Hybrid Cars: Leading the Charge?

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Many people see hybrid vehicles as a breakthrough invention of the 21st century to combat high gas prices and global climate change. However, the first working hybrid vehicle was designed by Ferdinand Porsche 116 years ago, in 1900, for a different reason: to reduce the noise and smell of automobiles. Porsche's hybrid never caught on, largely due to the extra cost and complexity of the system. Today, we are faced with a similar issue: Is the extra cost and complexity of hybrid vehicles offset by a worthwhile reduction in global climate change?

To address this question, we first have to define what climate change is, and what its causes are. By definition, climate change is "a change in global or regional climate patterns… and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels." As we burn fossil fuels, such as coal and gasoline, carbon dioxide gas (CO_2) is formed, and enters the atmosphere. Once there, it acts like a one way mirror, allowing energy from the sun to enter but not leave, resulting in higher overall surface temperatures on earth.

Of course, fossil fuels, and the resulting CO_2, are involved with many different areas of our economy and lifestyles. Figure 1-1 shows how different sectors of the U.S. culture contribute to national CO_2 emissions.

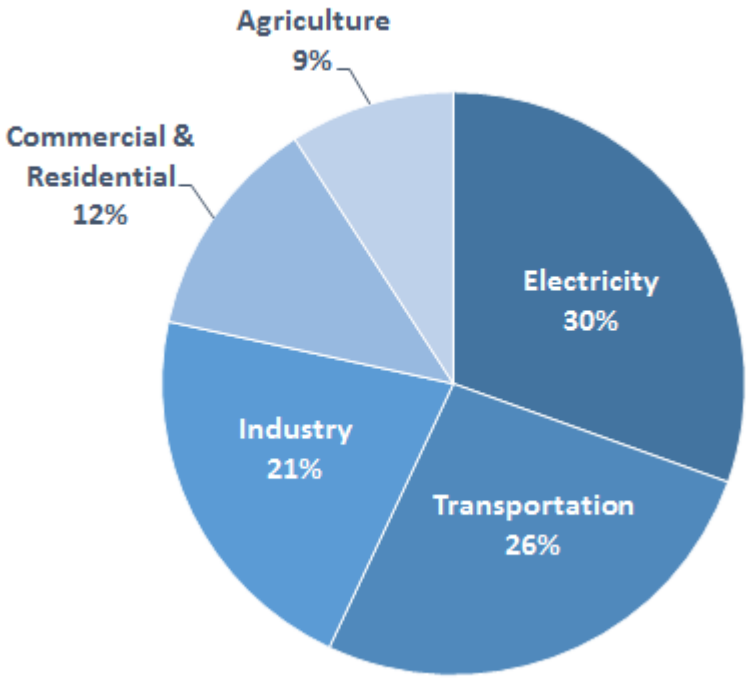


Figure 1-1

Source: "Sources of Greenhouse Gas Emissions." Industry Sector Emissions. E.P.A., n.d. Web. 29 June 2016.

To help determine if hybrid vehicles are an effective way of reducing CO_2 emissions, let's take a closer look at the figure above and gather some background on the subject.

Background

According to figure 1-1, focusing on transportation appears worthwhile, being that it is the second largest contributor (in the U.S.) of CO_2. That said, transportation consists of more than just cars; transportation encompasses many different areas, such as planes, ships, and trains. According to the Department of Transportation, of the 26% of emissions produced by transportation, about 63% is due to light cars and trucks (Transportation's Role, 2006). Combining those percentages, passenger cars work out to be just over 16% of the total CO_2 emissions in the U.S.

Looking at the number one contributor of CO_2, electricity, in the same manner, the 30% of emissions is separated into 4 main groups, as illustrated by figure 1-2 below.

