Strategy for Achieving Independence From Foreign Oil:

A Plan for America

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Introduction

The catch phrase *Energy Independence* is so all-inclusive that it distorts, rather than clarifies any discussion about oil independence.

America has many sources of energy, including; coal, natural gas, oil, nuclear, wind, hydro, solar, geothermal and ocean waves.

Coal, natural gas, nuclear, hydro, wind, solar and geothermal have historically (i.e., at least in the last half of the twentieth century) been used to generate electricity.

Today very little electricity is generated using oil, (i.e., only 3% of U.S. electricity generation and this primarily in Hawaii.)

Natural gas and oil are used in large quantities by industry for feedstock (e.g., natural gas to produce chemical products such as fertilizer) and for other industrial applications. In addition, natural gas has been a major source of home heating, while oil has also been used for home heating, primarily in the North East.

Oil is unique in that it has been the primary energy source in the transportation sector. This distinguishes oil from other energy sources when discussing energy independence.

Natural gas is also unique in that it must be produced in North America. (Under any scenario, imported liquid natural gas (LNG) will be a negligible source of natural gas in the U.S.)

It can be seen that energy independence comes in several flavors.

In a narrow sense, the U.S. is already energy independent when it comes to generating electricity. The U. S. has sufficient coal to generate electricity far into the future. Wind power, which can only be used to generate electricity, merely augments or displaces coal in the generation of electricity.

Natural gas independence can only be achieved by drilling for natural gas in North America where it can be transported by pipeline to users.

Oil independence can only be achieved by addressing the energy source for cars and trucks, and possibly by developing oil shale. [The Fischer-Tropsch method could produce a small amount of diesel fuel for the transportation sector. See Attachment A]

Essentially, all of America's oil imports are used in the transportation sector, (primarily for gasoline and diesel fuel). Segmented in this manner, oil produced in the U.S. is primarily used by industry, and to a lesser extent for jet fuel and for heating and to an even lesser extent for other miscellaneous uses such as lubricants.

"Energy Independence" is a meaningless catch phrase that confuses any analysis.

The real issues are:

- Independence from foreign oil, and,
- Natural gas independence.

This report addresses oil independence, though implementation of some elements of this strategy will also help improve domestic supplies of natural gas.

Executive Summary

This paper proposes that the primary objective of America's energy policy should be to achieve independence from foreign oil while increasing energy supplies and promoting economic development.

The United States imported over 10 million barrels of oil daily in 2000 and this is expected to rise to around 20 million bbls/day by 2025 without a new strategy for breaking the foreign oil habit.

The bulk of foreign oil comes from volatile areas of the world where supply routes (e.g., the Hormuz Straits) are easily interdicted or production (e.g., Abqaiq) and loading terminals (e,g., Ras Tanura) can be destroyed.

This paper adopts the position that America's national interests, possibly survival, depends on a timely effort to first reduce and then eliminate the use of foreign oil.

If it were not for America's national security, a more leisurely transition from foreign oil could be envisioned.

This strategy is equally important, if, as some believe, worldwide peak oil production is near at hand.

Americans must recognize that it may only be possible to achieve independence from foreign oil by phasing out the use of gasoline and diesel fuels to propel passenger vehicles and trucks.

Because vehicles last 14.5 years on average before being scrapped and because there will be more vehicles on the road due to our increasing population it will take decades, not years, to displace all gasoline/diesel vehicles with alternatively powered vehicles.

The core components of this strategy are the use of Hybrid Plug-in and hydrogen vehicles that use no oil (other than lubricants) plus the development of oil shale.

Because it will require many years for the core components of the strategy to achieve significant reductions in the use of oil or in producing oil from shale, and because these technologies may take longer to mature than has been assumed, the paper also emphasizes that oil production in Alaska and the Gulf of Mexico should proceed so as to provide oil while the core strategic components are being developed.

The paper also examines other alternatives and briefly describes their limitations in Attachment A.

A Hybrid Plug-in strategy or hydrogen strategy could allow the U.S. to achieve independence from foreign oil by around the middle of the twenty-first century: Or possibly in 30 years if oil shale development is successful.

At this juncture, it is unknown whether oil shale could be a stand alone strategy.

Other important considerations include:

- The hydrogen alternative is inefficient in so far as energy use is concerned.
- The Hybrid Plug-in alternative is only now being recognized as a viable alternative by large automobile manufacturers. General Motors has announced it plans to introduce a Plug-in Hybrid in 2008. Until now the PHEV was being developed by small entrepreneurial organizations. Hybrid Plug-in's are also less disruptive than the hydrogen alternative because they use existing manufacturing and fuel distribution infrastructure.
- The Oil Shale alternative requires massive investment, continued development of a new technology for removing oil from shale and involves some environmental problems in the immediate vicinity of any oil shale facility. The new "freeze wall" technology is far more environmentally friendly than the earlier retort process.

The core components of this strategy should be developed simultaneously and are:

Accelerate the development of Hybrid Plug-in vehicles.

- There is general agreement that PHEV's can achieve over 100 mpg, however, continued development is required to confirm this as fact.
- Continue R&D on battery technology to improve existing battery life and cost (and safety of Li-ion batteries).

Accelerate the transition to a hydrogen economy by:

- Emphasizing continued R&D for storage of hydrogen on vehicles. **Storage of hydrogen is currently the major obstacle to using hydrogen for powering vehicles.**
- Promoting the development and use of Internal Combustion Engine (ICE) vehicles propelled by hydrogen,
- Promoting the installation of distributed hydrogen fueling stations using either natural gas or electrolysis to produce hydrogen locally; or by trucking liquid hydrogen to these fueling stations from central production facilities. (Market forces would determine which method of hydrogen production will prevail long term.)
- Maintain an Hydrogen R&D program if Hybrid Plug-in vehicles prove successful.

