfort or features to reduce emissions. And it is still not clear how much of the hyperbole of electric car marketing comes from misrepresentation on window stickers and how this has affected sales.

# Hybrids or Plug-ins – MPG, MPG<sub>e</sub>, MPG<sub>ghg</sub> Implications

Table 1 and table 2 show the decline in market share of standard hybrids, offset by an increase in market share for plug-ins. Electric car supporters have suggested that the hybrid is simply an interim step from the internal combustion engine to plug-ins. But as already mentioned, the original sales projections for plug-ins have not materialized and standard hybrid sales continue to dominate the electrified market. Some manufacturers, particularly Toyota and Hyundai/Kia, continue to prioritize standard hybrids. Hyundai recently delivered a new line of high fuel economy vehicles, the IONIQ, which will include three optional drive trains – hybrid, plug-in hybrid, and battery EV but no standard gasoline model. The latest drive trains from these companies provide MPG ratings in the upper 50s, a level of fuel economy only achieved by Toyota to date.

Table 21 lists 2017's top ten hybrid models with the most sales (80% of total hybrid sales). For each model we have included information on the  $CO_2$  in grams per mile and the miles per gallon (MPG). The average grams of  $CO_2$  per mile are 248 and the average MPG is 45.

| Top 10 Standard Hybrids in Sales – 2017 Table 21 |                 |         |                       |     |  |  |
|--|-----------------|---------|-----------------------|-----|--|--|
| Company  | Model           | Sales   | CO₂<br>grams<br>/mile | MPG |  |  |
| Toyota   | Prius Lift-back | 65,361  | 190                   | 56  |  |  |
| Ford   | Fusion          | 57,474  | 254                   | 42  |  |  |
| Toyota   | RAV4            | 50,559  | 333                   | 32  |  |  |
| Kia  | Niro            | 27,237  | 218                   | 49  |  |  |
| Honda  | Accord          | 22,008  | 222                   | 48  |  |  |
| Toyota   | Camry           | 20,985  | 205                   | 52  |  |  |
| Toyota   | Highlander      | 16,864  | 381                   | 28  |  |  |
| Toyota   | Prius c         | 12,415  | 232                   | 46  |  |  |
| Hyundai  | loniq           | 10,765  | 184                   | 58  |  |  |
| Hyundai  | Sonata          | 9,550   | 254                   | 42  |  |  |
| Total  |                 | 293,218 |                       |     |  |  |
| Weighted Average CO <sub>2</sub> & MPG           |                 |         | 248                   | 45  |  |  |

Table 21: Weighted Average MPG and CO<sub>2</sub> for Top Ten Hybrid Cars in 2015

Table 22 shows 2017's top ten plug-in models with the most sales (80% of total plug-in sales). The table shows the data in the same way as in Table 21. The average grams of  $CO_2$  per mile for the plug-ins are 230 and the average MPGe is 94. However, the fuel economy is given in MPGe units, which do not include the energy to create electricity.

| Top 10 Plug-ins in Sales — 2017 Table 22 |             |                |                       |        |  |  |
|--|-------------|----------------|-----------------------|--------|--|--|
| Company                                  | Model       | Sales<br>Units | CO₂<br>grams<br>/mile | MPGe   |  |  |
| Tesla                                    | Model S 75  | 26,500         | 190                   | 103    |  |  |
| Chevrolet                                | Bolt        | 23,297         | 170                   | 119    |  |  |
| Tesla                                    | Model X 75  | 21,700         | 210                   | 93     |  |  |
| Toyota                                   | Prius Prime | 20,936         | 170                   | 133/54 |  |  |
| Chevrolet                                | Volt        | 20,349         | 200                   | 106/42 |  |  |
| Nissan                                   | Leaf        | 11,230         | 180                   | 112    |  |  |
| Ford                                     | Fusion-Eng  | 9,632          | 240                   | 97/42  |  |  |
| Ford                                     | C-max-Eng   | 8,140          | 250                   | 95/39  |  |  |
| BMW                                      | i3          | 6,276          | 170                   | 118    |  |  |
| BMW                                      | X5          | 5,349          | 590                   | 56/24  |  |  |
| Total                                    |             | 153,409        |                       |        |  |  |
| Weighted Average CO <sub>2</sub> & MPGe  |             |                | 207                   | 94     |  |  |