Figure 1-2

CO2 emissions from U.S. electric power sector by source, 2015

Source	Million metric tons	Share of total
Coal	1,364	71%
Natural gas	530	28%
Petroleum	24	1%
Other[3]	7	<1%
Total	1, 925	

Source: "Sources of Greenhouse Gas Emissions." Industry Sector Emissions. E.P.A., n.d. Web. 29 June 2016.

Coal is by far the largest contributor of CO_2 among power plants, contributing 71% of the total emissions produced by power generation. Combining these figures, we get just over 21% total emissions caused by coal. Furthermore, according to Center for Climate and Energy Solutions, coal represents 44% of all CO_2 emissions globally, with some of the largest producers and consumers being China, India, and the United States.

While coal may be a large contributor to global CO_2 production, there are often solutions to reduce its use or emissions. The railway industry shows this kind of movement in the late 1940's. In the early 1900's coal powered steam locomotives were a common method of transporting goods, materials and people across the country. However, following the end of World War II, these steam engines were replaced by the more modern diesel-electric locomotive. These operate using a set of large electric motors powered by a diesel generator.

While this design sounds similar to many automotive hybrid systems, there are some key differences in their designs. Unlike many modern 'plug-in' hybrid vehicles, which can travel for a small distance on battery power alone, these locomotives can only move while the engine is running, as they have no battery for drive systems. Also, unlike most hybrid vehicles on the market, the engine in has no mechanical connection to the drive wheels, eliminating the parasitic drag, weight, and complexity that a conventional gearbox would create.

Compared to steam, diesel-electric locomotives are vastly more thermally efficient. According to www.International Steam.co, a modern diesel locomotive has a thermal efficiency of around 36% (par. 2). This means that for every 100 BTU of fuel is put into the engine, 36 BTU of power will be produced. Steam, on the other hand, had

efficiency ranging from a typical American locomotive of about 6%, to around 12% with the most efficient steam engines designed in the late 1940's (par. 2). Therefore, in addition to diesel's lower CO_2 production when burned, less fuel needs to be used, further reducing emissions.

Transportation is not the only area where coal has been replaced with cleaner alternatives. Coal power plants have been replaced in many areas by natural gas or nuclear power. While every power source has its own unique set of challenges and disadvantages, according to the Energy Information Association (EIA), coal-fired power plants produce about 170% more CO_2 per megawatt/hour than natural gas fired plants (Sources of Greenhouse, 2015).

While the aforementioned programs did decrease CO_2 production, programs like these are not always financially viable. Therefore, we have to determine what the largest 'bang for buck' CO_2 reduction programs are.

The Cost of Being 'Green'

While there are hundreds of ways to reduce CO_2 emissions, almost all have one thing in common: they require capital to begin working. And, while the U.S. Government does fund many projects, it cannot afford to fund all. So, in order to make the most of every dollar spent, it is important to look at the cost of each method and determine which programs will reduce the most emissions for the least amount of capital.

Hybrid vehicles, especially 'plug-in' hybrids, can reduce CO_2 emissions by reducing the work done by the gasoline engine, and in turn the amount of gasoline (or diesel) burned. By burning less fuel, the car will produce less CO_2, reducing emissions. The government supports this shift in transportation, granting up to $7,500 in tax credits to individuals who buy hybrid or electric cars. And, in 2009, it granted 2.4 billion dollars to automakers and battery manufactures involved in hybrid-electric and fully electric cars (Whitehouse.gov, 2009).

The cost of this program was a large one. For the tax rebates alone, which started in 2008, over 260,000 eligible hybrid cars were sold. Assuming the minimum tax rebate of $2,500 for each vehicle (the minimum rebate), the total cost since 2008 is .64 billion dollars. Add to that number the 2.4 billion granted in 2009, and the total cost comes out to be around 3 billion dollars.

In an independent study, it was found that the program cost $177 per ton of CO_2 reduced (Beresteanu, 2011). While there are other factors, such as reduced oil consumption, we will only focus on the reduction of emissions for the purpose of this paper. So, with $177 per ton as a benchmark, do more cost effective options exist?

