The Committee on the Present Danger

fighting terrorism and the ideologies that drive it

a Committee on the Present Danger Policy Paper

Oil and Security

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(NOTE: An earlier version of this paper was posted on the CPD web site in late June, just prior to the Senate debate of the Energy Bill, in order to help inform that debate and for discussion and commentary by interested parties prior to CPD board and membership approval. That discussion and commentary has informed this draft, dated August 5, 2005. Board and membership approval are not yet final.)

SUMMARY

This paper could well be called, "It's the Batteries, Stupid." Four years ago, on the eve of 9/11, the need to reduce radically our reliance on oil was not clear to many and in any case the path of doing so seemed a long and difficult one. Today both assumptions are being undermined by the risks of the post-9/11 world and by technological progress in fuel efficiency and alternative fuels.

We spell out below the risks of petroleum dependency, particularly the vulnerability of the petroleum infrastructure in the Middle East to terrorist attack – a single well-designed attack could send oil to well over $100/barrel and devastate the world's economy. That reality, among other risks, and the fact that our current transportation infrastructure is locked in to oil, should be sufficient to convince any objective observer that oil dependence today creates serious and pressing dangers for the US and other oil-importing nations.

We propose in this paper that the government vigorously encourage and support at least six technologies: two types of alternative fuels that are beginning to come into the market (cellulosic ethanol and biodiesel derived from a wide range of waste streams), two types of fuel efficient vehicles that are now being sold to the public in some volume (hybrid gasoline-electric and modern clean diesels), and one vehicle construction technique, the use of manufactured carbon-carbon composites, that is now being used for aircraft and racing cars and is quite promising as a way of reducing vehicle weight and fuel requirements while improving safety.

The sixth technology, battery improvement to permit "plug-in" hybrid vehicles, will require some development – although nothing like the years that will be required for hydrogen fuel cells. It holds, however, remarkable promise. Improving batteries to permit them to be given an added charge when a hybrid is garaged, ordinarily at night, can substantially improve mileage because it can permit hybrids to use battery power alone for the first 10-30 miles. Since a great many trips fall within this range this can improve the mileage of a hybrid vehicle from, say, 50 mpg to over 100 mpg (of oil products). Also, since the average residential electricity cost is 8.5 cents/kwh (and in many areas, off-peak nighttime cost is 2-4 cents/kwh) this means that, after taking account of the differential efficiencies of electric and gasoline power, much of a plug-in hybrid's travel would be on electricity that is the equivalent of $1/gallon gasoline (or, off-peak, 25-50 cents/gallon) as contrasted with the same vehicle's use of today's approximately $2.50/gallon gasoline.

A plug-in hybrid averaging 125 mpg, if its fuel tank contains 85 per cent cellulosic ethanol, would be getting on the order of 500 mpg (of oil products). If it were constructed from carbon composites that mileage could double, and, if it were a diesel and powered by biodiesel or renewable diesel derived from waste, it would be using no oil products at all.

What are we waiting for?

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There are at least seven major reasons why dependence on petroleum and its products for the lion's share of the world's transportation fuel creates special dangers in our time. These dangers are all driven by rigidities and potential vulnerabilities that have become serious problems because of the geopolitical realities of the early 21st century. Those who reason about these issues solely on the basis of abstract economic models that are designed to ignore such geopolitical realities will find much to disagree with in what follows. Although such models have utility in assessing the importance of more or less purely economic factors in the long run, as Lord Keynes famously remarked: "In the long run, we are all dead."

These dangers in turn give rise to two proposed directions for government policy in order to reduce our vulnerability rapidly. In both cases we believe that existing technology should be used, i.e. technology that is already in the market or can be so in the very near future and that is compatible with the existing transportation infrastructure. To this end government policies in the United States and other oil-importing countries should: (1) encourage a shift to substantially more fuel-efficient vehicles, including fostering battery development for plug-in hybrid vehicles; and (2) encourage biofuels and other alternative and renewable fuels that wherever possible can be derived from waste products.

