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The Silver Bullet Syndrome and the Future of Energy Alternatives

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Americans love their cars. There are over 250 million vehicles on American roads today,[1] which translate to nearly one vehicle for every person in America. Those vehicles travel over three billion miles per year,2 making America one of the most vehicle-dependent nation on earth. Americans use more gasoline for their cars than the next twenty largest gasoline-consuming countries *combined*.[3] Though the price of gasoline has risen nearly threefold in the past three years, Americans have nevertheless increased the total miles driven per year.

But that love affair has begun to haunt us. Shifting international politics, U.S. national security issues, pollution, and, more recently, the global environment, have brought many scientists and policy makers to rethink the United States' great dependence on fossil fuels. The search for a solution has researchers, scientists, and politicians scrambling for the 'silver bullet'—the technology that will make it possible for America to remain addicted to its voracious appetite for driving automobiles without worrying about the immense cost that addiction presents to the environment. Although many hope that new technologies and alternative energies now being explored will allow the current paradigm to continue, the reality is multi-layered and complex. What is necessary is to challenge the car-obsessed paradigm, rethink political priorities, and both embrace and question scientific progress. There must also be an acknowledgment of both short and long-term solutions to environmental problems created by our car-obsessed society.

This article explores the debate over various alternatives to the fossil-fuel based automotive paradigm. I begin by discussing why the debate is now occurring: a combination of global environmental changes, the rising cost of fossil-fuel production, and concern over dependence on insecure sources of fossil fuels. I then discuss various fossil-fuel alternatives that have been proposed to modify or completely abandon the fossil-fuel paradigm. I suggest that most of the existing immediate alternatives are stop-gap measures motivated more by political expediency than genuine change. There are other existing alternatives that would go a long way toward solving our fossil-fuel based economy. These alternatives are not as widely embraced by the Amer-

ican public or government officials because they require more significant changes in thinking and lifestyle.

There is a 100-year long history to America's love affair with automobiles. Politics, economics, geography, and simple passion all contributed to the growing vehicle adoration. Ford's Model T made it possible for an expanding and increasingly wealthy American public to buy a vehicle after World War I. The immediate post-WWII era combined suburban sprawl, a rapidly expanding interstate road system, cheap oil from both domestic and international sources, and a strong belief in progress and technology. The result was a dramatic increase in automobiles and miles driven. For most the automobile was seen as one of the cornerstones to progress in America, the very epitome of freedom, mobility, and self-expression.

Love for the personal automobile was tempered beginning in the 1970s as the political ramifications of this increasing addiction began to become clear. The initial shock was the Oil and Petroleum Exporting Countries (OPEC) oil embargo against the United States in 1973. Many OPEC countries were outraged over U.S. support of Israel in the 1973 Yom Kipper war. They expressed their opposition through holding back oil production, the one commodity they controlled and on which the United States had grown increasingly dependant. Virtually overnight American drivers were faced with the reality of gasoline rationing and quadrupled oil prices. This supply-side shortage, deliberately caused by OPEC, resulted in the first significant challenge to American political and economic hegemony by developing countries. Oil was clearly seen as a political tool that could wield significant leverage in international politics.

Though it was clearly the case, most Americans had not considered the political connections of oil and international affairs in the twentieth century. Yet significant international events from the 1930s on were increasingly related to the guarantee for access to oil. Japan's attack on Pearl Harbor was related to its concern over being denied necessary oil supplies for its growing empire. In July 1941 the U.S. enacted an oil embargo against Japan, following its takeover of Indochina. Japan, desperate for guaranteed oil supplies, attacked the United States in Hawaii in December and immediately proceeded to march south to take over the Indonesian archipelago, source of great supplies of oil and other fossil fuels necessary to keep Japan's military machine running.[4] Hitler's obsession with oil self-sufficiency led him to commit to an enormous government-sanctioned synthetic fuels program to create liquid fuel from coal.[5]

In the post-WWII era, President Franklin Roosevelt, aware that the United States would be increasingly dependant on foreign sources of oil, worked closely with Great Britain on an agreement to secure access to Saudi Arabian oil.[6] Other conservative oil-rich monarchies in the Middle East were courted through the 1950s and 1960s. The U.S. helped bring back to power and then militarily supported the Shah of Iran through the 1950s, 60s and 70s, in part because of Iran's large oil fields.[7] The U.S. support of the overthrow of the Sukarno regime in Indonesia in favor of a less radical Suharto was prompted in part because of the possibility of guaranteed oil supplies.

Six years after OPEC's 1973 oil-embargo strategy made the oil-producing states leaders on the global political stage, the Shah of Iran was overthrown and was replaced by a stridently anti-American Ayatollah Khomeni. Oil prices again skyrocketed, reaching heights that would not be seen again until 2007. This time the markets panicked because of political turmoil in a major oil-producing country. No matter the cause, it seemed to be increasingly clear by the early 1980s that the politics of oil could easily disrupt America's economic stability. The late 1980s, however, seemed to put these fears to rest. Oil prices rapidly fell to historic lows, OPEC lost its strength, and the United States found ways to influence OPEC's policies. Rather than plan for future disruptions, Americans were lulled into the belief that cheap oil was here to stay.