Looking at the next biggest contributor to CO_2, energy production, we can see that coal fired power plants are a large part of the problem. They produce large amounts of CO_2 and are an integral part of America's, and other countries, power grid. Replacing coal power plants, however, is economically and logistically not possible for many years.

Because of this, many different concepts of CO_2 'scrubbers' have been developed to remove some of the emissions from the smokestacks of power plants. And, the process is relatively cheap. According to MIT's Energy Initiative, current carbon scrubbing systems for power plants cost about $61 per ton of CO_2 captured, with the possibility of being reduced to about $45 to $55 per ton (A New Way, par 15). Even comparing current carbon scrubbing to hybrids, the cost of capturing CO_2 is almost 1/3rd the cost.

Of course, these figures do not include the cost of implementing the system, which can be $100 to $200 million dollars (FROM 30,000 FEET, 2011). However, once installed, they can be used for the life of the power plant, which can be 40 years or more, resulting in a cost of $2.5 to $5 million a year. In comparison, NBC news says that an average car's life expectancy is around 8 years (Whats the Life, 2006). Also, the more scrubbing systems are installed, the cheaper the installation will be, as economies of scale bring the price of the equipment down.

To find at what point carbon scrubbers and hybrid vehicle funding would be equal, in terms of CO_2 reduced per year, one must first divide the capital cost (using the average of $150 million for scrubbing systems and a typical $7500 tax rebate for a hybrid car) by the average lifespan of the project (40 years and 8 years for scrubbers and hybrid cars, respectfully). Then, using the costs of $177 per ton for hybrids and $61 per ton for scrubbers, we can find an equilibrium point of about 43,095 tons of CO_2 reduced. Using data from the EPA, an average coal plant can produce around 3,435,617.88 metric tons CO2/year. Even at a 90% capture rate (the most that can be efficiently captured), each plant is still capable of reducing 3,092,056 tons of CO_2. This shows that the more efficient scrubbing approach can be well worth the investment, if used to its full potential.

While hybrid cars have a small capital investment before seeing reductions in CO_2, they are not the most efficient way to reduce CO_2. With many carbon scrubbing systems costing 1/3rd as much per ton of CO_2 removed, the added capital of installing them quickly is eliminated once we start removing CO_2 on a large scale. And, with many coal plants still producing high levels of emissions, we must also ask ourselves if America is truly ready for hybrid and electric cars.