Promote the development of oil shale:

- Oil shale production by itself may not be able to achieve independence from foreign oil; but can go a long way toward achieving oil independence.
- Oil from oil shale can also help ensure a longer term supply of domestically produced oil for use by American industry.

The supporting components of this strategy are:

A) Develop oil production at the Arctic National Wildlife Reserve (ANWR) and other domestic locations, principally in the Gulf of Mexico.

- Producing 7 million b/d of additional oil may be possible[1] (not including oil from shale). This could offset predicted declines in production and ensure oil for industry and other uses during the transition from an economy dependent on foreign oil.

B) Ensure the development of new power generating plants coupled with new transmission lines. Using PHEv's, hydrogen or oil shale will require large increases in electric generating and transmission capacity[2].

- This strategy may require between 100 and 400 gigawatts of additional new generating capacity by 2050. This is equivalent to building between 67 and 267 large, new (1,500 MW) power plants.
- Promote the development of the next generation of nuclear power plants using high temperature gas reactors that can produce hydrogen at a central location thru thermo chemical reactions.

C) Accelerate the development of bio-fuels; specifically butanol, cellulosic ethanol and bio-diesel, while increasing production of corn based ethanol.

- Ethanol from corn can offset some imported oil over the near term.
- Cellulosic ethanol and butanol can use corn stover (mostly a waste material) and could potentially use other feed stocks such as switch grass.
- Butanol is superior to ethanol and its use should be developed rapidly. In addition, once butanol is proven economically competitive, ethanol plants should be converted to butanol production[3].
- Bio-Diesel can help supply the diesel fuel needed by trucks.
- Bio-fuels may be useful later in the century when economic forces can determine the value of bio-fuels in the energy mix.

D) Continue the development of fuel cells suitable for use in automobiles.

- Market forces will dictate when **or if** fuel cells displace the ICE in hydrogen propelled vehicles.

E) Aggressively develop coal to liquid (CTL), using Fischer-Tropsch technology, to establish its viability as a back-up to oil shale. (see Attachment A for details on CTL and F-T technologies)

- Market forces will determine whether liquid fuels from coal are viable.
- Diesel fuel from F-T could help offset the portion of imported oil used for heavy trucks.

Major Additional Strategic Benefits

Economic Security.

This strategy will also improve America's economic security by removing the threat of interruptions to the oil supply that could cause oil prices to rise above $100 per barrel with resulting economic turmoil and by also **significantly improving the nation's balance of trade by reducing payments to foreign countries for oil**.

Environmental Benefit.

Eliminating gasoline for powering vehicles could reduce the nation's emission of CO_2 by 20%. CO_2 is considered by many to be the primary cause of global warming.

More Natural Gas.

Natural gas is also an important national security issue but is not addressed in this strategy. If oil production is increased in the Gulf of Mexico and elsewhere along the continental shelf, major increases in natural gas production would be possible.[4]

A New Risk?

It has long been accepted as common wisdom that oil is fungible and that it will be delivered based on economic considerations. For this reason, oil from Alaska could be delivered to Japan while equal quantities could be imported into the U.S. from Mexico or elsewhere.

For this reason, an embargo by one country (i.e., country X) may not affect oil delivered to the U. S. Country X's oil might be delivered to the EU rather than the U.S., while oil originally destined for the EU would be redirected toward the U.S.

There is a possibility that the prevailing common wisdom may not continue in the future.

Today, an increasingly large percentage of the world's oil is owned by countries; not independent oil companies such as ExxonMobil or Shell.

If there were a true oil shock, would market forces prevail or would individual countries remove oil from the market and gather it for their use?

Author's Notes:

Forecasting the price of oil is beyond the scope of this paper. The price of oil will be determined by global market forces, though removal of 10 to 20 million b/day of oil demand will exert some downward pressure on prices that may partially offset increased demand from China and India. If Europe or other areas were to develop strategies similar to the one proposed here, there would be additional downward pressure on oil prices.

All figures and calculations are approximately correct, and avoid the minutia that confuses and distorts most discussions on this subject.

The analysis is kept simple and avoids hypothetical issues such as whether savings in electricity can be transformed into savings of oil through substitution of oil with natural gas, avoids theoretical technologies and ignores incremental improvements such as would be derived from lighter weight vehicles.

Unless noted, the technologies described here are, for the most part, available today.

Introduction to Strategy

The U.S produced 9.3 million barrels of oil per day domestically from all sources[5] in 2000 while importing 10.4 million barrels per day (b/d). The Energy Information Agency (EIA) projects that domestic production will decline by 700,000 b/d by 2025. They also forecast that oil imports will be around 20 million barrels per day by 2025.

By developing domestic oil production in ANWR and the Gulf of Mexico, the drop off of 700,000 b/d by 2025 can be prevented and total domestic oil production increased.

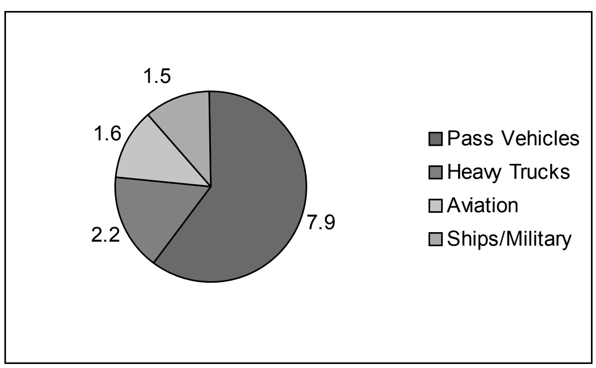
A recent report by the Minerals Management Service[6] shows that there are undiscovered economically recoverable oil resources in the Gulf of Mexico of 34 billion barrels when oil is at $40 per barrel. To this can be added the approximately 14 million barrels of known reserves (including Reserves Appreciation.)