The collapse of the Soviet Union and the consequent easing of tensions between East and West seemed to guarantee that cheap oil would be possible. New technologies augured for optimism as the "end of oil" was clearly nowhere in sight. But political cloud increasingly darkened while America largely slept. Iraq's invasion of Kuwait in 1990 again revealed the instability in Middle Eastern politics. The rise of political Islam and increasing numbers of acts of terror against Saudi oil installations brought additional questions of stability to the minds of oil analysts. Events surrounding September 11, 2001, and its aftermath, especially the U.S. invasion of Iraq, brought new questions. The fact that eleven of the fifteen suicide bombers were from Saudi Arabia raised many questions about the long-term stability of the house of Saud.

While the Middle East continued to be a cauldron of political instability, few analysts noticed that a demand-side threat to adequate oil supplies was emerging. The rise of China, and then India, in the late 1990s and the first decade of the twenty-first century caused a renewed concern over whether the United States would have access to all the oil it needed in its existing

paradigm. China's thirst for oil seems unquenchable and unstoppable. The rise of oil prices, especially on the future's market, seems directly linked to the expectation that China, and soon India, will be the major competitors to the United States for oil. China's willingness to deal with governments the United States disfavors, including Sudan, Iran, and Venezuela, make the United States seem even more vulnerable to the international oil market.

Also largely unheeded in the 1980s and 1990s was America's growing dependence on foreign oil. Between the first oil crisis in 1973 and 2005, U.S. dependence on foreign oil has risen from 25 percent to over 60 percent. Fueled largely by increased demand for oil over the past three decades, the U.S. has got itself into an increasingly untenable position of foreign energy dependency from which there is no quick solution. While 30 percent of this foreign oil is from our closest neighbors, Canada to the north and Mexico to the south, fully 50 percent of the foreign oil is from countries whose governments are considered unstable or hostile to the United States.[8]

The combined influence of each of these international events and growing oil dependency in the past decade have brought together seemingly disparate politicians and lobby groups in Washington. Conservatives like former National Security Adviser to President Reagan Robert C. McFarlane have been openly critical of U.S. energy security policy and have called on the need to seriously rethink the U.S. policy on foreign oil dependence. For McFarlane, "America cannot depend upon a finite supply of hydrocarbons located in unstable regions of the world for its energy needs. And without energy, economies collapse."[9] For more liberal-leaning groups energy security implies less need for U.S. military intervention overseas. Both sides of the political spectrum have coalesced on the need to move past accusatory language and have joined forces to argue for a serious move toward energy security.[10]

In the background of this debate is the growing acknowledgment that the world's oil days are limited. As a finite resource, there will be a day when the earth no longer gives up its oil; or, at least oil that is accessible for a reasonable price. That "someday," according to some scientists, is not too far in the future. The physicist M. King Hubbert rightly predicted in 1958 that the United States would peak in oil production in the early 1970s. Using his scientific methodology other geologists have calculated that the world's oil production is very close to peaking, or has recently done so.[11] Skeptics of this idea point to the fact the proven oil reserves have increased over the past thirty years and are now at 1.3 trillion barrels.[12] Regardless of who is

correct, the fact remains that oil is a finite resource, and that America's own oil stocks are rapidly in decline, forcing it to rely increasingly on foreign sources. While some argue that increased oil extraction from Alaska's Arctic National Wildlife Reserve or from oil trapped in shale could help increase U.S. oil supplies, the cost, in both environmental and economic terms, do not make these alternatives attractive.

The other leading argument fueling the desire to move seriously toward alternative energy in transportation is the growing evidence of climate change. This more recent concern comes on the heels of decades of concern over the long-term environmental effects of burning fossil fuels for transport. Initially, the major concern was over the negative human health effects of pollution. In the 1960' tetraethyl lead was found to cause birth deformities and slowed brain development in young children. Automotive hydrocarbons were found responsible for increasing levels of smog in urban areas, and for being toxic to humans. Nitrogen oxides were found to cause acid rain and contribute to increased urban smog levels. Particulate matter from diesel exhaust was found responsible for high levels of asthma in children. Beginning in California in 1963, car manufactures have been forced, most often with great reluctance, to add pollution control equipment to their vehicles in an effort to stem the rising environmental toll on humans. The switch to unleaded gasoline, ultra-low sulfur diesel, catalytic converters, and sophisticated electronic equipment were all part of the attempt to control pollution levels from automobiles and trucks. New automobiles, while many times cleaner than ones built even a decade ago, continue to pose great threats to the environment in part due to the great numbers of vehicles and the high number of miles driven by Americans each year.