PETROLEUM DEPENDENCE: THE DANGERS:

1. The current transportation infrastructure is committed to oil and oil-compatible products.

This fact substantially increases the difficulty of responding to oil price increases or disruptions in supply by substituting other fuels.

There is a range of fuels that can be used to produce electricity and heat and that can be used for other industrial uses, but petroleum and its products dominate the fuel market for vehicular transportation. With the important exception, described below, of a plug-in version of the hybrid gasoline/electric vehicle, which will allow recharging hybrids from the electricity grid, substituting other fuels for petroleum in the vehicle fleet as a whole has generally required major, time-consuming, and expensive infrastructure changes. One exception has been some use of liquid natural gas (LNG) and other fuels for fleets of buses or delivery vehicles, although not substantially for privately-owned ones, and the use of corn-derived ethanol mixed with gasoline in proportions up to 10 per cent ethanol ("gasohol") in some states. Neither has appreciably affected petroleum's dominance of the transportation fuel market.

Moreover, in the 1970's about 20 per cent of our electricity was made from oil – so shifting electricity generation toward, say, renewables or nuclear power could save oil. But since today only about two per cent of our electricity is oil-generated, a shift in the way we produce electricity would have almost no effect on the transportation or oil market. This could change, however, with the advent of plug-in hybrid vehicles, discussed below.

There are imaginative proposals for transitioning to other fuels for transportation, such as hydrogen to power automotive fuel cells, but this would require major infrastructure investment and restructuring. If privately-owned fuel cell vehicles were to be capable of being readily refueled, this would require reformers (equipment capable of reforming, say, natural gas into hydrogen) to be located at filling stations, and would also require natural gas to be available there as a hydrogen feed-stock. So not only would fuel cell development and technology for storing hydrogen on vehicles need to be further developed, but the automobile industry's development and production of fuel cells also would need to be coordinated with the energy industry's deployment of reformers and the fuel for them.

Moving toward automotive fuel cells thus requires us to face a huge question of pace and coordination of large-scale changes by both the automotive and energy industries. This poses a sort of industrial Alphonse and Gaston dilemma: who goes through the door first? (If, instead, it were decided that existing fuels such as gasoline were to be reformed into hydrogen on board vehicles instead of at filling stations, this would require on-board reformers to be developed and added to the fuel cell vehicles themselves – a very substantial undertaking.)

It is because of such complications that the National Commission on Energy Policy concluded in its December, 2004, report "Ending The Energy Stalemate" ("ETES") that "hydrogen offers little to no potential to improve oil security and reduce climate change risks in the next twenty years." (p. 72)
To have an impact on our vulnerabilities within the next decade or two, any competitor of oil-derived fuels will need to be compatible with the existing energy infrastructure and require only modest additions or amendments to it.

2. The Greater Middle East will continue to be the low-cost and dominant petroleum producer for the foreseeable future.
Home of around two-thirds of the world's proven reserves of conventional oil -- 45% of it in just Saudi Arabia, Iraq, and Iran -- the Greater Middle East will inevitably have to meet a growing percentage of world oil demand. This demand is expected to increase by more than 50 per cent in the next two decades, from 78 million barrels per day ("MBD") in 2002 to 118 MBD in 2025, according to the federal Energy Information Administration. Much of this will come from expected demand growth in China and India. One need not argue that world oil production has peaked to see that this puts substantial strain on the global oil system. It will mean higher prices and potential supply disruptions and will put considerable leverage in the hands of governments in the Greater Middle East as well as in those of other oil-exporting states which have not been marked recently by stability and certainty: Russia, Venezuela, and Nigeria, for example (ETES pp. 1-2). Deep-water drilling and other opportunities for increases in supply of conventional oil may provide important increases in supply but are unlikely to change this basic picture.
Even if other production comes on line, e.g. from unconventional sources such as tar sands in Alberta or shale in the American West, their relatively high cost of production could permit low-cost producers, particularly Saudi Arabia, to increase production, drop prices for a time, and undermine the economic viability of the higher-cost competitors, as occurred in the mid-1980's. For the foreseeable future, as long as vehicular transportation is dominated by oil as it is today, the Greater Middle East, and especially Saudi Arabia, will remain in the driver's seat.