Though it will take time to fully exploit these resources, they could produce several million b/d for fifteen or more years. The Gulf, together with ANWR, could provide most of the oil currently being imported while the core elements of the strategy are developed.

The objective is to develop the technologies (hydrogen, Hybrid Plug-in and oil shale) that allow America to become independent from foreign oil while using oil from the Gulf and ANWR to **bridge the gap** from where we are today to where we want to be in thirty years.

Maintaining U.S. domestic oil production at 9 million b/d or more is a critical element of this strategy, essential for providing oil for industrial and residential uses (see below).

Transportation used 67.5% of the 19.7 million barrels per day consumed in 2002.[7]



U.S. Transportation Oil Consumption – 2002 (13.2 Mil bbls/day)

Industrial Use of Oil Critically Important.

The remaining 6.5 million b/d in 2002 were used primarily for industry. An important aspect of this strategy is to ensure that domestic production provides sufficient oil for industrial, residential and airplane usage.

Overhang of Existing Vehicles and Population Growth.

The existing fleet of passenger vehicles creates an over hang, or fly wheel effect, that results in passenger vehicles in operation today continuing to consume oil for many years into the future. This overhang plus the growth in the number of vehicles attributable to population growth means that, even if plain Hybrids grow at a rate of 50% annually, it won't be until 2018, twelve years from now, before the consumption of oil by passenger vehicles is less than in 2002.

Hybrid Vehicles.

Only recently have manufacturer's taken Hybrids (combination of electric and gasoline powered without the ability to recharge over night) vehicles seriously, so forecasting Hybrid sales is difficult. Optimistically, if Hybrids (or their equivalents)[8] were to grow at a rate of 50% annually with repeat buyers always buying Hybrids the amount of oil consumed in 2025 would be approximately 7.2 million barrels per day. (See Attachment B.)

Thus even a dramatic increase in Hybrids, where Hybrids account for 50% of all new passenger vehicle sales in 2025, would result in only a modest reduction in oil usage of less than 1 million b/d compared to 2002**.**[9] The situation is further complicated by manufacturers shifting some of the benefits of Hybrids from gasoline savings to increases in horse power.

While Hybrids can certainly reduce the consumption of foreign oil, by themselves they will probably have only a minimal effect on achieving the strategic objective of complete independence from foreign oil. (See the section on Hybrid Plug-In vehicles.)

Ethanol and Butanol

If corn ethanol production was increased until 1/3 of the U.S. corn crop was dedicated to making ethanol, the U.S. could produce approximately 0.8 million barrels per day of corn ethanol in 2025.[10]

Cellulosic ethanol is an additional source and is still under development. This source is limited by the amount of corn waste (corn stover) available in the U.S.[9] If all the available corn stover was used to make cellulosic ethanol, the U.S. could produce approximately 0.6 million barrels of cellulosic ethanol in 2025.[12]

Pragmatically, total ethanol (corn and cellulosic combined) production could reach around 2.0 million barrels per day in 2025. For ethanol to be used in these quantities requires that vehicles be able to use a range of blends from 0 to 85% ethanol which will require modifications to existing ICE designs.[13]

Butanol is superior to ethanol and would be produced from the same feedstocks including cellulosic materials. Butanol can be used as a direct replacement for gasoline without having to modify internal combustion engines[3].

With hybrids and ethanol or butanol production as described above, the usage of oil, presumably foreign oil, would be approximately 2.0 million barrels per day less in 2025 than in 2002. The U.S. would still need to import approximately 5.2 million barrels of oil per day in 2025 for passenger vehicles.

Core Strategy Component:

Hydrogen (H2) Passenger Vehicles

The large overhang of standard passenger vehicles and hybrids (in 2025) means that H2 passenger cars will have only a small impact on the importation of foreign oil by 2025 and that independence from foreign oil will require around fifty years of H2 vehicle production.

Introducing 7,000 H2 cars in 2007 and increasing sales by 30% each year until 2025 results in sales of approximately 800,000 H2 cars in 2025 and a cumulative fleet of around 3.3 million H2 cars in 2025: This scenario results in additional oil savings of only approximately 150,000 b/d in 2025**.**

However, extending this scenario, where H2 vehicle sales increase 30% each year, and begin to exceed the sale of hybrid vehicles around 2040, the fleet of standard gasoline fueled vehicles disappears around 2045 and **imported oil for passenger vehicles stops at around 2050** where the U.S. fleet of passenger vehicles consists solely of ethanol or butanol and hydrogen powered vehicles. (Ethanol or butanol displacing oil for hybrid vehicles by 2050.)

While the use of oil for heavy trucks will remain a factor in achieving independence from foreign oil, it is possible that other innovations can keep oil usage from increasing from 2.2 million barrels per day while the numbers of trucks increase. If so, it would appear that the U.S. could achieve independence from foreign oil in around fifty years with Hydrogen powered vehicles and without Hybrid Plug-in vehicles or the production of oil from oil shale.

Hydrogen Technology and Infrastructure Requirements.

Internal combustion engines (ICE's) are fully capable of using hydrogen though they should be configured to do so when built. Using ICE's would smooth the transition to hydrogen as these engines are currently being built in U.S. factories for gasoline powered vehicles.

Fuel cells are currently ten or more times too expensive for use in passenger vehicles. If their costs can be substantially reduced, fuel cell vehicles would be about twice as efficient as ICE vehicles; and this would ultimately reduce the amount of hydrogen required in the years after 2020.

Storage of hydrogen gas on vehicles is now possible using 10,000 psi lightweight storage containers, as used in concept cars developed by BMW and others. Manufacturers will be challenged to design these cars to keep the passenger and storage space comparable to today's gasoline cars, while using these 10,000 psi containers.[14] Alternative storage systems, such as hydrides, are likely to emerge from R&D that will minimize the problem of storing hydrogen on the vehicle.