More recently, however, concern over automobiles' contribution to airborne pollution has shifted to carbon dioxide emissions. Though carbon dioxide is not a pollutant in itself, the spewing out of billions of additional tons of carbon dioxide by automobiles is being increasingly recognized as a major contributor to global warming. This has not always been accepted. The debate over anthropogenic contributions to twentieth century changes in the earth's atmosphere was "heated" for much of the 1990s and well into the present decade in the United States. Well- funded policy groups with links to automobile and energy companies kept congressional action on climate change to a minimum. A skeptical Republican Congress and President George W. Bush steadfastly refused to acknowledge the reality of global warming until very recently. Oklahoma Republican Daniel Inhofe, chair of

the Senate Committee on Environment and Public Works while Republicans controlled the Senate through the 1990s, stacked Committee hearings with witnesses who were part of a dwindling minority of scientists who disagreed with the prevailing scientific consensus on human contribution to global warming.[13]

A combination of factors has focused American public opinion and congressional interest on global warming. Hurricane Katrina and a series of other unprecedented natural disasters, including record heat waves and droughts throughout the United States and the world, demonstrated both the possible consequences and human and economic ramifications of global warming. Former Vice President Al Gore's documentary *An Inconvenient Truth* made accessible the science of global warming to millions of Americans. In two leading scientific reports, the British Stern Commission on the Environment and the United Nations Intergovernmental Panel on Climate Change both argued vociferously for the reality of global climate change and the pressing need to act quickly and comprehensively to avoid even greater future catastrophes.

The changing landscape of the debate over global warming has made vehicle carbon dioxide emissions an increasingly contentious issue in the United States. In response to these concerns California legislators passed a bill, which Governor Schwarzenegger signed, that required the state to decrease carbon dioxide emissions to 1990 levels by the year 2020, including mandatory emissions caps on significant emitters of carbon dioxide beginning in 2012.[14] Since carbon dioxide emissions are largely a by-product of fuel efficiency, several automobile companies took California to federal court claiming that the state did not have the authority to set fuel efficiency standards. In recent judgments federal judges threw out the automotive industry's lawsuit, as well as a similar lawsuit filed in Vermont. In both cases the judges recognized the close connection between carbon dioxide emissions and the negative and potentially serious environmental effects of global warming.[15] The subsequent challenge of state's emissions laws by the United States Environmental Protection Agency in favor of its own more cautious approach caused a fury of protest by the states filing for swift and comprehensive U.S. action. Public consensus for serious U.S. federal government action to combat human contribution to climate change has never been greater.

The combined effect of national security, environmental, and global warming concerns have produced a quantum leap in efforts to find and promote energy alternatives. Not since the energy crisis in 1973 has there been as

much publicity about the need to find realistic alternatives to fossil fuels for transportation uses. President Bush, long seen as a close friend of "big oil" and of Middle Eastern sheiks, was a holdout over a significant shift in energy policy. The shift in policy was reflected in Bush's 2006 State of the Union address when he acknowledged that America was "addicted to oil, which is often imported from unstable parts of the world," and went on to proclaim that "the best way to break this addiction is through technology."[16]

President Bush is a late convert to the need for promoting alternative fuel sources, specifically ones that would both reduce the U.S. dependence on oil from unstable regions and help reduce U.S. contribution to global warming. Fortunately, research and innovation over the past several decades have brought new energy technologies to the market. The major alternative energy technologies for passenger vehicle transport in the United States include ethanol, bio-diesel, variations of gasoline-electric hybrids, and hydrogen-powered fuel-cell automobiles.

In addition, there has been increased awareness of the role government can play in promoting energy efficiency and improving fuel economy standards. Following the 1973 energy crisis Congress began to set corporate average fuel economy (CAFE) standards for all major U.S. automobile sellers. The politics of CAFE and the way in which the American government encourages (or does not encourage) car manufactures to increase fuel efficiency is again a topic of much discussion.

The remainder of this article discusses the science and the politics of each of the alternative fuels mentioned above in relation to the two primary goals: reduced dependency on foreign energy sources, and a positive impact on the environment, especially in relation to global warming. I will also explore the role that the federal government plays in the process of promoting alternatives, and in promoting these two primary goals.