3. The petroleum infrastructure is highly vulnerable to terrorist and other attacks.
The radical Islamist movement, including but not exclusively al Qaeda, has on a number of occasions explicitly called for worldwide attacks on the petroleum infrastructure and has carried some out in the Greater Middle East. A more well-planned attack than what has occurred to date -- such as that set out in the opening pages of Robert Baer's recent book,

Sleeping With the Devil, (terrorists flying an aircraft into the unique sulfur-cleaning towers in northeastern Saudi Arabia) -- could take some six million barrels per day off the market for a year or more, sending petroleum prices sharply upward to well over $100/barrel and severely damaging much of the world's economy. Domestic infrastructure in the West is not immune from such disruption. U.S. refineries, for example, are concentrated in a few places, principally the Gulf Coast. The recent accident in the Texas City refinery--producing multiple fatalities--points out potential infrastructure vulnerabilities. The Trans-Alaska Pipeline has been subject to several amateurish attacks that have taken it briefly out of commission; a seriously planned attack on it could be far more devastating. In view of these overall infrastructure vulnerabilities we do not suggest that policy should focus exclusively on petroleum imports, although such infrastructure vulnerabilities are likely to be the most severe in the Greater Middle East. It is there that terrorists have the easiest access and the largest proportion of proven oil reserves, and low-cost production are also located there. Nor do we hold the view that by changing trade patterns anything particularly is accomplished. To a first approximation there is one worldwide oil market and it is not generally useful for the U.S., for example, to import less from the Greater Middle East and for others then to import more from there. In effect, all of us oil-importing countries are in this together.

4. The possibility exists, particularly under regimes that could come to power in the Greater Middle East, of embargoes or other disruptions of supply.

It is often said that whoever governs the oil-rich nations of the Greater Middle East will need to sell their oil. This is not true, however, if the rulers choose to try to live, for most purposes, in the seventh century. Bin Laden has advocated, for example, major reductions in oil production.

In 1979 there was a serious attempted coup in Saudi Arabia. Much of what the outside world saw was the seizure by Islamist fanatics of the Great Mosque in Mecca, but the effort was more widespread. Even if one is optimistic that democracy and the rule of law will spread in the Greater Middle East and that this will lead after a time to more peaceful and stable societies there, it is undeniable that there is substantial risk that for some time the region will be characterized by chaotic change and unpredictable governmental behavior. Reform, particularly if it is hesitant, has in a number of cases been trumped by radical takeovers (Jacobins, Bolsheviks). There is no reason to believe that the Greater Middle East is immune from these sorts of historic risks.

5. Wealth transfers from oil have been used, and continue to be used, to fund terrorism and Its ideological support.

Estimates of the amount spent by the Saudis in the last 30 years spreading Wahhabi beliefs throughout the world vary from $70 billion to $100 billion. Furthermore, some oil-rich families of the Greater Middle East fund terrorist groups directly. The spread of

Wahhabi doctrine – fanatically hostile to Shi'ite and Suffi Muslims, Jews, Christians, women, modernity, and much else – plays a major role with respect to Islamist terrorist groups: a role similar to that played by angry German nationalism with respect to Nazism in the decades after World War I. Not all angry German nationalists became Nazis and not all those schooled in Wahhabi beliefs become terrorists, but in each case the broader doctrine of hatred has provided the soil in which the particular totalitarian movement has grown. Whether in lectures in the *madrassas* of Pakistan, in textbooks printed by Wahhabis for Indonesian schoolchildren, or on bookshelves of mosques in the US, the hatred spread by Wahhabis and funded by oil is evident and influential.
It is sometimes contended that we should not seek substitutes for oil because disruption of the flow of funds to the Greater Middle East could further radicalize the population of some states there. The solution, however, surely lies in helping these states diversify their economies over time, not in perpetually acquiescing to the economic rent they collect from oil exports and to the uses to which these revenues are put.