Storage remains the greatest impediment to developing production models of hydrogen powered vehicles.

The infrastructure needed to support H2 vehicles consists of hydrogen fueling stations and hydrogen production facilities coupled with considerable new power generating capacity if hydrogen is produced using electrolysis.[15]

Demonstration fueling stations exist in California and Washington D.C.; the technologies are available now. The tactics for where these stations should be located, how the system of stations should evolve over time and how they are to be financed are beyond the scope of this paper. Jump starting the process would seem to be easier with fueling stations than with other components of the system.[16]

Production of hydrogen can be done at the fueling station using either electrolysis or natural gas reforming, or can be produced centrally and trucked as a liquid to the fueling station or distributed in pipelines. All four (with the possible exception of pipelines) are viable alternatives: Economic forces should establish the best approach over time.

It would not be until around 2020 that significant new infrastructure would be required to produce the hydrogen required under the proposed scenario of 30% annual growth in H2 vehicle sales. For example, if all the required hydrogen were to be produced using electrolysis, approximately 1.5 Gigawatts of additional power generation capacity would be required around 2020.[17]

Beyond 2020 significant new power generation capacity for electrolysis or significant centralized hydrogen production will be required.

By 2025, 5 Gigawatts of new generating capacity would be required.

If all gasoline vehicles were replaced soley by hydrogen vehicles by 2050, where hydrogen was produced by electrolysis, 420 Gigawatts of new generating capacity would be required.

Nuclear power plants would be the most efficient choice, especially if Generation 4 plants capable of higher temperatures could be used to produce hydrogen with thermo-chemical reactions. Producing hydrogen in this manner would reduce the required number of new generating plants needed for producing hydrogen.

Core *Strategy Component*

Hybrid Plug-in Vehicles

General Motors announcement of its plan to produce a Saturn Vue PHEV and its unveiling of its Volt concept car signaled important support for PHEV's. Ford also signaled support for PHEV's.

Until now some small organizations had experimented by adding an extra battery to the Prius to allow the car to run on battery power for up to 60 miles[18] between battery charges, with the car switching automatically to run on gasoline when the charge is depleted thereby significantly reducing gasoline usage.

All Hybrid Plug-in's are currently experimental models, mostly made by interest groups.

Mileage estimates for a Hybrid Plug-in are up to 150 miles per gallon of gasoline[19]: The uncertainty revolves around the average distance vehicles travel daily; if they travel less than the 60 mile range of the battery they achieve the maximum mileage per gallon of gas. Whether they will be able to operate as pure electric vehicles is not known and current Hybrid Plug-in vehicles under development require the use of gasoline even at low speeds and short distances. Presumably vehicles would be recharged nightly from 120 volt outlets in the home.

On average, vehicles in the U.S. travel 12,000 miles per years: or 33 miles per day. The average is misleading because it includes weekends and ignores second cars left unused. Stop and go commuting may account for most of the miles driven which may add to the drain on the battery.

One significant issue is cost. At this early stage, cost estimates are rough at best. By one estimate, every additional 10 miles of vehicle range in electric mode adds about $1,000 to the cost of a Hybrid Plug-in vehicle. (The battery for a SUV sized vehicle could cost $10,000.) This is in addition to a $2,000 - $4,000 premium for the basic hybrid[20].

For a Prius, and presumably other Hybrids, the basic battery for normal usage costs about $4,000 (initially included in the price of the car) and must be replaced after ten years. Add to this an additional $6,000 to $10,000 for a second battery (Lithium-ion) that must also be replaced after ten years. (Current Edrive cars replace the original battery with a new Lithium-ion battery at an installed cost of $12,000)

Toyota says that the price of the replacement Nickel-Metal Hydride (Ni-MH) battery will eventually cost only $1,000. The cost of the replacement Lithium-ion battery is not expected to come down any time soon.

Batteries are, in fact, the largest unknown in the Hybrid Plug-in strategy. By one account it will require several years for battery and car manufacturers to develop batteries that are cost effective and capable of the deep and repetitive discharging required by this application. Lithium-ion batteries need to be made that avoid thermal runaway and the resulting concern about safety.

Recent news is encouraging and could indicate that Li-ion batteries that meet automobile manufacturers requirements could be available by mid 2008.

A123 Systems, a maker of Lithium-ion batteries, has said it will begin marketing a Li-ion battery pack in 2008 for third party conversion of hybrids to Plug-in Electric Vehicles (PHEV's). GM has announced it will test Li-ion batteries from two manufacturers and expects to complete its tests by mid 2008.

The first cost of a hybrid plug-in vehicle would therefore be about $10,000 more than a standard vehicle but would also entail battery replacement costs of around $7,000 after approximately ten years[20]. It would be expected that Hybrid Plug-in vehicles would pay for their added cost with fuel savings over the life of the vehicle.

The first cost of a hydrogen vehicle might initially be around $5,000 more than a standard vehicle and would not require the replacement battery cost. (See table.)

Consumers tend to make buying decisions based on first cost rather than lifetime costs: Witness the low sales of relatively inexpensive (compared to a car) compact fluorescent bulbs even though compact fluorescents more than pay for themselves over their lifetime.

A computer projection of gasoline usage by Hybrid Plug-in vehicles shows that a Hybrid Plug-in strategy might be able to achieve independence from foreign oil.

Using the same introduction date and quantity (i.e., 7,000 vehicles in 2007) and the same 30% annual increase in sales for both the hydrogen and Hybrid Plug-in vehicles, with each achieving 80% of new vehicle sales in the computer projection, results in the hydrogen vehicle using around 1.5 million fewer barrels per day than the Hybrid Plug-in by 2050: But oil usage by the Hybrid Plug-in is well within the range of feasibility re the stated objective; independence from foreign oil.

