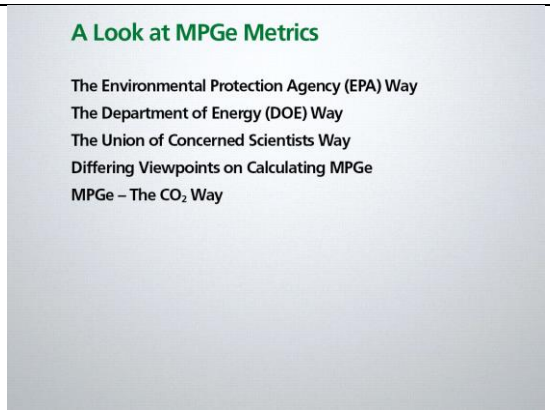
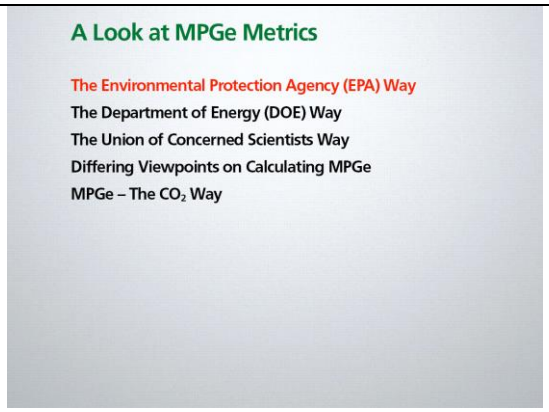
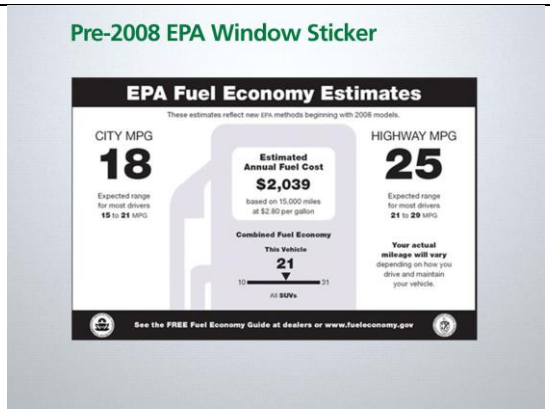
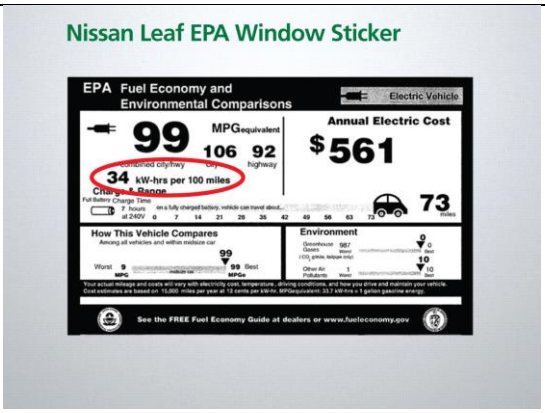
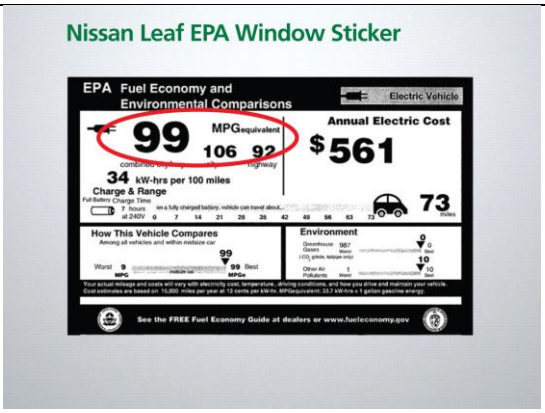
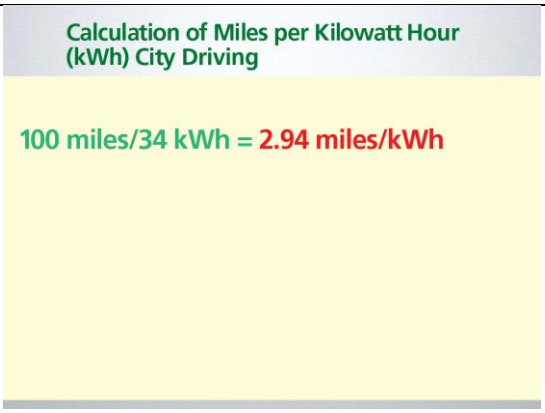
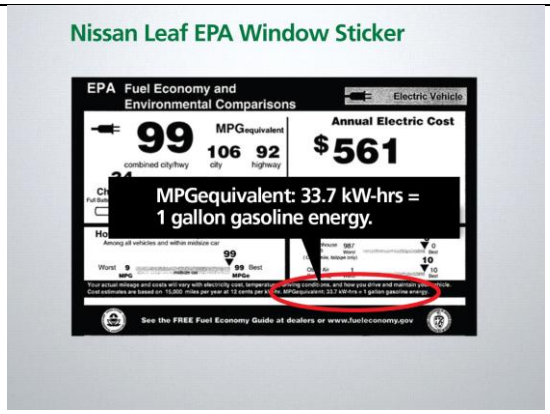
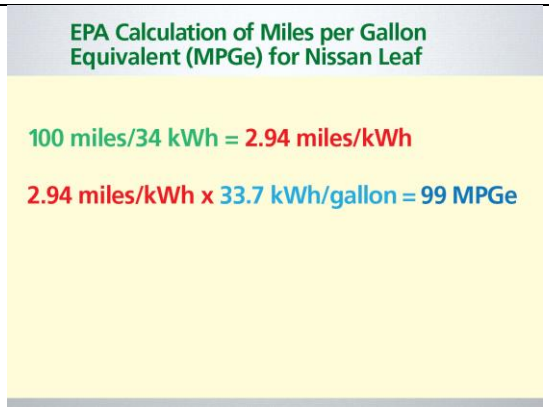
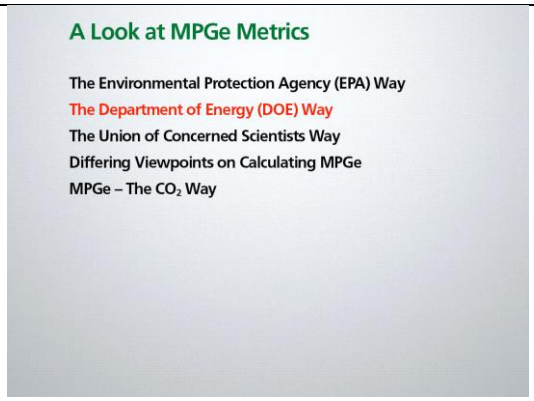
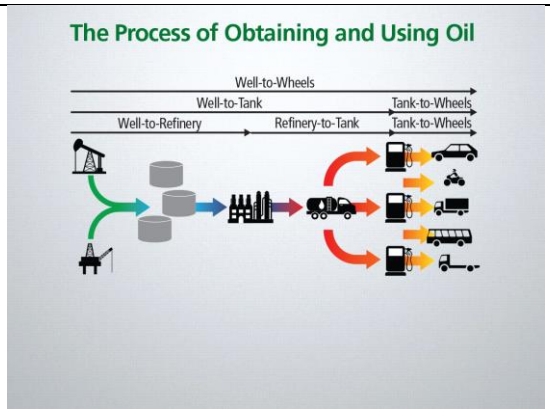
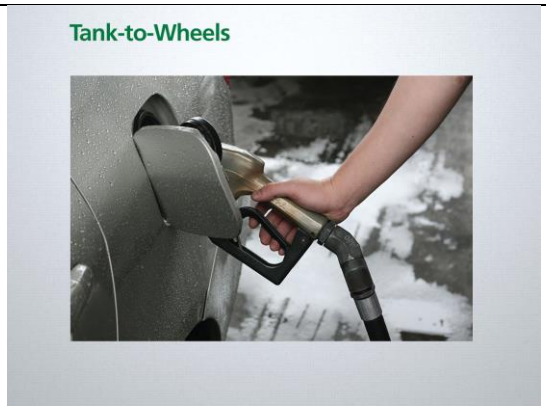
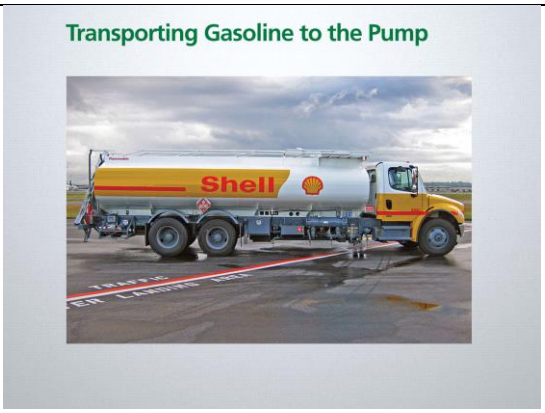
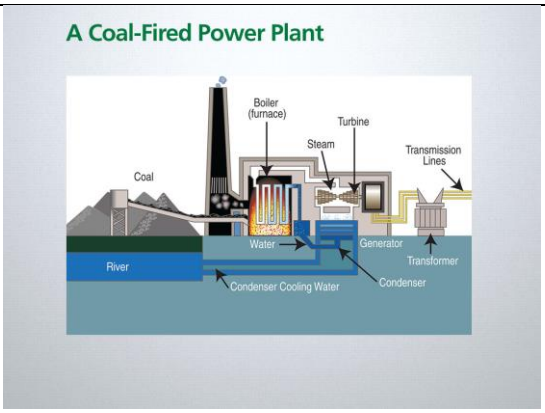
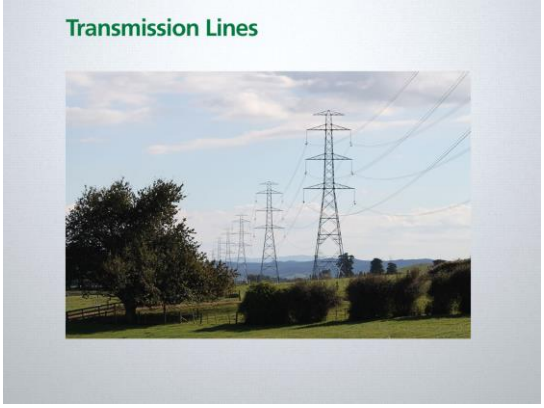
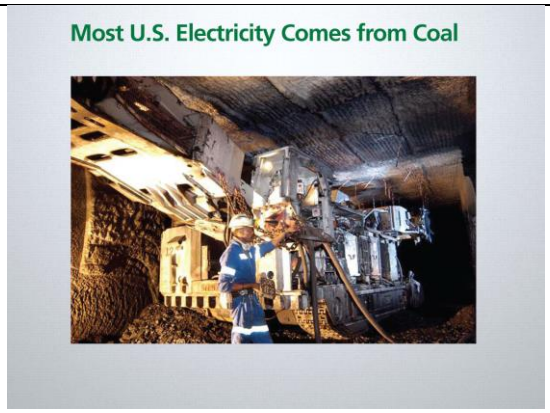
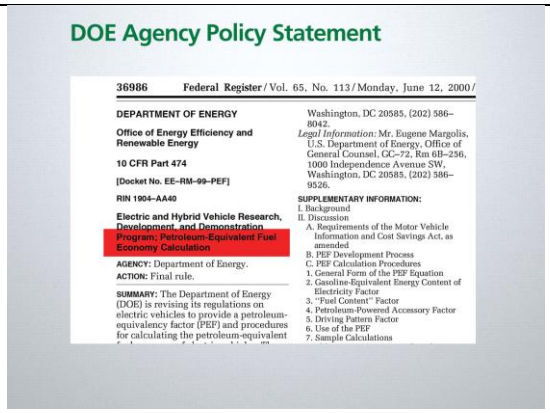
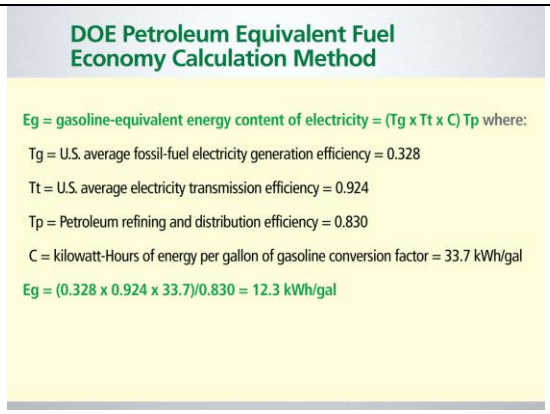
Part 3A: A Look at MPGe Metrics – The EPA Way		
M1	The Environmental Protection Agency (EPA), the Department of Energy (DOE), and the Union of Concerned Scientists (UCS) use different methods of computing and displaying Miles Per Gallon equivalent (MPGe). Despite the high plugin MPGe numbers, CO_2 emissions from the most popular electric cars are about the same as those from a Prius.	
M2	One reason for low electric plug-in sales is confusion about their fuel economy as measured by Miles Per Gallon equivalent, or MPGe, on the EPA designed car window stickers.	
M3	The 2007 Energy Independence and Security Act required that the EPA design new car window stickers that show both miles per gallon and CO_2 emissions per mile.	
M4	Prior to the passage of this law, window stickers were much simpler, showing miles per gallon for city and highway driving, as well as an estimated annual fuel cost.	