Table 22: Weighted MPGe and CO<sub>2</sub> for Top Ten Plug-in Cars in 2015

Note that as "climate friendly" cars,  $CO_2$  emissions are very close for the two types of electrified cars; 238 grams/mile for the hybrids and 207 grams/mile for the plug-ins, about a 15% difference. In terms of MPG and MPGe, respectively 45 for the hybrid and 94 for the plug-ins, there is a 210% difference. This again points out the flawed methods of the EPA.

In a November 2017, University of Michigan Transportation Research Institute (UMTRI) study, the UMTRI assessed the relative amounts of greenhouse-gas emissions from driving a batteryelectric vehicle (BEV) compared with greenhouse-gas emissions from driving a conventional gasoline-powered vehicle in different countries of the world.<sup>25</sup> They determined that when the indirect (power plant) emissions were included, that emissions from BEVs depended on the mix of fuel sources used to generate electricity; countries differ widely in their fuel-source mix. For a BEV, the average for the world is 51.5 MPG<sub>ghg</sub>. The corresponding value for the U.S. is 55.4 MPG<sub>ghg</sub>. China currently comes in at 40.0 MPG<sub>ghg</sub>. The Prius ECO's fuel economy is 56 MPG. The UMTRI report shows that the flawed methods of reporting plug-in vehicle fuel economy in the U.S. are under scrutiny.

As a graphic reminder of the misleading way plug-in car window stickers read, the US government maintains the following figure. This figure emphasizes the very close emissions of all electrified vehicles and the roughly 50% CO<sub>2</sub> reductions of electrified cars compared to conventional cars.



Figure 3: CO<sub>2</sub> Generated Annually for EV, PHEV, HEV and Conventional Cars<sup>26</sup>

# Conclusions

<u>President Obama's original goal</u> was not reached – After ten years of development and production, plug-in sales have been somewhat disappointing. The original 2008 Obama projection of one million plug-in hybrid (PHEVs) cars sold by 2015 was never met; the total through 2015 was slightly less than 200,000 PHEVs. Total plug-in hybrids sold through 2017 are approximately 356,000 cars.

<u>Worldwide Growth of the Light Vehicle Sales</u> – Vehicle sales worldwide has grown at an annual rate of 4.1% since 2009, which is higher than the 1.2% growth in population over the same period. The number of vehicles in use is now about 1.3 billion.<sup>27</sup> Plug-in cars have less than 2% of the market for new vehicles and only a fraction of a percent of the existing base of all existing vehicles in use (vehicle fleet). The growth in car sales cancels out the emission savings from new technologies.

<u>Effects of Electrified Car Improvements</u> – Most car models change power trains every five to seven years. This typically represents a major improvement in MPG over the previous model. For standard hybrids the big change has been the new Prius Eco, the 2017 Camry Hybrid, the Hyundai Ioniq Blue, and the Kia Niro. These represent a step function in improved Miles Per Gallon. Plug-ins completed such a transition with the delivery of the 2018 Leaf. However, the new version of the Leaf, the Chevrolet Bolt, and the Tesla 3 represent a step function in terms of driving range more than in terms of MPG. The market reaction to these significant improvements will provide a measure of the success of plug-ins for the next six years until another set of new drive trains are developed.

<u>People in the U.S. have lost Interest in Reducing Automobile Emissions</u> – The new 2017 Camry has a fuel economy of 32 mpg for the conventional model and 52 mpg for the hybrid version. In 2014 the standard Camry fuel economy was 28 mpg and the hybrid version was 40 mpg. In 2017, Camry hybrid sales were 21,000 out of about 400,000 total Camry sales (about 5% hybrids). This was a drop in hybrid Camry sales, which were 46,000 in 2014, out of 428,000 total Camrys sold (about 10% hybrids). MPG increase in the standard Camry between 2014 and 2017 was 4 mpg; MPG increase in the hybrid Camry between the same two years was 12 mpg, yet the hybrids percent of sales declined. This example, together with declines in Prius sales (52-56 MPG) from 99,000 units in 2016 to 66,000 units in 2017, shows a shrinking interest in reducing CO<sub>2</sub>.