In making these projections it is assumed that the Hybrid Plug-in vehicle gets five times greater mileage than today's average car: This translates into between 100 to 125 mpg. It is assumed that the Hybrid Plug-in and remaining standard vehicles would use ethanol or butanol rather than oil by 2050.

The situation is further complicated by manufacturers shifting some of the benefits of Hybrids from gasoline savings to increases in horse power.

One variable is whether 100 mpg gas mileage can be maintained at highway speeds over 55 mph[23]. Also of concern is whether battery technology can advance to the point where batteries are not adding an unacceptable surcharge over standard gasoline vehicles.

The accompanying table compares hydrogen and Hybrid Plug-in Vehicles:

Table comparing hydrogen and Hybrid Plug-in vehicles.

	Hydrogen Vehicle	Hybrid Plug-In Vehicle
Infrastructure Investment	Requires fueling stations (probably located with existing gasoline stations.)	Uses existing gasoline stations.[a]
Infrastructure Investment	Many new power plants; perhaps as many as 276, large 1500 megawatt power plants.	Many new power plants; perhaps as many as 67, large 1500 megawatt plants.
Probability of achieving independence from foreign oil.[b]	Nearly 100%	Nearly 100% when used in combination with ethanol or butanol.
Initial Cost Premium Over Standard Vehicle.[c]	~$5,000[d]	~$10,000; plus replacement cost of $7,000 for batteries after approximately ten years usage.[e]
Safety	Appears to be as safe as gasoline; but requires acceptance by public.	Battery disposal may be a problem. Li-Ion batteries need to avoid thermal runaway.

a) An unintended consequence of a drastically reduced need for gasoline is the probable closure of many gasoline stations making it more difficult to buy gasoline conveniently.
b) In both instances it is assumed that the technologies currently exist to produce these vehicles.
c) These cost premiums are speculative at this time.
d) Department of Energy (DOE) target is $100 per kg of storage by 2020. Where 1kg equals approximately 1 gallon of gasoline, the equivalent of a 20 gallon gasoline tank would cost $2,000.
e) Battery costs could be lowered with high volume manufacturing. By one analysis, it may be possible to eventually cut the initial cost premium by two thirds, though this is highly speculative at this time.

Core Strategy Component

Oil Shale.

The history of oil shale in the U.S. goes back to the late 1800's when oil was extracted using primitive retorts by essentially cooking pieces of shale to loosen the oil.

Oil shale[24] became an important issue with the 1973 oil embargo which precipitated large investments in oil shale production. The industry went bust, however, when oil prices collapsed in the 1980's: Around $5 billion were lost before the last of the companies gave up in 1992.

Total U.S. oil shale resources are estimated to be 1.8 trillion barrels; concentrated in Utah, Colorado, and Wyoming. Over 50% of the world's recoverable oil shale deposits are located in this area: 80% of these resources are on Federal lands.

By one estimate, 300 billion barrels of oil could be recovered from these shale deposits.

There are two methods for producing oil from shale.

The surface retort method:

> This is the proven method for extracting oil from shale and dates back to the late 1800's. It involves mining the shale and then heating the shale to extract the oil. One ton of ore is required to produce a barrel of oil.
>
> Environmentalists have hated this method as it uses large amounts of water, produces air emissions where there currently are none and leaves large areas of finely broken shale and water residue behind. Producing a million barrels of oil requires disposing of more than a million tons of byproducts[25]. Greenpeace lobbied hard to have Australia's single oil shale plant shut down.
>
> One company, Oil Tech, has developed a proprietary retort and believes that an enlarged version could produce 1,000 barrels per day.

The in Situ method:

> This method, being developed by Shell, heats the shale underground to vaporize the oil while freezing the surrounding shale to entrap the vaporized oil and drafting it to a production well for removal.
>
> The next step in developing this process is to test the freezewall technology where wells are drilled around the recovery area so as to form a "freezewall" when existing water trapped underground is frozen to form an impenetrable barrier thousands of feet deep. Holes are then drilled within the perimeter of the freezewall so that heaters can be dropped down the holes to heat the enclosed area to around 700 degrees F.
>
> Shell believes that this method is less costly and may have less environmental impact than the retort method: Land restoration costs are minimal. Shell believes the process can recover around 60% of the entrapped oil compared with 30% for the surface retort method.
>
> Shell is about five years from deciding whether to commercialize the process.

The major barrier to developing oil shale is the large investment required. Memories of the 1980's collapse in oil prices are a major impediment in this regard.

The Alberta Energy Research Institute estimates that it requires an investment of $US 3.3 billion to produce 100,000 barrels per day (b/d) of crude oil from Canadian Tar Sands. Lacking industry estimates for oil shale investment, the Tar Sands may represent a surrogate for oil shale investment requirements. If so, an investment of over $US 30 billion would be required to produce 1 million b/d of oil from oil shale.

Compounding the high investment requirements for oil shale production is the lack of pipeline capacity, water availability, power distribution, and refining capacity in this region of the Rocky Mountains[26].

The US Congress' Committee on Resources published a table indicating that 4 million b/d of oil could be produced from oil shale by 2030 [27].

Using the Tar Sands surrogate, an investment of $120 billion would be required to produce the 4 million b/d of oil from oil shale.

The recent energy bill made initial tentative steps towards encouraging oil shale development. It requires the Interior Department to begin leasing Federal lands within 2.5 years as the next step, following the Bureau of Land Management 160 acre leases that started only recently. It also eliminated an 85 year old law that limited companies to only one oil shale lease nationwide.

Already there is a backlash concerning these first tentative steps, as editorialized by the Denver Post threatening environmental impacts. While there may be clear benefits to America for developing oil shale deposits, the environmental community could delay significant progress.