M5	In 2011, the EPA specified a new window sticker format that became mandatory in 2013. It included a new kind of measure – the number of gallons of gasoline consumed to drive 100 miles.	
M6	The new law also required that electric cars show the number of kilowatt hours consumed to drive 100 miles. For the 2012 Leaf this was 34 kilowatt hours.	
M7	Since electric cars don't use gasoline, the window stickers included a new term, *miles-per-gallon equivalent,* as shown on the first electric car window sticker. The 2012 Leaf was rated at 99 miles per gallon equivalent for combined city and highway.	
M8	To calculate the Leaf miles per gallon equivalent, the EPA first divides the 100 miles by the 34 kWh giving 2.94 miles per kWh.	

M9	Buried in the small print of the electric car window sticker is the statement: 33.7 kW-hrs = 1 gallon gasoline energy, which gives the kilowatt hours in a gallon of gasoline.	
M10	The second step in the EPA method is to multiply 2.94 miles per kilowatt hour by the 33.7 kWhs on the label. This gives the 99 miles-per-gallon equivalent for the 2012 Leaf.	
M11	as shown in the top left corner of the window sticker.	
M12	Many scientists have challenged the use of 33.7 kwh per gallon of gasoline by the EPA as the basis for determining an EVs MPG equivalency because this method does not take into account the considerable energy consumed in making electricity.	

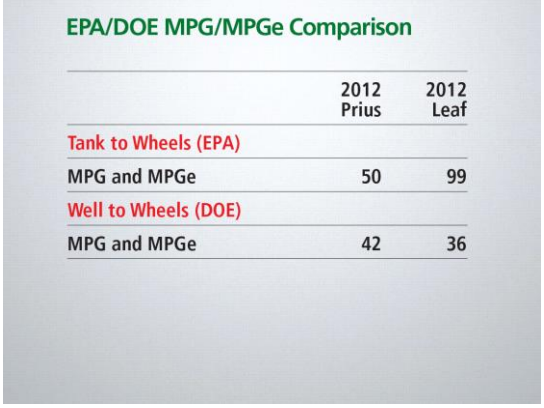
Part 3B: A Look at MPGe Metrics – The Department of Energy Way		
M13	The Department of Energy uses a different value for the amount of electricity that is equivalent to the chemical energy in a gallon of gasoline.	
M14	The DOE miles-per-gallon estimates are based on what is called “well-to-wheels” values. This means the energy used to produce a liquid fuel like gasoline or an alternate fuel like electricity are counted.	
M15	The total process of obtaining and burning gasoline is normally divided into different states. The most important are well-to-tank and tank-to-wheels. Added together they give the well-to-wheels value.	
M16	“Tank-to-wheels” measures the energy used to turn the wheels of the car and does not include the energy used in refining gasoline or in making electricity. The EPA only considers “tank-to-wheels” in its miles per gallon equivalent values on car window stickers.	