Ethanol

Ethanol is making a comeback. Touted in the mid 1970s as the key to breaking the dependency on foreign oil, ethanol lost its shine in the early 1980s. Oil prices came down and ethanol was no longer an attractive alternative to fossil-fuel based gasoline when the cost to produce a gallon was significantly more than gasoline. But increased volatility in the oil markets, concerns over securing a reliable fuel supply, the high price of oil, and concerns over global warming have all triggered interest in ethanol. In the Unit-

ed States this has meant increased corn production, the primary crop used to produce ethyl alcohol, a form of ethanol. For supporters of ethanol, the rapid increase in ethanol production makes sense for several reasons. First, the cost difference between regular gasoline made from fossil fuels and that made from ethanol is decreasing, making it a more cost-effective proposition. While formerly, high subsidies were required for ethanol producers to make a profit, with gasoline prices over $3 a gallon it is no longer theoretically necessary to have ethanol subsidized. Second, millions of vehicles already operating in the United States are capable of using 85 percent ethanol ("E85"), so no major engine conversion is necessary to enable ethanol to substantially increase in use. If ethanol is someday required to be used by all vehicles the cost necessary to convert cars to run on ethanol is only a few hundred dollars. Third, the widespread use of ethanol could potentially mean far less dependence on foreign sources of oil. Proponents look to Brazil, a country that has, in the space of two decades, become completely self-sufficient in energy production largely because of large-scale conversion to ethanol as an automotive fuel source. Five million automobiles in America today, and millions more in the near future, could potentially run on ethanol. Fourth, the carbon dioxide produced by ethanol was trapped in corn several months or years ago, not millions of years ago, which means that the carbon dioxide emissions from ethanol do not contribute to global warming. Widespread use of ethanol, proponents argue, could go a great way towards decreasing the transportation sector's portion of global warming.

There are many skeptics of the United States' approach to ethanol as a fuel substitute to oil, however. They dispute many of the core arguments for ethanol as the bio-fuel of choice, and see large agri-business concerns like Archer Daniel Midland as key to the real reason why ethanol is now being promoted in the United States Congress. The short-term effect of the rapid increase in ethanol production has been a great increase in the cost of corn-based products both in the United States and abroad. With fuel competing with food, the price of corn doubled in 2006.[17] For Americans this price rise was reflected in a great number of foods, since corn and corn-based products appear in a great variety of products. For people who rely on corn as a staple, the dramatic price increase was sometimes catastrophic. Peasants in Mexico who could not grow their own corn were faced with a 40 percent price increase for tortillas.[18] While farmers, both in Mexico and the United States, benefitted from the higher prices, those impacted were often on the lower end of the socio-economic ladder. Further, critics of ethanol fuel production

raised the ethical question of whether growing a crop for fuel while people were starving was morally acceptable. Even if ethanol were financially viable, it can be argued that corn-based ethanol production has a dubious quality about it because of the questions it raises.

Other ethanol skeptics questioned whether, even with oil at $90/barrel, it was possible for ethanol to compete with fossil fuels without large government subsides. The reality is that corn farmers continue to receive billions of dollars in subsidies in order to grow their crops. Since many of the "farmers" are in reality large agri-business ventures, ethanol critics argue that the group that is really benefitting from corn-based ethanol are large agri-businesses like Archers Daniel Midland and Cargill.

A third argument critics have raised against corn-based ethanol is its supposed value in fighting global warming. While it is true that burning ethanol does not produced any global-warming CO^2s, the total energy required to produce a gallon of ethanol is estimated to have, at best, no negative impact on harmful CO^2 levels, and may actually contribute to carbon-based emissions. This is due to the considerable amount of energy involved in the growing and harvesting of corn, as well as the actual conversion of corn to ethanol. Additionally, corn-based ethanol produces significantly lower amounts of energy than Brazil's sugarcane-based ethanol, and even less than fossil-fuel based gasoline. The result is that fuel consumption suffers when using ethanol, which means that significantly more ethanol must be produced to power a vehicle for the same distance than if the vehicle were burning gasoline.

Combined with this concern is the question of just how much land is necessary to produce the ethanol required to make the United States independent of foreign sources of oil for transport. Ethanol energy output, as measured in British thermal units (BTU's) is only 65 percent of that of gasoline. In part because of this relatively low energy value, and because of the vast amounts of energy necessary to raise corn and turn it into ethanol, over 300,000,000 acres of land would be required to replace our current gasoline usage with ethanol, or virtually the entire U.S. cropland.[19] If this were actually done, the resulting price shifts would create havoc on national and international food prices, leading to exactly the opposite kind of result the switch to ethanol would be designed to engender in the first place, that of increased national economic stability.

Proponents of ethanol continue to gain ground against their detractors, however. Congress approved $7 billion in corn subsidies to farmers,[20] in

large part because of pressure on Congress to begin to create alternative fuels. Billions of dollars of research funds are being made available for research on improving the energy efficiency of ethanol, and on the conversion process. Many of these research dollars are being pored into the development of cellulosic ethanol. Cellulosic processes converts agricultural waste products like corn stalks and grasses like switchgrass into ethanol. This bypasses the food or fuel argument, and creates a much more sustainable production that is not as energy or water intensive as present-day corn to ethanol production. Significant hurdles exist, however, to making ethanol from agriculture waste, and the most optimistic scenario is that "cellulosic ethanol" production is several years away. In the meantime corn-based ethanol is largely a stop-gap measure that ultimately does not create a viable long-term solution to either reducing dependency on foreign sources of oil or help solving the problem of increased vehicular CO^2 emissions.