6. The Current Account deficits for a number of countries create risks ranging from major world economic disruption to deepening poverty, and could be substantially reduced by reducing oil imports.

The U.S. in essence borrows about $2 billion a day, every day, principally now from major Asian states, to finance its consumption. The single largest category of imports is the approximately $1 billion per working day borrowed to import oil. The accumulating debt increases the risk of a flight from the dollar or major increases in interest rates. Any such development could have major negative economic consequences for both the U.S. and its trading partners.

For developing nations, the service of debt is a major factor in their continued poverty. For many, debt is heavily driven by the need to import oil that at today's oil prices cannot be paid for by sales of agricultural products, textiles, and other typical developing nation exports.

If such deficits are to be reduced, however, say by domestic production of substitutes for petroleum, this should be based on recognition of real economic value such as waste cleanup, soil replenishment, or other tangible benefits.

7. Global-warming gas emissions from man-made sources create at least the risk of climate change.

Although the point is not universally accepted, the weight of scientific opinion suggests that global warming gases (GWG) produced by human activity form one important component of potential climate change. Oil products used in transportation provide a major share of U.S. man-made global warming gas emissions.

THREE PROPOSED DIRECTIONS FOR POLICY:

The above considerations suggest that government policies with respect to the vehicular transportation market should point in the following directions:

1. Encourage improved vehicle mileage, using technology now in production.

Three currently available technologies stand out to improve vehicle mileage.

Diesels

First, modern diesel vehicles are coming to be capable of meeting rigorous emission standards (such as Tier 2 standards, being introduced into the U.S., 2004-08). In this context it is possible without compromising environmental standards to take advantage of diesels' substantial mileage advantage over gasoline-fueled internal combustion engines. Substantial penetration of diesels into the private vehicle market in Europe is one major reason why the average fleet mileage of such new vehicles is 42 miles per gallon in Europe and only 24 mpg in the US. Although the U.S. has, since 1981, increased vehicle weight by 24 per cent and horsepower by 93 per cent, it has actually somewhat lost ground with respect to mileage over that near-quarter century. In the 12 years from 1975 to 1987, however, the US improved the mileage of new vehicles from 15 to 26 mpg.

Hybrid gasoline-electric

Second, hybrid gasoline-electric vehicles now on the market show substantial fuel savings over their conventional counterparts. The National Commission on Energy Policy found that for the four hybrids on the market in December 2004 that had exact counterpart models with conventional gasoline engines, not only were mileage advantages quite significant (10-15 mpg) for the hybrids, but in each case the horsepower of the hybrid was higher than the horsepower of the conventional vehicle. (ETES p. 11) If automobile companies wish to market hybrids by emphasizing hotter performance rather than fuel conservation they can do so, consistent with the facts.

Light-weight Carbon Composite Construction

Third, constructing vehicles with inexpensive versions of the carbon fiber composites that have been used for years for aircraft construction can substantially reduce vehicle weight and increase fuel efficiency while at the same time making the vehicle considerably safer than with current construction materials. This is set forth thoroughly in the 2004 report of the Rocky Mountain Institute's *Winning the Oil Endgame* ("WTOE"). Aerodynamic design can have major importance as well. This breaks the traditional tie between size and safety. Much lighter vehicles, large or small, can be substantially more fuel-efficient and also safer. Such composite use has already been used for automotive construction in Formula 1 race cars and is now being adopted by BMW and other automobile companies. The goal is mass-produced vehicles with 80% of the performance of hand-layup aerospace composites at 20% of the cost. Such construction is expected to approximately double the efficiency of a normal hybrid vehicle without increasing manufacturing cost. (WTOE 64-66).