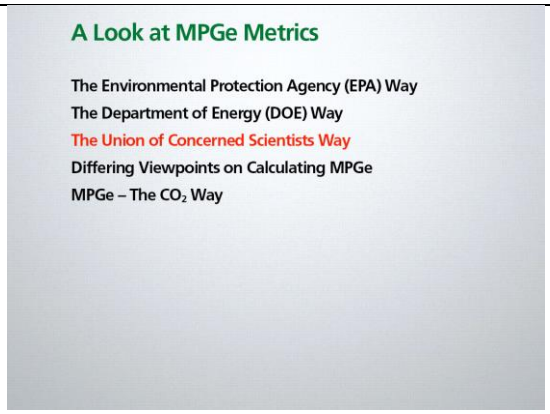
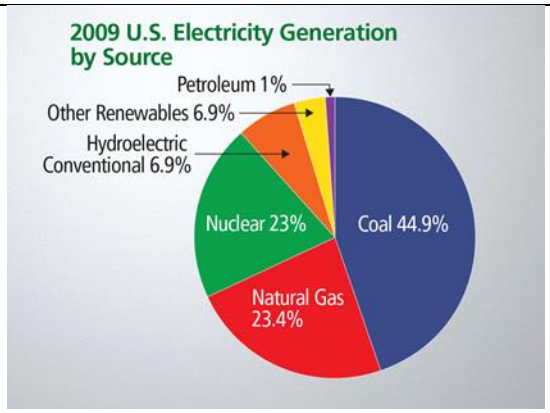
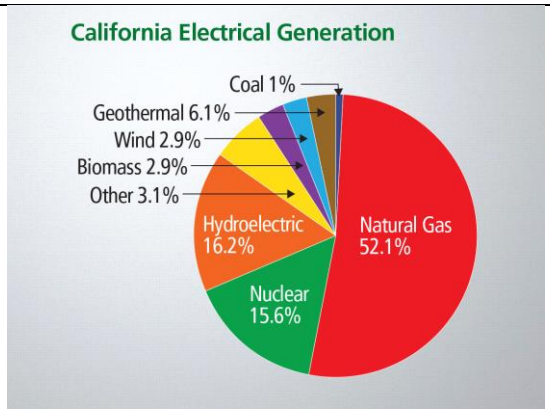
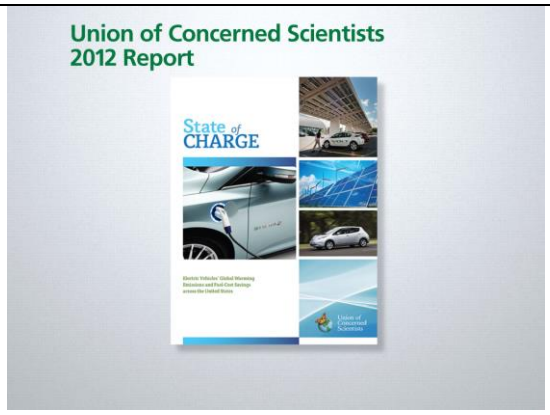
M17	Well-to-wheels analysis includes the energy used to make gasoline from oil in refineries….	
M18	…as well as the transportation energy required to deliver gasoline from the refinery to the local gasoline station	
M19	The burning of fossil fuels to produce electricity from a power plant is analogous to the refinery. Most power plants use coal or natural gas to generate electricity.	
M20	The transmission lines that carry electricity are analogous to the gasoline tankers.	

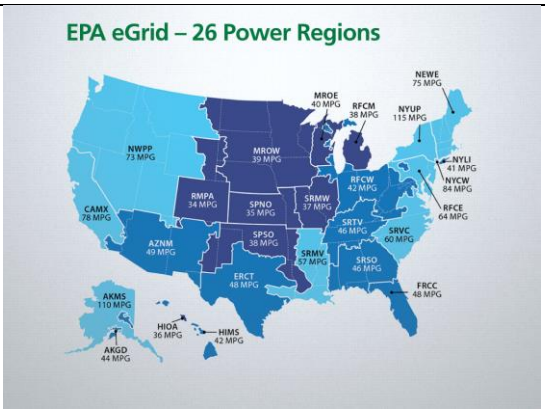
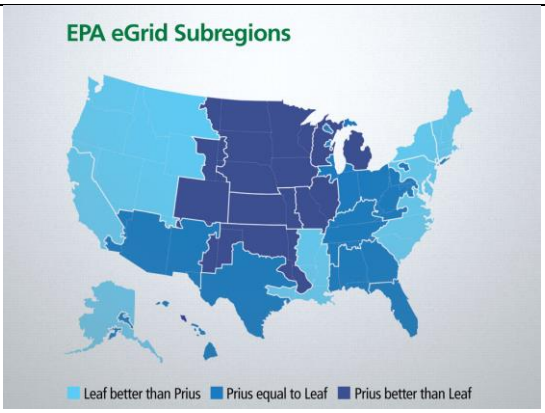
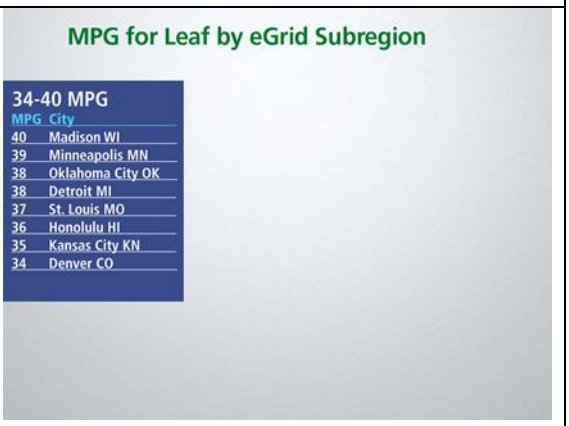
M21	And the battery in an electric car is analogous to the gasoline tank.	
M22	The term "well to wheels: was originally applied to gasoline cars. For electric cars a more appropriate term might be "mine-to-wheels" reflecting the high use of coal. However, "well-to-wheels" is the conventional term used for vehicles and will be used here.	
M23	The Department of Energy method of determining well to wheels miles per is called **"Petroleum-Equivalent Fuel Economy Calculation."** It was defined in a key Final Rule by the DOE published in July 2000. A Final Rule is a description of a government agency policy recorded in the U.S. Federal Register.	
M24	The Petroleum Equivalent Fuel Economy Calculation is a formula for determining the well-to-wheels equivalent energy content of electricity. This equivalency calculation, labeled Eg uses four terms – <u>Tg, Tt, Tp and C.</u>	