Biodiesel

In some respects biodiesel is promoted for similar reasons as ethanol—a bio-fuel that promises to reduce America's dependence on oil while reducing global warming. There are some differences in the production of bio-diesel, however, that warrant it separate treatment as an alternative fuel. Bio-diesel can be made from a variety of agricultural products: from soybeans, canola and peanuts, to more "exotic" products like India's jatropha plant, or algae. Unlike ethanol, which uses a distillation process to create ethyl alcohol, biodiesel is created through a transesterification process that converts plant oils into fuel. In many respects the conversion process is simpler than corn to ethanol, and the energy produced from bio-diesel as measured in BTU's virtually matches that of regular diesel. Since diesel engines are approximately 40 percent more efficient than their gasoline counterparts, bio-diesel proponents see the possibility of a greatly increased bio-diesel output also resulting in greatly increased vehicle efficiency. Indeed, in many European countries where diesel engines power 60 percent or more of the vehicles, mileage averages surpass that of the United States by 30 percent or more. In addition, vehicles that currently run on diesel generally need no special modifications to run on bio-diesel. Automobile manufactures such as Volkswagen and Mercedes are beginning to warranty their engines that run a small percentage of biodiesel, and many individuals claim that running their vehicles on 50 percent or more bio-diesel has no ill effects, save a fuel filter that needs to be replaced soon after bio-diesel is introduced because the al-

ternative fuel tends to "clean out" the debris left by regular diesel. Bio-diesel can also be produced using waste vegetable oil, converting what was often relegated to being thrown out into a fuel to power vehicles.

As in the case of ethanol, skeptics of bio-diesel point to a host of issues that make the large-scale conversion of America's vehicles virtually impossible. The first issue is the possibility of widespread bio-diesel use. Since virtually all of American automobiles are currently powered by gasoline, the potential for switching to bio-diesel is, at best, a several decades long proposition. The only immediate widespread bio-diesel conversion possible would be the trucking industry. Secondly, the production of soybeans, canola, or palm oil would need to increase exponentially if America was to begin to wean itself off of oil. As in the case of ethanol there is simply not enough arable land to grow the soybeans, canola, or other crops that can be used to create biodiesel. Europe, much more committed to both diesel and bio-diesel for transport, has greatly increased its importation of soybeans and palm oils. Because land area for bio-fuel crops is limited in Europe, energy companies have turned to importing oils from tropical countries where sufficient production can occur.

Environmentalists, however, point to the huge negative impact that large-scale soybean and palm oil production is having in the tropics. Studies conducted in Malaysia and Indonesia have shown that increased production of palm oil plantations could result in the destruction of millions of additional acres of tropical rain forest.[21] Ironically, the argument that the move to increased use of biodiesel will help reduce global warming is, according to the critics, completely fictitious, as the trees being removed for increased bio-fuel production results in significant decrease in the capacity for carbon-dioxide capture.

Bio-diesel proponents hope that alternative plants to soybean and corn may point to solutions to some of these problems. The "miracle" plant jatropha, found mainly in India, is seen as one of these. Jatropha grows in near-desert conditions and is not edible, ending the food-or-fuel debate. It is a robust plant, needing nearly no water or maintenance, yet produces significant amounts of oil two or three times yearly for 20 to 30 years. Other bio-fuels experts point to the potential of algae, some types of which produce 30,000 gallons of oil per acre,[22] ten times as much oil as ethanol produced on an acre of corn and with far less inputs.

Hybrid, Plug-in Hybrid, and Electric

Early in the twentieth century there was an ongoing debate over whether electricity or gasoline would provide the motive power for the emerging automobile industry. Gasoline won the day, and for most of the century electric vehicles were relegated to the margins of the automotive industry. The case for electric vehicles was given a significant boost in 1990, however, when the California Air Resources Board (CARB) enacted a "zero emissions rule" (ZEV), requiring two percent of automobiles sold in California in 1998 to be ZEV vehicles, and 10 percent in 2003, to be completely emissions free.[23] Since California comprises an important portion of vehicle sales, and since other states often model their emissions laws after California's, this was seen as an important portent for the future. Automobile companies complained vociferously, but several nonetheless set out to build electric vehicles. The story of what happened to the electric car in California is told in dramatic fashion in the 2006 documentary *Who Killed the Electric Car?* The film asserts that a combination of factors, including pressure from the automobile industry, the White House, and the chair of the Air Resources Board himself, killed the production of electric cars after the board reversed itself and no longer required there to be a percentage of emissions-free cars.[24] In a scene befitting the ending to a "whodunit" murder mystery, it is revealed that the chair of CARB is in league with those advocating for hydrogen-powered automobiles; hence his change of heart on electric vehicles.