<u>Modeling Plug-in and Hybrid CO<sub>2</sub> performance</u> – The MPG/MPG<sub>e</sub>/MPG<sub>ghg</sub> confusion will be clarified somewhat with the delivery of the Hyundai Ioniq new family of electrified cars with three optional drive trains – HEV, PHEV and BEV and no conventional internal combustion engine. The Hybrid model (HEV) arrived in 2017 and the other two versions arrived in early 2018. According to fueleconomy.gov, the Ioniq HEV generates 184 grams of CO<sub>2</sub> per mile, the Ioniq PHEV generates 190 grams of CO<sub>2</sub> per mile and the Ioniq BEV generates 150 grams of CO<sub>2</sub> per mile. This model family will hopefully contribute to the use of MPG<sub>ghg</sub> rather than the erroneous MPG<sub>e</sub>.

<u>Future Government Subsidies</u> – Government subsidies are vital in supporting the plug-in market. They are scheduled to end for each manufacturer when 200,000 units have been sold. When these subsidies disappear, plug-in sales could plummet. Standard hybrids are not subsidized so must compete in the market without government assistance. Toyota and Hyundai/Kia are successfully doing so.

<u>Customer Psychology</u> – Technology has reduced the fuel needed for a given car's weight and horsepower markedly. In the U.S. the majority of new car owners choosing to purchase cars with greater power and weight has offset this. Further improvements in fuel economy will depend both on technology to reduce fuel use per car, but also on downsizing or down-weighting vehicles as well. As this report was being compiled at the end of 2017 and the beginning of 2018, it was a shock to realize that in spite of all we know about the climate crisis and the availability of cars that get over 50 MPG, in 2017 Americans chose to increase purchases of vehicles with poorer MPG ratings. At this time it seems clear that there will need to be laws that place much stricter regulations on MPG and emissions of all types of vehicles (cars, trucks, SUVs, and CUVs), if the climate crisis is to be taken seriously.

https://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean\_vehicles/electric-car-global-warmingemissions-report.pdf

<sup>7</sup> Plug-In Folly Part 3 by Pat Murphy, Plan Curtail, November 2015, Miles per Gallon Equivalent (MPGe) Metrics Page, Part 3 A : A Look at MPGe Metrics – The EPA Way http://www.plancurtail.org/wp-content/uploads/2016/01/PIF-MPGe-Part-3-74-slides-103015.pdf

<sup>8</sup> 2017 Full Year Japan Best Selling Car Models and Mini Cars January 11, 2018 by Henk Bekker in Japan https://www.best-selling-cars.com/japan/2017-full-year-japan-best-selling-car-models-mini-cars/

<sup>9</sup> 2017 Full Year Japan Best Selling Car Manufacturers and Brands January 11, 2018 by Henk Bekker in Japan. https://www.best-selling-cars.com/japan/2017-full-year-japan-best-selling-car-manufacturers-brands/

<sup>10</sup> 2015 Ford CMax Ads To Downplay Twice Cut Gas Mileage Focus On Fun Tech 102714

http://www.greencarreports.com/news/1095135\_2015-ford-c-max-ads-to-downplay-twice-cut-gas-mileage-focus-onfun-techby Stephen Edelstein, Green Car Reports, Oct 27, 2014

<sup>11</sup> Ford To Focus On Performance Not Electric Drive Technology 030415 by Eric Loveday, Inside EVs, March 4, 2015 http://insideevs.com/ford-focus-performance-electric-drive-technology/

<sup>12</sup> Hyundai & Kia overstate MPG ratings for 2011-2013 vehicles: will make refunds by James Nelson, November 2, 2012, http://www.examiner.com/node/54866696

<sup>13</sup> 2016 Chevrolet Malibu Hybrid announced, will use Volt-related hardware.

http://www.worldcarfans.com/115032591092/2016-chevrolet-malibu-hybrid-announced-will-use-volt-related