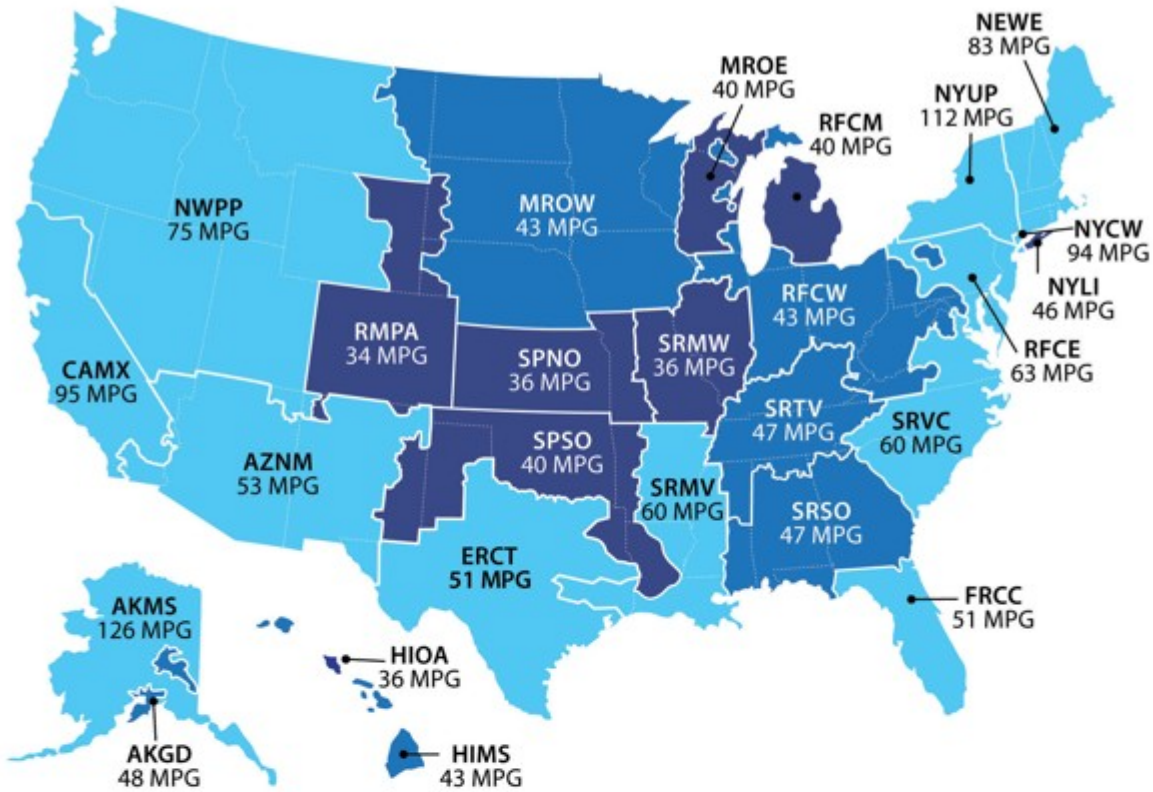
Is the time right?

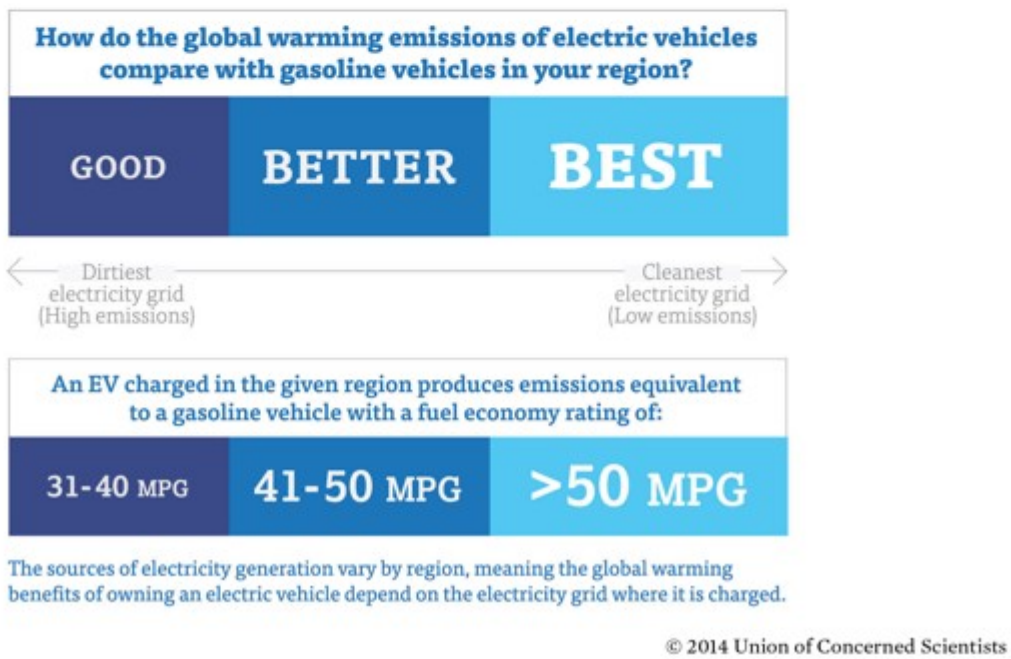
Many people see hybrid and electric cars as a foolproof way to reduce emissions, and at first glance, it would appear so. Electric motors and generators can regenerate power from braking, and reduce or eliminate the need to run a gasoline engine. But, best of all, they can be plugged into an owners wall and be run on clean, non-polluting electricity. Or is it? In order to fully understand a hybrid or electric car's carbon footprint, we must look at where this power source comes from.