Because of CARB's policy change, there was little incentive to invest in electric technology by most automobile makers. The two that did, however, were Toyota and Honda, which subsequently came out with hybrid automobiles that increased their efficiency but did not have to run solely on electricity. Since its introduction in 2001 the Toyota Prius has become synonymous with high fuel mileage and low emissions. The fact that a major automobile manufacturer has produced these cars, and now has licensed the technology to other manufacturers, is proof, according to some, that it is possible to greatly increase vehicle fuel efficiency and thereby help fight global warming, extend oil production, reduce dependence on foreign oil, and increase U.S. national security.

Critics of hybrid technology argue that very little has actually changed since the development of hybrid technology. The claims of hybrid auto manufacturers of vastly increased fuel mileage are greatly distorted. While hybrids do increase fuel efficiency through reducing the use of the internal combustion engine, the efficiency is minimal on longer trips where the elec-

tric motors do little assisting, and in cold weather, where batteries do not work as effectively. The fuel efficiency of hybrids also depends largely on the computer programming that controls the vehicles. While a hybrid vehicle can be programmed to maximize fuel economy, it can also be programmed to maximize a vehicle's power, since, in effect, there are two engines powering the vehicle. The result is a hybrid with little improvement in fuel efficiency.[25] Hybrid skeptics also point to the fact that the people who buy a hybrid like the Toyota Prius are already desirous of increased efficiency. If hybrids were in more "average" vehicles, including Sport Utility Vehicles (SUVs), the ordinary driver would not naturally see that much benefit to their fuel mileage. In any case, argue the critics, SUVs still make up a much larger and increasing share of automobile sales in the United States, so any gains made by hybrid technology are being lost to poor mileage in SUVs. Indeed, in spite of the tremendous vehicle efficiency and design improvements, the combined corporate average fuel economy of cars sold in the United States has remained very near twenty miles per gallon, virtually unchanged over the past ten years.[26]

Many of the same critics of hybrid technology argue that the answer is in two alternatives to the hybrid: plug-in hybrid electric vehicles (PHEVs) or all electric vehicles (EVs). The advantages of plug-in hybrids, according to proponents, are both dramatic fuel economy and emissions improvements over regular hybrid vehicles. Some companies that have altered the electronics and added batteries to the Toyota Prius have made it possible to drive for ten-thirty miles on only the electric motor after charging the car overnight in a regular 110 volt home outlet.[27] Combined with other electronic improvements, companies who now convert a Toyota Prius to a plug-in hybrid claim the cars average over one hundred m.p.g. for the first fifty-sixty miles of normal daily driving.[28] For plug-in hybrids proponents, plug-in technology combines the best of both worlds—greatly increased fuel efficiency over regular hybrids and the option of driving long distances without the fear of running out of electric power. Since many Americans commute less than thirty miles on a daily basis, plug-in hybrids with a twenty mile all-electric range could be powered by their home's electricity for a large percentage of driving time.

The electricity obtained through plugging in the automobile overnight or while at work most often comes from a power plant, of course. Detractors argue that this power plant may be coal or oil powered, which ends up being environmentally more damaging than if the car was not a hybrid at all. But

proponents argue that eventually electricity could come from roof-top solar panels at home, or on garages where the cars are parked during the day, or from environmentally clean wind or geo-thermal power plants.

The cost of plug-in hybrids currently greatly exceeds that of a regular hybrid vehicles, which themselves often are a $3000 premium over a comparable non-hybrid vehicle. Companies have sprung up in California to convert regular Toyota Prius hybrids into plug-in models, but the $10,000 price tag puts it out of reach for most consumers and would hardly pay for itself in the fuel savings over the life of the vehicle.[29]

While plug-in hybrid technology may be more promising than regular hybrids, there are others who feel that existing electric vehicle technology has developed sufficiently to enter mainstream vehicle sales. For many decades a small band of enthusiasts has converted conventional vehicles to electric vehicles. These conversions never really entered the mainstream market, however, plagued as they were by poor performance and high initial costs. When in 1990 the California Air Resources Board required auto manufacturers to sell two percent of their vehicles as zero-emissions vehicles, however, there began to be a concerted effort to create an affordable, practical electric vehicle. Toyota, General Motors, and several other large auto manufacturers developed their own electric vehicles. Toyota modified an existing small gasoline-powered SUV to create the RAV-EV, while General Motors created an entirely new vehicle, the EV-1. As we have seen, CARB changed its rules early in the production cycles of each of these vehicles and no longer required auto manufacturers to sell electric vehicles. With regulatory support no longer creating a strong incentive, General Motors "pulled the plug" on electric vehicle development in 2002.[30] Now, a few years later, with oil prices at record levels and concern for global warming constantly in the news, General Motors has promoted a new all-electric vehicle, the Volt.[31] Though only in prototype form, the Volt takes many of the latest EV innovations and puts them in an attractively designed and engineered vehicle. Likewise Tesla, a newly formed EV company, has created in prototype form the Tesla Roadster. With its sports car styling, high performance, and claimed 220-mile battery range,[32] the Tesla is seen by EV proponents as a model of what the EV could be. Primarily because of the lithium-ion batteries in the vehicle, the car is both extremely efficient and extremely expensive at $98,000. Tesla hopes to bring out a more practical four-passenger vehicle in the near future, however, and price it closer to $50,000. Other newly formed EV companies in Europe have begun small-scale production of vehicles for city transport and commutes, with hopes of bringing their vehicles for sale in the United States.