Congressional hearings could result in federal policies that encourage oil shale development. Currently, the closest step to industrial policy is through the Pentagon fuel program which buys 300,000 barrels of oil per day. Starting in 2009 the military may earmark a portion of that spending for fuel specifications that match oil shale.

A strategy that includes the development of oil shale deposits could accelerate the point at which the United States achieves independence from foreign oil.

Producing oil from shale requires large amounts of electricity. Extrapolating a Rand study, it would require 120 Gigawatts of new generating capacity to produce 10 million barrels of oil per day.

Assuming a strategy involving hydrogen or Hybrid Plug-in vehicles or a combination thereof, together with the other elements of the strategy described herein (e.g., cellulosic ethanol, development of other oil resources such as ANWR) it may be possible to achieve independence from foreign oil in around 30 years if oil shale is included in the strategy.

Conclusion

It will take time to achieve independence from foreign oil: time that world events may not accommodate. In a very important way***, time is our enemy***.

Doubling gasoline mileage by adopting hybrids and other technologies will have only a modest effect on reducing oil consumption. Hybrids and ethanol or butanol can assist in the transition: Ethanol or butanol may have a role to play later depending on market forces. Wind, solar, geothermal and other similar alternatives cannot achieve independence from foreign oil. (See Attachment A.)

Development of domestic oil resources in ANWR and the Gulf of Mexico could supply a significant portion of the oil used for vehicles over the next few decades and help bridge the gap from where we are today to where we could be in thirty years with oil shale, Hybrid Plug-in and hydrogen vehicles achieving independence from foreign oil. Incremental production from ANWR and the Gulf of Mexico could start in around four years if the government allows development to proceed.

Adoption of the hydrogen alternative can achieve independence from foreign oil in around fifty years. Storage of hydrogen on vehicles remains the single greatest obstacle to producing hydrogen powered vehicles. Long term, market forces can determine the best ways to produce and distribute hydrogen.

Adoption of the Hybrid Plug-in vehicle alternative can also achieve independence from foreign oil in around fifty years. The alternative involves important uncertainties; specifically, how quickly battery technology can lower costs and, for Li-Ion batteries, improve safety.

Adopting both the hydrogen and Hybrid-Plug-in alternatives introduces competition and market forces while helping ensure success.

The oil shale alternative coupled with the hydrogen and Hybrid Plug-in alternatives could allow America to achieve independence from foreign oil in thirty years rather than the longer time frame if only the hydrogen or Hybrid Plug-in alternatives are adopted.

The strategy will also improve America's economic security while reducing CO_2 emissions.

Related Effects.

Every major change in the economy has side effects; this one will be no different.

- This strategy will also improve America's economic security by removing the threat of interruptions to the oil supply that could cause economic turmoil and by also **significantly improving the nation's balance of trade by reducing payments to foreign countries for oil.**
- Eliminating oil for powering vehicles could reduce the nation's emission of CO_2 by 20%[28]. CO_2 is considered by many to be the primary cause of global warming.
- Achieving independence from foreign oil will help insulate America from the burgeoning consumers of oil in China and India.
- Federal highway spending is largely funded by the gasoline tax. The increased number of hybrids could reduce the amount of funds from the gasoline tax by as much as 10% by 2025. Hydrogen and Hybrid Plug-in vehicles could also result in a huge reduction in Highway Trust Fund (HTF) revenues by mid century. However, traffic will continue grow as the number of vehicles increase with population growth. Thus, policymakers need to identify new sources of funding to ensure that the nation's investment in highway infrastructure keeps pace with the additional vehicle travel.

Attachment A

Alternative Proposals for Achieving Independence from Foreign Oil

a) A recent DOE report on Coal to Liqids (CTL) using the Fischer-Tropsch process determined that an ROI of 20% could be achieved with the price of oil at $61. However, it also determined that the ROI would be less than 10% with the price of oil at $40 per barrel.

These economics indicate that CTL is an unlikely component of any strategy for achieving independence from foreign oil. In the U.S. the process would probably use gas produced from coal as its source material. F-T could become a fall back alternative if oil from shale and increased production of oil from other domestic sources is not possible.

Liquid fuels derived from the Fischer Tropsch (F-T) process have been produced since before WWII. Germany made extensive use of such fuels during WWII. SASOL in South Africa has used low grade coal to produce liquid fuels since the 1950's. SASOL currently produces around 200,000 barrels per day of liquid fuels in South Africa.

Most other F-T plants have used natural gas to produce liquid fuels. Some energy companies are proposing F-T to make use of stranded natural gas. Some are exploring liquid fuels from natural gas (GTL or Gas to Liquid) as an alternative to shipping liquefied (cryogenic) natural gas. Using natural gas in the U.S. to make liquid fuels does not reduce America's dependence on foreign sources. Exxon Mobil Corp., Royal Dutch/Shell Group and ChevronTexaco Corp., have committed $20 billion to build GTL facilities in Qatar using that country's huge natural gas reserves.

To make liquid fuels from coal requires that coal first be converted to a gas. DOE is providing part of the investment for a demonstration CTL plant in Orlando Florida. By one source it requires 2.8 million tons of coal for each 10,000 barrels per day of liquid fuel.

The diesel fuel produced from F-T is excellent and can be used directly or as a blend with oil derived diesel fuel.

See Baseline *Technical and Economic Assessment of a Commercial Scale Fischer-Tropsch Liquids Facility, Final Report;* issued by DOE 4/9/07

b) Electric vehicles were once thought to be the logical replacement for gasoline and diesel propelled vehicles.[29] Electric vehicles were to use batteries that could be recharged while parked. Several decades of research have failed to develop a battery that provides the range let alone the weight and cost requirements needed for a passenger vehicle. The physics of batteries, barring a revolutionary discovery not now envisioned, precludes the possibility that a suitable battery will be invented in the next several decades....if ever. The Lithium Ion battery, currently the most promising, costs around $30,000 for a battery that meets the required range to be commercially acceptable. For these reasons, electric vehicles are not considered a viable option.