2. Encourage the commercialization of alternative transportation fuels that can be available soon, are compatible with existing infrastructure, and can be derived from waste or otherwise produced cheaply.

Biomass (cellulosic) ethanol.

The use of ethanol produced from corn in the U.S. and sugar cane in Brazil has given birth to the commercialization of an alternative fuel that is coming to show substantial promise, particularly as new feedstocks are developed. Some six million vehicles in the U.S. and all vehicles in Brazil other than those that use solely ethanol are capable of using ethanol in mixtures of up to 85 percent ethanol and 15 per cent gasoline (E-85); these are called Flexible Fuel Vehicles ("FFV") and require, compared to conventional vehicles, only a somewhat different kind of material for the fuel line and a differently-programmed computer chip. The cost of incorporating this feature in new vehicles is trivial. Also, there are no large-scale changes in infrastructure required for ethanol use. It may be shipped in tank cars, and mixing it with gasoline is a simple matter.

Although human beings have been producing ethanol, grain alcohol, from sugar and starch for millennia, it is only in recent years that the genetic engineering of biocatalysts has made possible such production from the hemicellulose and cellulose that constitute the substantial majority of the material in most plants. The genetically-engineered material is in the biocatalyst only; there is no need for genetically modified plants.

These developments may be compared in importance to the invention of thermal and catalytic cracking of petroleum in the first decades of the 20th century – processes which made it possible to use a very large share of petroleum to make gasoline rather than the tiny share that was available at the beginning of the century. For example, with such genetically-engineered biocatalysts it is not only grains of corn but corn cobs and most of the rest of the corn plant that may be used to make ethanol.

Such biomass, or cellulosic, ethanol is now likely to see commercial production begin first in a facility of the Canadian company, Iogen, with backing from Shell Oil, at a cost of around $1.30/gallon. The National Renewable Energy Laboratory estimates costs will drop to around $1.07/gallon over the next five years, and the Energy Commission estimates a drop in costs to 67-77 cents/gallon when the process is fully mature (ETES p. 75). The most common feedstocks will likely be agricultural wastes, such as rice straw, or natural grasses such as switchgrass, a variety of prairie grass that is often planted on soil bank land to replenish the soil's fertility. There will be decided financial advantages in using as feedstocks any wastes which carry a tipping fee (a negative cost) to finance disposal: e.g. waste paper, or rice straw, which cannot be left in the fields after harvest because of its silicon content.

Old or misstated data are sometimes cited for the proposition that huge amounts of land would have to be introduced into cultivation or taken away from food production in order to have such biomass available for cellulosic ethanol production. This is incorrect. The National Commission on Energy Policy reported in December that, if fleet mileage in the U.S. rises to 40 mpg -- somewhat below the current European Union fleet average for new vehicles of 42 mpg and well below the current Japanese average of 47 mpg – then as switchgrass yields improve modestly to around 10 tons/acre it would take only 30 million acres of land to produce sufficient cellulosic ethanol to fuel half the U.S. passenger fleet. (ETES pp. 76-77). By way of calibration, this would essentially eliminate the need for oil imports for passenger vehicle fuel and would require only the amount of land now in the soil bank (the Conservation Reserve Program ("CRP") on which such soil-restoring crops as switchgrass are already being grown. Practically speaking, one would probably use for ethanol production only a little over half of the soil bank lands and add to this some portion of the plants now grown as animal feed crops (for example, on the 70 million acres that now grow soybeans for animal feed). In short, the U.S. and many other countries should easily find sufficient land available for enough energy crop cultivation to make a substantial dent in oil use. (Id.)