Electric vehicle detractors point to a number of significant hurdles that will likely prevent EV's from large-scale adoption in the United States. Chief among these is the cost and problems related to the batteries. The move to nickel-metal-hydrade (NIMH) and lithium-ion has helped with the problem of the vehicle's limited driving range, but the high cost and battery disposal issues remain significant. One possible way to work around the high battery cost that has been proposed is to have customers buy the vehicle but lease the batteries, much like one can now lease an ordinary car. This would significantly reduce the vehicles initial cost, while ensuring that the battery packs are exchanged at appropriate intervals for replacement.[33]

Hydrogen Fuel Cell

A final alternative to the traditional fossil-fuel powered vehicle is one powered by hydrogen fuel cells. In President Bush's 2003 State of the Union speech he promoted this technology as providing pollution-free automobiles.[34] Proponents of hydrogen fuel cells argue that the technology is on the cusp of providing a virtually unlimited source of clean energy to power the future of transport. Since hydrogen is so bountiful, it is simply a matter of developing the technology to safely store it in a manner appropriate to vehicle transport. Prototype hydrogen-powered buses now running in Canadian, European, and American cities have shown that the technology is possible and could be implemented in a more wide-scale mode in the near future.[35]

Detractors, however, point to numerous technical and environmental questions related to the development of hydrogen fuel-cells. Chief among the questions is how to make the hydrogen in the first place. While hydrogen is abundant in ordinary water, it is only a carrier of energy rather than a supplier of energy. In order to be used in a fuel cell, hydrogen must be extracted from water, an energy intensive process that is only as clean as the type of energy used in its creation. Creating hydrogen through traditional fossil-fuels does little to solve the problem of global warming, as the process of creating the hydrogen creates as much CO^2 as what would otherwise be produced in an ordinary vehicle. Scientists are trying to develop more efficient ways of extracting hydrogen from water. If it were possible to extract it through a nuclear fusion process it would be a virtually unlimited source of clean energy. Likewise, if hydrogen were produced through renewable energy sources like solar, wind, or geo-thermal energy, it could pave the way to a "hydrogen economy." The most prominent example of the hydrogen

economy being promoted today is in Iceland, where the government has set a target date of 2050 to be completely free of fossil-fuel energy.[36]

While supporters of a hydrogen economy are enthusiastic about the possibilities, even they admit hydrogen is a long-term proposal, not a short-term solution. While some optimists see hydrogen fuel cell vehicles by 2010, most experts argue that fifteen to thirty or more years are necessary to develop the technology and infrastructure required to make the hydrogen fuel cell a feasible alternative to internal combustion engines.[37] Tremendous amounts of research must be done to answer questions related to the safety and viability of hydrogen as an alternative fuel. Before it can be adopted for wide-scale use it must be fully tested and a network of hydrogen filling stations must be developed throughout at least the main transportation arteries. The cost for these developments runs into the hundreds of billions of dollars. California Governor Schwarzenegger wants his state to be at the forefront of this conversion to the hydrogen economy. In 2004 he outlined the California Hydrogen Highway Blueprint, in which $54 million will be spent to develop one hundred hydrogen fueling stations by 2010.[38] For hydrogen proponents, the cost is manageable given the tremendous potential for the negative effects of global warming on the state, the nation, and the world. For detractors, the cost is yet one more reason to avoid going down this road.

Is There a Silver Bullet for Alternative Energy?

This review of alternative fuel technologies reveals several realities regarding the possibilities and pitfalls of alternative fuels. The first is that there is no "silver bullet" when it comes to alternative fuels for transportation in the United States. Each alternative presents both a potential partial solution and the potential for additional problems when attempting to move beyond fossil fuels. Some alternatives, like ethanol, may better address the goal of becoming more self-sufficient in energy, while others, like electric vehicles, may better address the question global climate change. The result is that there is no obvious substitute for petroleum, which has been virtually the entire source for transport over the past eighty years. Rather, we may move toward different fuel sources depending on the purpose of transport. Shorter distance vehicles intended primarily for commuting and intra-city transport may someday be dominated by electric vehicles powered by home and office-based solar arrays. Vehicles whose purpose is longer distance driving may be powered by algae-based bio-diesel. Those wanting a combination of

the two may be able to choose a plug-in bio-diesel hybrid.[39] Perhaps in some not too distant future fuel-cells will be powered by hydrogen that is created through a photosynthesis process.