While electricity seems like a clean and efficient way to run a car, this isn't always the case. While it is true that power can be generated by renewable sources such as wind and solar, the truth is that currently only about 13% of our power comes from these sources (How Much U.S. Energy, 2016). In the Midwest especially, coal powers the majority of the electric grid. And, if an electric vehicle is plugged into a largely coal powered grid, it effectively becomes a coal powered car!

To get a better understanding of this concept, the figure 1-3 shows the emissions of a fully electric vehicle, adjusted to account for pollution from the energy source. As you can see, vehicles on the west coast do well, averaging the equivalent emissions of a 95mpg car. However, in the Midwest, that number can drop to an unimpressive 34mpg.

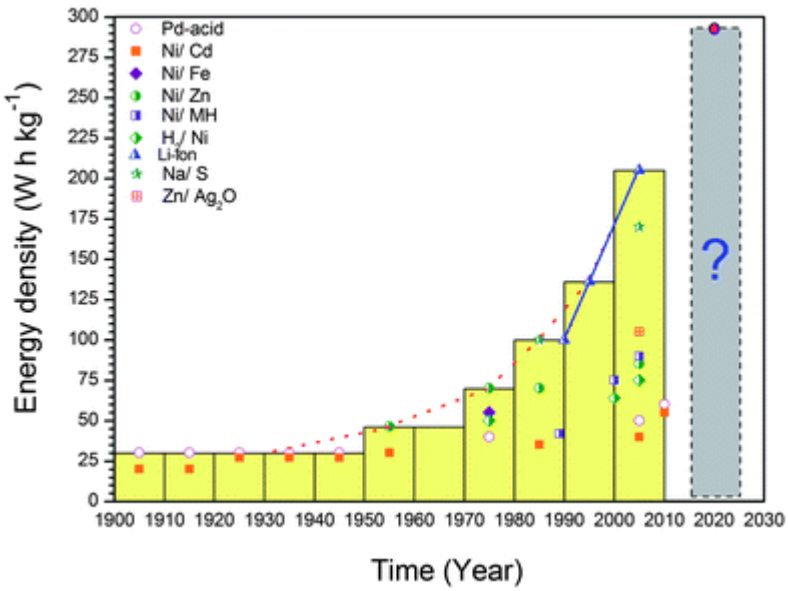
ource: "4 Key Problems With the Idea That Electric Vehicles Can Pollute More Than Gas Cars." CityLab. The Atlantic Monthly Group, 10 July 2015. Web. 30 June 2016.





Looking at this, there is a question that stands to reason: does it make sense to fund electric and hybrid cars if the grid they are dependent on is still dirty? In some parts of the country it may be worth it, but for others, the money would be better spent on improving the grid.

Also, by waiting for the electric grid to improve, it also buys time for battery technology production and capacity to improve. Looking at the history of the battery energy density (below in figure 1-4), we can see that batteries have become more energy dense, and therefore more effective for cars due to their smaller size, over the last 100 years.



Source: Zu, Chen-Xi, and Hong Li. "Thermodynamic Analysis on Energy Densities of Batteries." Energy & Environmental Science Energy Environ. Sci. 4.8 (2011): 2614. Web. 30 June 2016.

Looking at this timeline, it is easy to imagine that battery technology could vastly improve in the next few years. If so, cars would be able to use a smaller battery, which would allow the cars to be physically smaller and lighter, further reducing their net carbon footprint. Despite all of this, smaller batteries won't answer the all-important question about hybrid cars: Do they really make sense?

Hybrid Cars: Does the Design Make Sense?