<sup>14</sup> Charging into the Future by Larry Edsall, Motor Books, 2010

<sup>15</sup> Electric Vehicle Benefits and Costs in the United States June 2015, http://www.cmu.edu/epp/policybriefs/briefs/Electric-Vehicles-Costs-Benefits.pdf

<sup>16</sup> Electric Vehicle Adoption Potential in the United States June 2015 http://www.cmu.edu/epp/policybriefs/briefs/Electric-Vehicle-Adoption.pdf

<sup>17</sup> CMU policy briefs outline benefits and potential for adoption of electrified vehicles in the US, Green Car Congress, July 1, 2015 http://www.greencarcongress.com/2015/07/20150701-michalek.html

<sup>18</sup> Electric cars will fail but we will build them anyway say global auto execs KPMG, January 12, 2018 by Mark Stevenson

https://www.greencarreports.com/news/1114758 electric-cars-will-fail-but-well-build-them-anyway-say-global-autoexecs-kpmg

<sup>19</sup> KPMG study finds autonomous vehicles & mobility services could add one trillion more vehicle miles traveled annually by 2050, Green Car Congress, 26 November 2015 http://www.greencarcongress.com/2015/11/20151126kpmg.html

<sup>20</sup> Without state subsidies, electric car sales in Georgia crash by Rob Nikolewski, October 28, 2015, http://watchdog.org/244308/subsidies-electric-car/

<sup>21</sup> Georgia Electric Car Sales Plummet After Incentive Replaced By Tax by Stephen Edelstein, Green Car Reports, November 4, 2015

http://www.greencarreports.com/news/1100751 georgia-electric-car-sales-plummet-after-incentive-replaced-by-tax

<sup>22</sup> Most Electric Car Tax Credits Benefit Highest Income Households by Stephen Edelstein, Green Car Reports, September 8, 2015

http://www.greencarreports.com/news/1099916 most-electric-car-tax-credits-benefit-highest-income-households <sup>23</sup> Auto Makers Miss US Emissions Target Despite Record Fuel Economy by Chester Dawson and Mike Spector. Wall Street Journal, Jan. 11, 2018

http://www.cetusnews.com/tech/Auto-Makers-Miss-U-S--Emissions-Target-Despite-Record-Fuel-

Economy.S17yX5HSEM.html

<sup>24</sup> Average US new vehicle fuel economy in December down from November; 2017 average unchanged from 2016, by Green Car Congress, January 5, 2018,

http://www.greencarcongress.com/2018/01/20180104-umtri.html

<sup>25</sup> UMTRI study shows wide global variability in GHG emissions from operating an EV 110717

<sup>&</sup>lt;sup>1</sup> Part 2A:The Battery Electric Car – The Birth of the Modern Electric Car http://www.plancurtail.org/wpcontent/uploads/2016/01/PIF-BEV-Part-2-39-slides-103015.pdf

<sup>&</sup>lt;sup>2</sup> Data from Hybridcars.com http://www.hybridcars.com/

<sup>&</sup>lt;sup>3</sup> Barrack Obama and Joe Biden: New Energy for America.

http://energy.gov/sites/prod/files/edg/media/Obama New Energy 0804.pdf

<sup>&</sup>lt;sup>4</sup> https://www.afdc.energy.gov/vehicles/electric emissions.php

<sup>&</sup>lt;sup>5</sup> http://www.greencarcongress.com/2018/01/20180104-umtri.html

<sup>&</sup>lt;sup>6</sup> State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States by Don Anair and Amine Mahmassani, June, 2012, 48p,

http://www.greencarcongress.com/2017/11/20171107-umtri.html 7 November 2017

<sup>26</sup> Switching to electric cars is key to fixing Americas critically insufficient' climate policies by Dana Nuccitelli , The Guardian, 22 Jan 2018

https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/jan/22/switching-to-electric-cars-is-

<u>key-to-fixing-americas-critically-insufficient-climate-policies</u>
<sup>27</sup> Relentless Car Buying Crowds World Roads, Wall Street Journal, by John D. Stoll and Adrienne Roberts. <u>https://www.wsj.com/articles/car-sales-to-top-90-million-globally-for-first-time-1514920642</u>