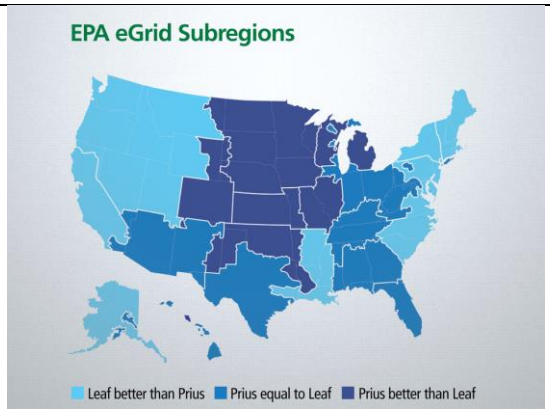
M25	The first term Tg is the efficiency of generating electricity from fossil fuel, which is about 33 percent across the US. The number is low because two-thirds of the energy in the fuel used in a power plant to generate electricity is lost in the form of heat released to the atmosphere.	**DOE Petroleum Equivalent Fuel Economy Calculation Method** Eg = gasoline-equivalent energy content of electricity = (Tg x Tt x C) Tp where: Tg = U.S. average fossil-fuel electricity generation efficiency = 0.328 Tt = U.S. average electricity transmission efficiency = 0.924 Tp = Petroleum refining and distribution efficiency = 0.830 C = kilowatt-Hours of energy per gallon of gasoline conversion factor = 33.7 kWh/gal Eg = (0.328 x 0.924 x 33.7)/0.830 = 12.3 kWh/gal
M26	The second term Tt is the efficiency of transmitting the electricity over the power lines of the grid, which is about 92 percent. The energy lost is mostly in heat from the power lines.	**DOE Petroleum Equivalent Fuel Economy Calculation Method** Eg = gasoline-equivalent energy content of electricity = (Tg x Tt x C) Tp where: Tg = U.S. average fossil-fuel electricity generation efficiency = 0.328 Tt = U.S. average electricity transmission efficiency = 0.924 Tp = Petroleum refining and distribution efficiency = 0.830 C = kilowatt-Hours of energy per gallon of gasoline conversion factor = 33.7 kWh/gal Eg = (0.328 x 0.924 x 33.7)/0.830 = 12.3 kWh/gal
M27	Refining of fossil fuels must also be included to give a fair comparison and Tp shows the efficiency of this process. The energy lost in refining and distributing gasoline is about 17 percent of the total fuel.	**DOE Petroleum Equivalent Fuel Economy Calculation Method** Eg = gasoline-equivalent energy content of electricity = (Tg x Tt x C) Tp where: Tg = U.S. average fossil-fuel electricity generation efficiency = 0.328 Tt = U.S. average electricity transmission efficiency = 0.924 Tp = Petroleum refining and distribution efficiency = 0.830 C = kilowatt-Hours of energy per gallon of gasoline conversion factor = 33.7 kWh/gal Eg = (0.328 x 0.924 x 33.7)/0.830 = 12.3 kWh/gal
M28	The fourth term, C, is a constant that was discussed earlier. It represents the gallon of gasoline energy equivalent of electricity, or 33.7 kilowatt hours.	**DOE Petroleum Equivalent Fuel Economy Calculation Method** Eg = gasoline-equivalent energy content of electricity = (Tg x Tt x C) Tp where: Tg = U.S. average fossil-fuel electricity generation efficiency = 0.328 Tt = U.S. average electricity transmission efficiency = 0.924 Tp = Petroleum refining and distribution efficiency = 0.830 C = kilowatt-Hours of energy per gallon of gasoline conversion factor = 33.7 kWh/gal Eg = (0.328 x 0.924 x 33.7)/0.830 = 12.3 kWh/gal

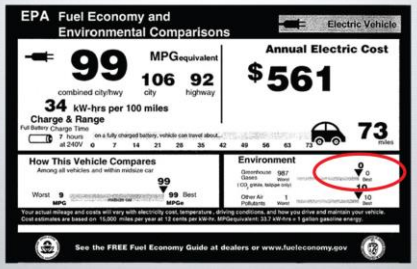
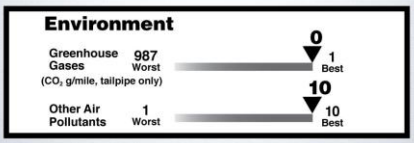
M29	Evaluating the DOE formula gives a result of 12.3 kilowatt hours per gallon of gasoline, significantly less than the 33.7 kilowatt hours per gallon used by the EPA tank-to-wheels method.	**DOE Petroleum Equivalent Fuel Economy Calculation Method** Eg = gasoline-equivalent energy content of electricity = (Tg x Tt x C) Tp where: Tg = U.S. average fossil-fuel electricity generation efficiency = 0.328 Tt = U.S. average electricity transmission efficiency = 0.924 Tp = Petroleum refining and distribution efficiency = 0.830 C = kilowatt-Hours of energy per gallon of gasoline conversion factor = 33.7 kWh/gal Eg = (0.328 x 0.924 x 33.7)/0.830 = 12.3 kWh/gal
M30	To calculate the miles per gallon equivalent, the Department of Energy first divides 100 miles by the 34 kWh from the window sticker, giving 2.94 miles per kWh. This step is identical to the EPA's first step.	**DOE Calculation of Miles per Gallon Equivalent (MPGe) for Nissan Leaf** 100 miles/34 kWh = 2.94 miles/kWh
M31	Next the Department of Energy method multiplies the 2.94 miles by the12.3 kilowatt hours per gallon to get 36 miles-per-gallon equivalent.	**DOE Calculation of Miles per Gallon Equivalent (MPGe) for Nissan Leaf** 100 miles/34 kWh = 2.94 miles/kWh 2.94 miles/kWh x 12.3 kWh/gallon = 36 MPGe
M32	This is significantly lower than the EPA number for the Leaf of 99 MPGe	**EPA Calculation of Miles per Gallon Equivalent (MPGe) for Nissan Leaf** 100 miles/34 kWh = 2.94 miles/kWh 2.94 miles/kWh x 33.7 kWh/gallon = 99 MPGe