As Elon Musk, the founder of Paypal, Tesla Motors, and Spacex said about the 2010 Toyota Prius, “A Prius is not a true hybrid, really. The current Prius is, like, 2 percent electric. It's a gasoline car with slightly better mileage.” While Musk was comparing the Prius to his all-electric Tesla cars, he still may have a point. In saying this, he is almost begging the question: As long as we are limiting ourselves to gasoline, how far can hybrid systems take us?

First, let’s look at how hybrid vehicles are designed. For many, a standard gas powered platform is taken, and a battery, motor, controller, and other components are added. By doing this, it seems fairly obvious that the weight of the car will increase. As evidence by the Ford Fusion Hybrid, this is indeed true. A standard Ford Fusion weighs in with a curb weight of 3285lbs, while the Ford Fusion Hybrid has a curb weight of 3720lbs, a difference of 435lbs. This negates some of the benefit of having a hybrid car, as the fuel mileage, whether gasoline or electricity, is reduced following Newton’s second law: Force= Mass x Acceleration. If a car has a larger weight (which is directly proportional to mass), in order to maintain the same acceleration, the car will require a larger force from the engine.

This fact leads us to another question: Is there any reason to have two drive systems in a car? Redundant systems are common on equipment that is put into service in severe conditions, such as spacecraft and military vehicles. However, for a car that rarely leaves our paved streets, there is little reason to have redundant propulsion systems. The car industry has built, and continues to build, cars with a single drive system for over a hundred years, suggesting the demand for hybrid cars is not the redundant drive systems.

Many will argue that the main reason to buy a hybrid car is the superior gas mileage that they can obtain, and they have a point. The current Toyota Prius can obtain up to 54 mpg hwy, a very impressive figure. However, in Europe, which has different diesel emission standards, some small diesel cars, such as the Ford Fiesta 1.8 diesel, can obtain 63 mpg.

Burning diesel does produce about 12% more co2, according to the EIA (How Much Carbon Dioxide, 2016), and it even the high mpg Fiesta can’t combat that issue. The Prius has a CO_2 rating of 70g per km (2016 Toyota Prius, 2015), while the Fiesta has about 120g per km. Both numbers are great, but the Prius does have a CO_2 advantage.

The smaller fuel consumption of the diesel Fiesta offers an interesting perk, however. By using less fuel, it requires less oil to be extracted from the ground, refined, and shipped to nearby fuel stations, all of which requires large amounts of energy. And, as we hear often in the news, America is highly dependent on oil from other nations, particularly nations in the war-plagued Middle East. By driving cars with high MPG numbers, we can not only reduce the cost of operation, but reduce indirect energy costs

(of moving and creating the fuel), and also reduce our nation's dependence on oil from foreign countries. If America allowed automakers to import cars from Europe and other nations, consumers would have access to many more efficient and inexpensive cars.

All in all, hybrid vehicles do work well, and can offer impressively low emissions. However, in terms of MPG, hybrid vehicles can, and have, been beaten. So, hybrid vehicles are an effective way of reducing CO_2, especially if a fully electric vehicle does not fit a person's lifestyle. And, while having two drive systems may be redundant, the added weight and complexity appears to pay off in CO_2 emissions.

Closing

So, after looking at all the facts, we must ask the question again: do hybrids make financial sense in today's world? By gathering up the findings from the cost, infrastructure, and design of hybrid cars, we can make an informed decision.

First, as discussed earlier in this paper, the cost of reducing CO_2 with hybrid cars is pound for pound, not as effective as other methods. Of course, the capital costs are lower, but on a large scale, they do not make financial sense.

Second, hybrid cars are limited in their cleanliness by the electric grid they run off. As long as America's numerous coal power plants run without effective carbon scrubbers or are replaced, hybrid and electric cars cannot operate at their full potential. And, by focusing on the electric grid instead of hybrid cars, there is a good possibility that battery technology will greatly improve.