Attachment A, Continued.

Alternative Proposals for Achieving Independence from Foreign Oil

c) Renewable energy such as wind, solar, geothermal and hydro all generate electricity; and except for the very small percentage of electricity generated from oil (2.5%) electricity from these renewables does not replace oil. The only renewables that can displace foreign oil are so called bio-fuels, such as cellulosic ethanol. Wind, geothermal, solar and hydro are therefore not viable alternatives for achieving independence from foreign oil. The land area required to generate electricity from renewables, to produce the required quantity of hydrogen, is prohibitively large.

d) Conservation, sprawl and transit are frequently touted as being ways to eliminate dependence on foreign oil: None of these concepts can achieve independence from foreign oil.

e) Canadian Tar Sands can produce oil for around $18 per barrel. There are sufficient tar sands to provide oil for Canada and America for many years into the future. Accepting that Canada is a friendly country, an argument could be made that America should rely on this resource for oil; assuming the Canadian government was willing to agree to such a course of action.

   Aside from having to rely on the best intentions of the Canadian people, such a strategy would require government intervention in the form of investment or guaranteed financing. Mid East oil can be produced for around $5 per barrel and the OPEC cartel could lower its price to below $18 thereby making investments in tar sands a loosing proposition. This threat could keep private investors from making the kind of commitment required for tar sands to produce 8 million barrels/day for the U.S. market plus whatever Canada's needs might be: Current Canadian Oil consumption in total is 3 million barrels/day. In addition the investment is huge, possibly 200 billion dollars. The time required to complete such a huge undertaking would also probably preclude this as a viable option.

   Total oil production from tar sands in Canada is currently only around one million barrels/day. Plans are to double or triple this output by 2015.

   In view of these factors, tar sands are not considered a viable option for the U.S. to achieve independence from foreign oil.

f) Corporate Average Fuel Economy (CAFE) standards. If, beginning in 2010, all new cars obtained twice the mileage as current passenger vehicles; they would still consume around 4.6 million barrels of oil per day in 2025. After 2025, without hydrogen or Hybrid Plug-in vehicles, oil consumption would increase beyond 4.6 million barrels per day as the number of vehicles increase in line with population growth.

Attachment B

Supporting Data For Strategy to Achieve Independence From Foreign Oil

Source Data Input			Source	
Number of Passenger Vehicles	135,920,677	2002	http://www.bts.gov/publications/national_transportation_statistics/2004/html/table_01_11.html	
Number 4 wheel trucks (SUV's, PU Trucks, Vans)	85,011,305	2002	http://www.fhwa.dot.gov/policy/ohim/hs03/htm/mv1.htm	
Total Vehicles	**220,931,982**	2002		
Number of Passenger Vehicles	135,669,897	2003	http://www.bts.gov/publications/national_transportation_statistics/2004/html/table_01_11.html	
Number 4 wheel trucks (SUV's, PU Trucks, Vans)	87,031,553	2003	http://www.fhwa.dot.gov/policy/ohim/hs03/htm/mv1.htm	
Total Vehicles	**222,701,450**	2003		
Population 2003	290,809,777	2003	http://www.census.gov/	
Population 2050	419,854,000			
Vehicle sales Cars & light trucks	17,000,000	2003	http://www.bea.gov/bea/dn/gap_hist.xls	
bbls oil per day used for passenger vehicles (**See note 30 a)**	7,900,000	2002	Winning the oil endgame by Lovins and	http://www.eia.doe.gov/emeu/aer/txt/stb0513c.xls
bbls of oil per day per vehicle	0.036	2002		
For Pass Cars			http://www.fhwa.dot.gov/policy/ohim/hs03/htm/mv9.htm	

		2004	2005	**2025**	**2050**
Vehicle Sales Annual Estimated		**17,229,139**	**17,363,526**	**20,282,665**	**24,631,103**
20% of annual estimated sales =		3,445,828	3,472,705	4,056,533	4,926,221
50% of annual estimated sales =		8,614,570	8,681,763	10,141,332	12,315,552
80% of annual estimated sales =		13,783,311	13,890,821	16,226,132	19,704,883

		2004	2005	2025	2050
Passenger Vehicle Forecast Increase due to population growth; Maintaining ratio of population to vehicles (See notes 30 a & b)	0.78%	**224,438,521**	**226,189,142**	**264,215,829**	**320,861,555**
				39,777,308	**96,423,033**
Cross check ratio population to passenger vehicles 2003 and 2050	1.305827946				1.308520743

Attachment B Continued

Oil Consumption Tables

	2004	2005	**2025**	**2050**
Oil Consumption No hybrids & No H2 Cars				
bbls oil per day, spread sheet estimate	8,025,385	8,087,983	9,447,727	
bbls oil per day from EIA in 2025	>>>>		9,400,000	

Impact of Hybrid Vehicles

	2004	2005	**2025**	**2050**
When sales of hybrids increase 50% annually with hybrid sales limited to 50% total vehicle sales: Except repeat buyers buy Hybrids				
Vehicles standard	224,238,521	225,839,142	141,820,923	
Residual Hybrids from prior sales	100,000	200,000	112,253,574	
Number Hybrid Vehicles 50% increments	100,000	150,000	10,141,332	
Vehicles Hydrogen	0	0	0	
Total vehicles	224,438,521	226,189,142	264,215,829	
Bbls of oil used with 50% increase per yr of hybrids				
Vehicles standard	8,018,234	8,075,468	5,071,177	
Vehicles hybrid with 1/2 yr usage of current yr sales	2,682	4,917	2,097,617	
Total oil used bbls per day	8,020,916	8,080,385	**7,168,795**	