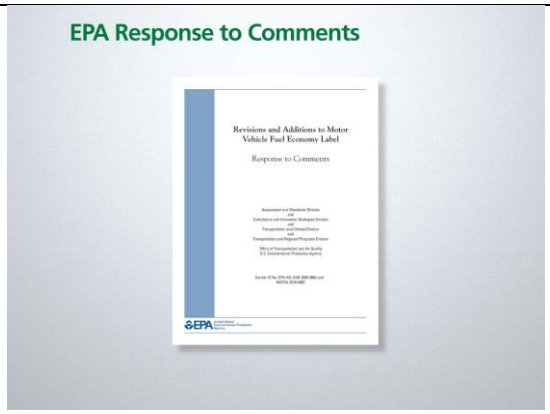
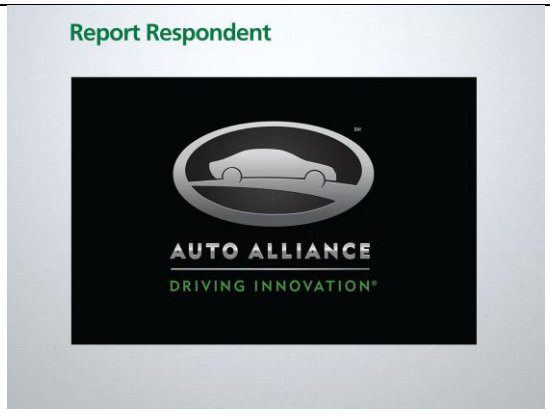
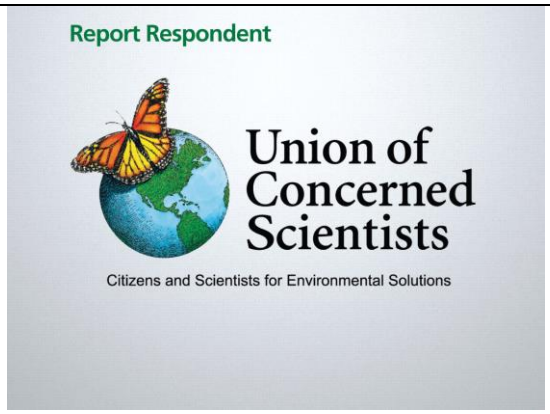
M33	The two most popular high MPG cars are the hybrid Toyota Prius and the electric Nissan Leaf. If one uses the tank to wheels method, the 2012 Leaf appears to be about twice as efficient as the Prius, or about 99 MPGe. But using well to wheels, the 2012 Leaf fuel economy is only 36 MPGe compared to the Prius 42 MPG.	
M34	The EPA has the authority from Congress to select the method used to show miles per gallon equivalent on the window sticker. It has chosen to use tank-to-wheels. Thus car window stickers do not incorporate the energy to generate and transmit electricity when giving a MPG equivalent number. This gives the consumer misleading miles-per-gallon equivalent values for electric cars, in the range of 100 miles per gallon and up. Yet these high miles-per-gallon numbers have not led to high sales volumes, possibly because consumers are confused.	

Part 3C: A Look at MPGe Metrics – The Union of Concerned Scientists Way		
M35	The Union of Concerned Scientists' calculations of MPG add in several important factors.	
M36	Some people argue that MPG equivalent depends on the fuel mix of different utilities and is too hard to calculate. Fuel mix refers to the distribution of coal, natural gas, nuclear, and renewables for a region of the country.	
M37	The mix is quite different depending on the region of the country.	
M38	The Union of Concerned Scientists addressed this important issue in a 2012 report entitled *State of Charge.*	

M39	The organization used the miles per gallon and grams of CO_2 generated per mile of a 2012 Toyota Prius, with a 50 miles-per-gallon rating, as a benchmark against which to compare the 2012 Nissan Leaf.	
M40	There are 26 different power regions in the nation, each with a different fuel mix. The Union of Concerned Scientists determined what the miles-per-gallon equivalent of a battery electric vehicle would be in each of these regions.	
M41	The *State of Charge* report divides the country into three areas – based on this Leaf to Prius comparison. The equivalent fuel economy for the Leaf ranged from 34 miles per gallon in Colorado to 115 miles per gallon in upstate New York. The average 2012 Leaf fuel economy for all 26 regions was 49 miles per gallon.	
M42	The report includes tables for each of the three regions. The region with the poorest Leaf miles-per-gallon equivalency (36 MPGe) is in the Midwest, an area of the country heavily dependent on coal.	

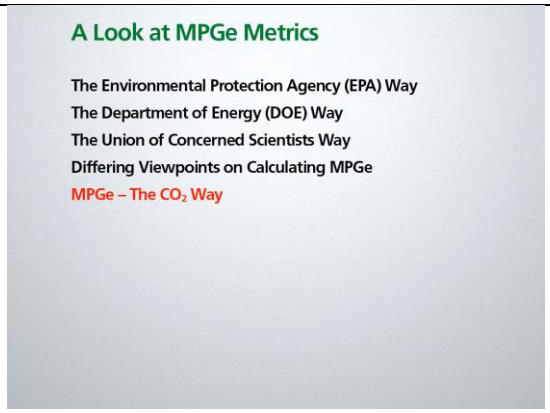
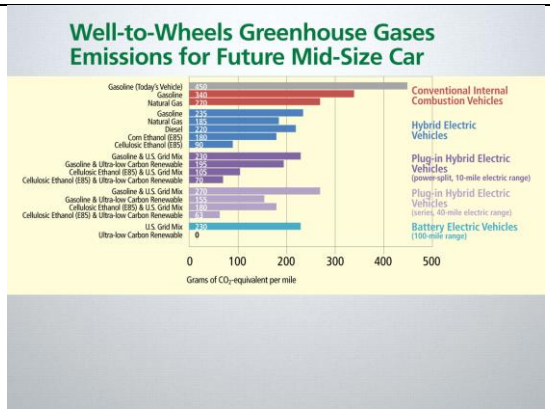
M43	In the second area, covering much of the south central portion of the country (as well as a few other areas) the Leaf fuel economy equivalent is 45 miles per gallon versus the Prius' 50 miles per gallon.	
M44	The third region includes the East and West coasts. The Leaf averages 80 miles per gallon in these parts of the county, a higher miles-per-gallon rating than the Prius.	
M45	The Union of Concerned Scientists' report includes a colored map. The light blue shows where an all-electric vehicle is more efficient than a Prius gasoline hybrid. Prius Hybrids have an advantage in the areas in medium blue. The Leaf and Prius are roughly equal in the darker blue areas. But, as noted above, overall the 2012 Prius has a slight advantage over the 2012 Leaf.	
M46	The Union of Concerned Scientists has demonstrated that it is not difficult to derive a miles-per-gallon equivalent rating for different regions of the country with different fuel mixes. The current window stickers on cars do not include that information and it should be provided.	