There is also a common and erroneous impression that ethanol generally requires as much energy to produce as one obtains from using it and that its use does not substantially reduce global warming gas emissions. The production and use of ethanol merely recycles in a different way the CO_2 that has been fixed by plants in the photosynthesis process. It does not release carbon that would otherwise stay stored underground, as occurs with fossil fuel use, but when starch, such as corn, is used for ethanol production much energy, including fossil-fuel energy, is consumed in the process of fertilizing, plowing, and harvesting. Even starch-based ethanol, however, does reduce greenhouse gas emissions by around 30 per cent. Because so little energy is required to cultivate crops such as switchgrass for cellulosic ethanol production, and because electricity can be co-produced using the residues of such cellulosic fuel production, reductions in greenhouse gas emissions for celluslosic ethanol when compared to gasoline are greater than 100 per cent. The production and use of cellulosic ethanol is, in other words, a carbon sink. (ETES p. 73).

Biodiesel and Renewable Diesel

The National Commission on Energy Policy pointed out some of the problems with most current biodiesel "produced from rapeseed, soybean, and other vegetable oils – as well as . . . used cooking oils." It said that these are "unlikely to become economic on a large scale" and that they could "cause problems when used in blends higher than 20 percent in older diesel engines". It added that "waste oil is likely to contain impurities that give rise of undesirable emissions." (ETES p. 75)

The Commission notes, however, that biodiesel is generally "compatible with existing distribution infrastructure" and outlines the potential of a newer process ("thermal depolymerization") that produces renewable diesel without the above disadvantages, from "animal offal, agricultural residues, municipal solid waste, sewage, and old tires". It points to the current use of this process at a Conagra turkey processing facility in Carthage, Missouri, where a "20 million commercial-scale facility" is beginning to convert turkey offal into "a variety of useful products, from fertilizer to low-sulfur diesel fuel" at a potential average cost of "about 72 cents per gallon." (ETES p. 77)

Other Alternative Fuels

Progress has been made in recent years on utilizing not only coal but slag from strip mines, via gasification, for conversion into diesel fuel using a modern version of the gasified-coal-to-diesel process used in Germany during World War II.
Qatar has begun a large-scale process of converting natural gas to diesel fuel.
Outside the realm of conventional oil, the tar sands of Alberta and the oil shale of the Western U.S. exist in huge deposits, the exploitation of which is currently costly and accompanied by major environmental difficulties, but both definitely hold promise for a substantial increases in oil supply.

3. Plug-in hybrids and battery improvements

A modification to hybrids could permit them to become "plug-in-hybrids," drawing power from the electricity grid at night and using all electricity for short trips. The "vast majority of the most fuel-hungry trips are under six miles" and "well within the range" of current (nickel-metal hydride) batteries' capacity, according to Huber and Mills (*The, Bottomless Well,* 2005, p. 84). Other experts, however, emphasize that whether with existing battery types (2-5 kwh capacity) or with the emerging (and more capable) lithium batteries, it is important that any battery used in a plug-in hybrid be capable of taking daily charging without being damaged and be capable of powering the vehicle at an adequate speed. By most assessments some battery development will be necessary in order for this to be the case. Such development should have the highest research and development priority because it promises to revolutionize transportation economics and to have a dramatic effect on the problems caused by oil dependence.

With a plug-in hybrid vehicle one has the advantage of an electric car, but not the disadvantage. Electric cars cannot be recharged if their batteries run down at some spot away from electric power. But since all hybrids have tanks containing liquid fuel plug-in hybrids have no such disadvantage.

Moreover the attractiveness to the consumer of being able to use electricity from overnight charging for a substantial share of the day's driving is stunning. The average residential price of electricity in the US is about 8.5 cents/kwh, and many utilities sell off-peak power for 2-4 cents/kwh (id at 83). When one takes into consideration the different efficiencies of liquid–fueled and electric propulsion, then where the rubber meets the road the cost of powering a plug-in hybrid with average-cost residential electricity would be about 40 per cent of the cost of powering the same vehicle with today's approximately $2.50/gallon gasoline, or, said another way, for the consumer to be able to buy fuel in the form of electricity at the equivalent of $1/gallon gasoline.* Using off-peak power would then equate to being able to buy 25-to-50 cent/gallon gasoline. Given the burdensome cost imposed by current fuel prices on commuters and others who need to drive substantial distances, the possibility of powering one's family vehicle with fuel that can cost as little as one-tenth of today's gasoline (in the U.S. market) should solve rapidly the question whether there would be public interest in and acceptability of plug-in hybrids.