Lastly, hybrid cars do not necessarily get the best mileage. While they do produce less emissions than most cars, small diesel cars return tremendous mileage, albit with around 20% more CO_2 emissions. A 20% reduction in CO_2 is good, but not good enough to justify the additional cost and complexity of a hybrid system.

Even though hybrid vehicles can be effective at reducing greenhouse gas emissions, they currently do not make sense to fund because of the above ideas. Instead, the government and citizens should invest money that would go towards hybrid cars into cleaning up our energy grid via carbon scrubbers and other carbon capturing technology.

In order to accomplish this, many things need to happen. First, the government needs to stop incentivizing hybrid cars, and instead focus that money on the energy grid. By doing this, the important CO reducing equipment can be installed faster on power plants.

Second, we need to embrace cars that are built in Europe and other parts of the world, and allow them to be sold and driven in the United States. By doing this, families can buy efficient and affordable diesel cars, helping to reduce our nation's oil demand. By embracing these affordable cars, more units will be sold, and there will be a large reduction in CO_2 and oil use as a nation.

Furthermore, nations should collaborate and create a system of international crash test and emission standards. By allowing automakers to quickly adapt a vehicle sold in one nation to be marketed in another, more time and money could be dedicated to development of cars, benefiting not only efficiency and emissions, but also overall quality and durability.

Third, citizens should be prepared to pay a little more for electricity. While the power companies can be expected to share a large part of the cost of implementing scrubber systems, they cannot be expected to sustain losses because of them. Thus, power companies will pass on the costs associated with running these systems onto the consumers.

Finally, once the electric grid is operating with relative cleanliness, we can begin to embrace electric and hybrid cars once again, as they will be far more effective at reducing emissions. Also, by this time technology should have advanced, allowing us to build better, more efficient, and cheaper electric cars than ever before.

Of course, it seems difficult for a typical citizen to start or help this movement. And, while the change seems daunting, it starts with small steps. So, what can we do?

To start, we can write our local and national political representatives, and make sure they are aware of the issues with hybrid cars. As always, if the issue is not known, it cannot be solved.

We can also begin buying efficient diesel and gasoline powered cars that are not equipped with a hybrid system. By showing automakers that there is a market for these cars, more development will go into this sector, and manufacturers will be motivated to create more efficient vehicles because of the larger market.

Perhaps most importantly, thought, is that the facts about hybrid vehicles need to be made public knowledge. While some aspects have been briefly brought to light, the whole story has not been presented to the American, or global, public. We need to spread to word, by social media, news broadcasts, or word of mouth, that hybrid's aren't all they are advertised to be.

And, perhaps automakers know this. When the first hybrid car was built by Ferdinand Porsche, the car didn't catch on. While this may be for many reasons, the most likely is that most consumers realized that the invention was not worth the added cost and complexity. Interestingly though, the car, and its marketing failure, seem to be

all but forgotten about. If people in the early 1900's came to the conclusion hybrid cars were unnecessary, why do we see them as necessary now? And, why are the early hybrid cars never talked about?

One of the most likely reasons may be that our societies have changed in the past 100 years, and it is now seen as somewhat fashionable to drive efficient, 'green' cars. With automakers advertising hybrid cars as the clean answer to transportation, it is easy to see how this perception could catch on. Keeping the early hybrid cars history in the past is also a part of this marketing plan, helping to keep people from wondering if the cars are really benefiting the environment.

Whatever the reasons may be, the fact of the matter is that we have to come up with new ways to capture CO_2, and to keep refining the technology we have today. This includes refining gasoline and diesel cars, the nation's power grid, and electric and other renewable modes of transportation.

While this plan does not offer the instant gratification of driving a hybrid car, it is ultimately a more efficient way to deal with our increasing CO_2 issue. By doing this, it will help to produce cleaner air, not only for Americans, but people of all nations, and help them to live heathy, productive, and fulfilling lives.

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