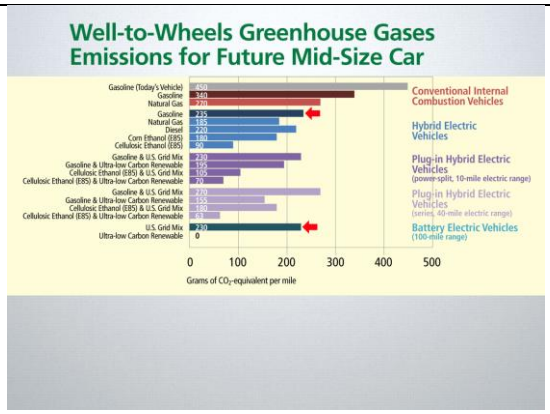
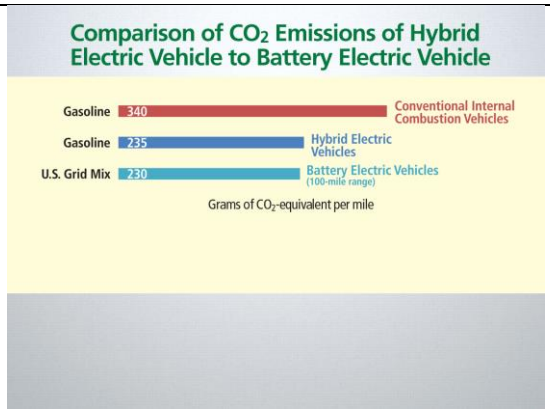
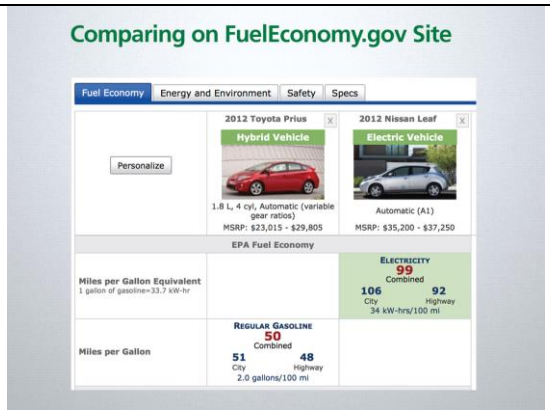
Part 3D: A Look at MPGe Metrics – Differing Viewpoints on Calculating MPGe		
M47	The debate on miles-per-gallon equivalent continued, expanding into a parallel debate on CO_2 emissions, measured in grams of CO_2 emitted per mile travelled.	**A Look at MPGe Metrics** The Environmental Protection Agency (EPA) Way The Department of Energy (DOE) Way The Union of Concerned Scientists Way Differing Viewpoints on Calculating MPGe MPGe – The CO_2 Way
M48	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.	**EPA Proposal for Measuring CO_2** 
M49	The first window sticker for the Leaf published after this meeting, was in November 2010. On this label CO_2 emissions in grams per mile were listed as zero in the lower right hand corner of the label.	**EPA Window Sticker for Nissan Leaf** 
M50	The EPA used the same logic for CO_2 analysis as it used for miles-per-gallon equivalent, which ignores the CO_2 emitted by power plants.	**EPA Window Sticker for Nissan Leaf** 

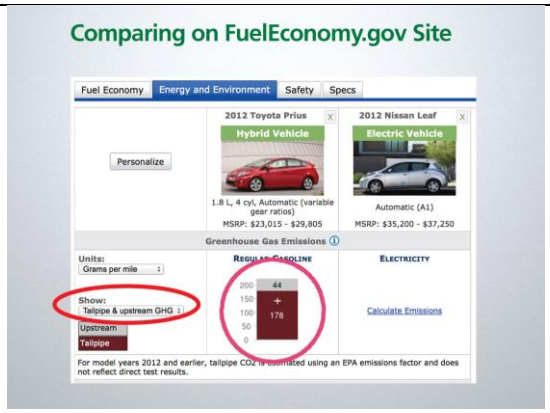
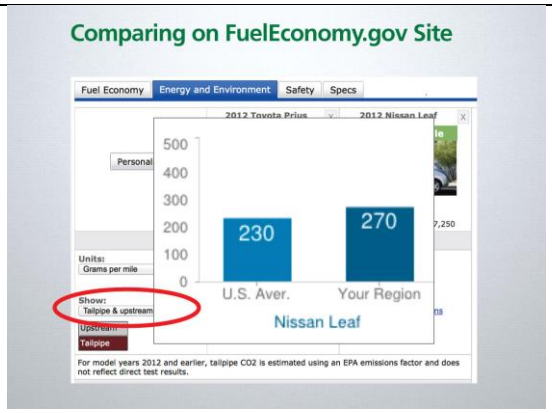
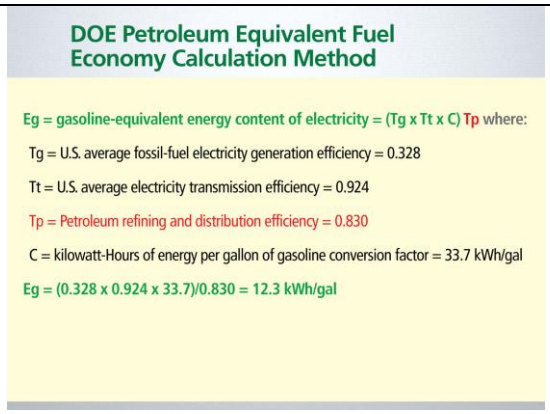
M51	In May 2011 the EPA published a 367-page response to reviewers of the September 27, 2010 document. There were many comments on the EPA proposal to ignore the emissions generated by power plants. The terminology used in this report to describe the emissions associated with electricity generation and transmission was “upstream emissions.”	
M52	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…”	
M53	Advocacy organizations for electric and plug-in hybrid vehicles generally supported leaving out upstream emissions as well, with the Electric Drive Transportation Association stating: “Attempting to include upstream emissions on the label would confuse, not inform, the consumers…”	
M54	Many reputable non-profit organizations spoke out for having the information included by the EPA. The Union of Concerned Scientists 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.”	