Although the use of off-peak power for plug-in hybrids should not initially require substantial new investments in electricity generation, greater reliance on electricity for transportation should lead us to look particularly to the security of the electricity grid as well as the fuel we use to generate electricity. In the U.S. the 2002 report of the National Academies of Science, Engineering, and Medicine ("Making the Nation Safer") emphasized particularly the need to improve the security of transformers and of the Supervisory Control and Data Acquisition (SCADA) systems in the face of terrorist threats. The National Commission on Energy Policy has seconded those concerns. With or without the advent of plug-in hybrids, these electricity grid vulnerabilities require urgent attention.

Conclusion

The dangers from oil dependence in today's world require us both to look to ways to reduce demand for oil and to increase supply of transportation fuel by methods beyond the increase of oil production.

The realistic opportunities for reducing demand soon suggest that government policies should encourage hybrid gasoline-electric vehicles, particularly the battery developments needed to bring plug-in versions thereof to the market, and modern diesel technology. The realistic opportunities for increasing supply of transportation fuel soon suggest that government policies should encourage the commercialization of alternative fuels that can be used in the existing infrastructure: cellulosic ethanol and biodiesel/renewable diesel. Both of these fuels could be introduced more quickly and efficiently if they achieve cost advantages from the utilization of waste products as feedstocks.

The effects of these policies are multiplicative. All should be pursued since it is impossible to predict which will be fully successful or at what pace, even though all are today either beginning commercial production or are nearly to that point. The battery development for plug-in hybrids is of substantial importance and should for the time being replace the current r&d emphasis on automotive hydrogen fuel cells.

If even one of these technologies is moved promptly into the market, the reduction in oil dependence could be substantial. If several begin to be successfully introduced into large-scale use, the reduction could be stunning. For example, a 50-mpg hybrid gasoline/electric vehicle, on the road today, if constructed from carbon composites would achieve around 100 mpg. If it were to operate on 85 percent cellulosic ethanol or a similar proportion of biodiesel or renewable diesel fuel, it would be achieving hundreds of miles per gallon of petroleum-derived fuel. If it were a plug-in version operating on upgraded lithium batteries so that 20-30 mile trips could be undertaken on its overnight charge before it began utilizing liquid fuel at all, it could be obtaining in the range of 1000 mpg (of petroleum).

A range of important objectives – economic, geopolitical, environmental – would be served by our embarking on such a path. Of greatest importance, we would be substantially more secure.

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*In the original June 2005 draft of this paper the reader would have seen an estimate that the cost of powering a hybrid with average (8.5 cents/kwh) residential electricity from the grid would be about one-quarter the cost of powering the same vehicle in its normal operating mode using $2/gallon gasoline. This was because we were utilizing an estimate in Huber and Mills that "Burning $2-a-gallon gasoline, the power generated by current hybrid-car engines runs about 35 cents per kilowatt-hour (kWh)." (id p. 83). After assessing comments received on the June draft paper we are now convinced that, whatever the proper number for hybrids' power generation at an earlier time, the better estimate for the cost of operating the most modern hybrids in their normal mode as of August 2005 is a little less than half this 35-cents/kwh estimate. Thus the use of average-cost electricity from the grid would equate to about half the cost of using $2/gallon gasoline, not one-quarter. We would stress that these comparisons take account of the different efficiencies of gasoline and electric power and represent differences where the rubber meets the road, not differences between the cost of different types of energy as stored in a tank or a battery.