But these possibilities will not happen without specific goals and regulations created to move the transportation industry in certain directions. From the 1960s to the present, California emissions regulations have been at the forefront of forcing automobile manufacturers to create vehicles which pollute less or are more efficient. Even when the federal government has lagged, California has insisted on tightening regulations. Exhaust gas recirculation systems in the 1960s, catalytic converters in the 1970s, emissions control stations in the 1980s, and regulations for ultra low sulfur diesel in the past year, are all examples of California forcing the automotive industry to move toward cleaner combusting engine technology over the past fifty years. As discussed earlier, in the 1990s it was only because of California's insistence on zero-emissions vehicles that new electric vehicles began to be designed. When California lost its vision for these vehicles, the technology programs halted.

Today, the latest iteration of this long-running confrontation between California and automobile manufacturers is taking place, with the federal government lagging behind. In 2002 California passed a law stating that all automobile manufacturers selling vehicles in California produce them with significantly reduced carbon dioxide emissions beginning in the 2009 model year.[40] The automobile manufacturers sued the state, arguing that the ruling in effect set vehicle fuel economy standards, since carbon dioxide output is directly tied with fuel efficiency. Since only the federal government has the jurisdiction to set fuel economy standards, the car manufacturers argued that the state had overstepped its bounds. It further argued that the California ruling was invalid because it set a limit on carbon dioxide, which is not a pollutant.[41] The Bush administration sided with the automobile manufacturers, and the case went to federal court. The court sided with California,[42] writing that California was entitled to stricter standards under guidelines set forth in the 1970 Clean Air Act, with guidance from the federal Environmental Protection Agency (EPA). Without a doubt the political and environmental landscape has begun to shift.

Further evidence of this shift took place in December 2007 when both houses of Congress agreed to finally increase corporate average fuel economy standards. The increase, though modest and extending far into the future, requires automobile manufacturers to gradually step-up fuel efficiency from

the current 28.5 miles per gallon to an average of 35 miles per gallon for most vehicles by 2020.[43] The fuel economy standard had not been raised in the United States for nearly thirty years. When it was introduced in the mid 1970s as a response to the OPEC oil embargo, it was viewed as an essential means to wean America's dependence from foreign oil; it subsequently brought the United States into a position of global leadership in improving fuel economy. The intervening years, replete with inexpensive oil and a strong push by automobile manufacturers to preserve the status quo, however, has resulted in America's leadership in fuel economy standards falling well below Japan, Europe, and, most recently, China.[44] This is in part because many of the least efficient vehicles—large pickup trucks and SUVs—are exempt from the regulations because of their status as "farm vehicles." The December 2007 bill, which was signed by President Bush and now becomes law, sets forth gradual change, much more gradual than that envisioned by California's 2002 "Greenhouse Gas" legislation. As this is being written California and the federal government are sparring over whether California will be able to retain its fuel economy standards or whether the federal governments standards, as outlined in the energy bill, will supercede these standards.[45]

There are some people on both sides of the political spectrum that see the need for an urgent course of action in altering the current United States energy path. Whether for need of increased national security or for reducing the impact of global warming, there are some who see America's current policies extremely short-sighted and ultimately destined to fail. Dramatic action is immediately required to save the planet from human-induced environmental disaster, and to save the United States from further acts of terror.

Many courses of action have been recommended to move quickly in a new direction. Thomas Friedman suggests that an immediate "patriot tax" of $1/gallon of gasoline be levied to help create an incentive for people to buy smaller, more fuel-efficient vehicles.[46] Another option would be a substantial tax credit for buying a fuel-efficient vehicle, and a substantial tax penalty for buying an vehicle with poor fuel mileage ratings. A "Manhattan Project" for alternative fuels has been suggested as a means to demonstrate the seriousness with which Americans take the problem of dependence on fossil fuels. As the original Manhattan Project created an atomic bomb in the space of only a few years, this project would aim to push the technology forward to create a viable alternative energy to fossil fuels.[47] Each of these proposals suggests that there is no time to waste, and that there are more alternatives than simply relying on alternative fuels.

The technology may eventually be within our grasp to create new, pollution-, fossil-, and carbon-dioxide- free emitting vehicles. But the technology to do this is decades away, and the alternatives are, for now, only partial solutions at best. If the United States hopes to lead, rather than follow, in averting global climate change, it must do so with bold initiatives and planning. Promoting alternative sources, from ethanol and bio-diesel to electric and hydrogen-powered fuel cells, may be a partial solution. But the United States must also, in the short term, strive to boldly lead in the global goal of improving fuel efficiency of current vehicles. Only through concerted efforts on a wide variety of fronts will America ever hope to significantly address the issue of the automobile's contribution to carbon dioxide emissions while improving the United State's energy security.

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