M55	And the American Council for an Energy Efficient Economy said: “For purposes of providing consumer information, there is no justification for mischaracterizing emissions information in this way, even temporarily. The label is not, or should not be, a means of boosting sales of a given technology, but should rather be a tool to improve understanding.”	
M56	Honda was one of the few automakers that supported including upstream emissions on the label, stating that “the Motor Vehicle Fuel Economy Label is not an appropriate place to promote incentives….and ignoring upstream emissions is similarly misleading and unhelpful.”	
M57	MIT’s Sloan On-The-Road research group stated “Furthermore, the provision of accurate information to consumers is the primary role of labels and any incentive to consumers or manufacturers should not come at the expense of this primary objective.”	
M58	The EPA decided not to account for the CO_2 from electricity generation and transmission on the window sticker but did agree to make such emission information available on the EPA website.	

M59	Very few people are aware of the controversies that surround the different methods of calculating miles-per-gallon equivalency and CO_2 emissions per mile. Or realize that in gasoline consumed or CO_2 emitted, hybrids have a distinct advantage over electric cars and the EPA is obscuring this fact by their MPGe calculations.

Part 3E: A Look at MPGe Metrics – MPGe – The CO_2 Way		
M60	It is often easier to understand the difference between electric and gasoline cars by measuring CO_2 emissions. CO_2 analysis avoids the complexity and confusion of different miles-per-gallon equivalent methods.	
M61	Argonne National Laboratory has developed a modeling system for evaluating CO_2 generation and fuel consumption for well-to-wheels analysis called GREET.	
M62	GREET stands for *"Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model".* It is used to measure and compare both fuel consumption and emissions for a variety of car types	
M63	In 2010, the organization estimated the well-to-wheels emissions for a midsize car using different power trains, including a conventional engine, a conventional hybrid, two plug-in hybrid cars, and an electric vehicle. The GREET model shows how much CO_2 each of these kinds of cars produce. The model also shows the CO_2 for different kinds of fuels, such as biofuels, hydrogen, natural gas, and diesel.	

M64	The most important comparison for this presentation is the gasoline hybrid and the electric car, shown in dark and light blue and identified by the red arrows.	
M65	This subset of the graph shows hybrid cars and battery electric cars generate about one-third less emissions than an equivalent conventional gasoline car, shown in red.	
M66	As note earlier, the Prius and the Leaf are the best representatives of these cars. The GREET approach can be verified by comparing the emissions of the 2012 version of these two cars from the EPA fuel economy website.	
M67	The EPA comparison first displays the Fuel Economy on its web site, identified by the leftmost tab at the top.	

M68	Selecting the second tab from the left displays the Energy and Environment section. Under “show” in the lower left of the menu, two options are provided. The first choice is “Tailpipe CO_2” which is the EPA terminology for tank-to-wheels. It shows that tank to wheels CO_2 emissions per mile are 178 grams for the Prius and 0 grams for the Leaf.	
M69	The second option under “show” is “Tailpipe & Upstream GHG”, the EPA term for well-to-wheels. The Prius emissions per mile increased by 44 grams to a total of 222 grams. The Leaf column includes an option to “Calculate Emissions.”	
M70	After selecting this option, the consumer enters his or her Zip code and the program provides the CO_2 emissions for their region as well as the national CO_2 average. For the 2012 Leaf the CO_2 emissions increase from 0 grams to 230 grams on average, using well to wheels, the DOE term for Tailpipe and upstream GHGs. As noted, the equivalent Prius number is 222 grams.	
M71	Earlier it was noted petroleum refining and distribution takes 17 percent of the total energy in oil. This is not accounted for in the comparison just made. Including the 17% increases the CO_2 from the Prius to about 250 grams.	

M72	When all aspects of the energy cycle are included to achieve a more accurate well to wheels analysis, the two cars are very close. There is no reason why a car's window sticker could not provide accurate well to wheels information.	**EPA/DOE MPG/MPGe & CO_2 Comparison** 2012 Prius / 2012 Leaf Tank to Wheels (EPA) MPG and MPGe: 50 / 99 CO_2 (grams/mile): 178 / 0 Well to Wheels (DOE) MPG and MPGe: 42 / 36 CO_2 (grams/mile): 250 / 230
M73	The previous discussion used the January 2013 Greet model comparing 2012 versions of the Leaf and Prius. The same comparison was made by The Union of Concerned Scientists. Both cars are constantly improving MPG with new models. Projections for future expected models show these newer cars will have similar results, with a slight advantage to the Leaf.	**EPA/DOE MPG/MPGe & CO_2 Comparison** 2016 Prius / 2016 Leaf Tank to Wheels (EPA) MPG and MPGe: 55 / 115 CO_2 (grams/mile): 161 / 0 Well to Wheels (DOE) MPG and MPGe: 46 / 42 CO_2 (grams/mile): 205 / 190
M74	There is confusion concerning miles-per-gallon equivalent for electric cars. CO_2 emissions information is more complete and accurate. It shows there is little difference between a conventional hybrid such as the Prius and a battery car such as the Leaf. Driving an electric car in regions powered mostly by coal and natural gas generates much more CO_2 than driving a Prius. But in other regions the Prius generates more CO_2 than the Leaf.	