Attachment B Continued

Impact of Hydrogen Vehicles

		2004	2005	**2025**	**2050**
When sales of hybrids increase 50% annually with hybrid sales limited to 50% total vehicle sales: Except repeat buyers buy Hybrids; H2 vehicle sales increase 30% annually until 50% of total new vehicle sales					
Vehicles standard		224,238,521	225,839,142	141,281,189	0
Residual Hybrids from prior sales	**(See note 30c)**	100,000	200,000	109,468,795	144,539,299
Number Hybrid Vehicles sales in 50% increments		100,000	150,000	10,141,332	12,315,552
Vehicles Hydrogen from prior sales		0	0	2,537,324	151,691,153
Number Vehicles Hydrogen sales in 30% increments	**(See note 30d)**	0	0	787,188	12,315,552
Total vehicles		224,438,521	226,189,142	264,215,829	320,861,555
Bbls of oil used with 50% sales increase per yr of hybrids					
Vehicles standard		8,018,234	8,075,468	5,051,878	0
Vehicles hybrid with 1/2 yr usage of current yr sales		2,682	4,917	2,047,829	2,694,284
Adjust for half year effect on std vehicles from new H2 sales		0	0	14,074	0
Total oil used bbls per day/ Except 2050 Ethanol		8,020,916	8,080,385	**7,099,707**	**2,694,284**

Attachment B Continued

Ethanol Production			Source
Corn Ethanol Production 2004 Gallons/ year	3,563,200,000		http://www.ethanolrfa.org/eth_prod_fac.html
Corn Ethanol Production '05 increase G/year	500,000,000		http://www.ethanolrfa.org/Economic_Contribution_2004.PDF
Corn Ethanol Output Increase/year until Max Limit	110.00%		Note: After 2007. 2007 is actual as of March from ethanolrfa.org
Max Limit = 33% of 2004 Acres	33.00%		
Max Limit of Acreage Devoted to Corn	26,070,000		
Cellulosic Ethanol per plant bbls per year	1,425,689		
Corn Stover available for Cellulosic Ethanol in US	100,000,000	dry tons	http://www.nrel.gov/docs/fy04osti/33893.pdf
Maximum Cellulosic Ethanol From Avail Stover	166	plants	
Corn Stover per required per plant	603,513	tons	
Acres of corn in 2004	79,000,000	acres	http://www.ethanolrfa.org/Economic_Contribution_2004.PDF
Percentage used for Corn Ethanol	13%		
Acres used for Corn Ethanol	10,270,000	acres	
1 gallon equals	0.031746	bbls	
Underdeveloped farmland	30,000,000	acres	
Celulosic available from underdeveloped land	94,936,709		Based on stover from 79 million acres of corn at 250 million tons total

	2004	2005	2006	2007	**2025**
Acres used for corn ethanol, approximate	10,330,351	11,153,568	11,976,784	12,800,000	26,063,397
increased capacity corn ethanol bbls per day		24,696	24,696	24,696	0
Production of Ethanol from Corn bbls per day	309,911	334,607	359,304	384,000	**781,902**
Cellulosic Ethanol Plants	0	1	2	5	20
Total Cellulosic Ethanol plants	0	1	3	8	166
Production of Cellulosic Ethanol bbls per day	0	3,906	11,718	31,248	**636,678**
Total Ethanol bbls per day	**309,911**	**338,513**	**371,022**	**415,248**	**1,418,579**
Additional ethanol from additional 30 million acres of underdeveloped farmland					**604,441**
Total Ethanol Including 30 million underdeveloped farmland					**2,023,020**

Attachment B Continued

Hydrogen Production (To determine approximately when electricity demand becomes significant)

Conversion Factors		
BTU content per gallon of gas	125,000	BTU's
1kwHr produces BTU of H2 @ 100% conversion efficiency	3,412	BTU's
1kwHr produces BTU of H2 @ 70% conversion efficiency	2,388	BTU's
hours in year	8760	hours
1 barrel (petroleum)	42	gallons
BTU per barrel (of gasoline)	3,937,500	BTU's

Assumptions For Hydrogen Production.

Each hydrogen vehicle travels 10,000 miles annually.		10,000	
Each H2 vehicle uses 1 kg of H2 for each gallon of gasoline displaced.			
Miles per gallon		40	
ICE cars not Fuel Cells. FC Cars should be twice as efficient but these are ICE's			
	2004	2005	2025
Number of miles for H2 vehicles from spread sheet above		0	33,245,123,109
gallons of gasoline displaced by H2 vehicles		0	831,128,078
BTU content		0	103,891,009,714,876
Kwhrs to produce comparable amount of hydrogen BTU's at 70% efficiency			43,498,161,830
MW required to generate required Kwhrs with .91% capacity factor			5,457

Note 30 for notes about tables

Notes:

Note 1: A report prepared by the Congressional Committee on Resources indicated that domestic oil production could be increased by 17.2 million b/d from various North American sources, including 4 million b/d from oil shale. It also included 6.1 million b/d of oil from Canada. By definition, Canadian production is foreign oil and would not be included in this strategy.

Note 2: See *Nuclear Power's Role in Breaking America's Addiction to Foreign Oil*, American Nuclear Society June 2006.

Note 3: Butanol is superior to Ethanol for the following reasons:

- It contains more energy than Ethanol.
- It can be transported in pipelines while Ethanol must be shipped by truck, rail or barge.
- There is no need to modify Internal Combustion Engines (ICE) as is the case with Ethanol.

Butanol contains 110,000 BTU's per gallon versus only 84,000 BTU's per gallon for Ethanol. Gasoline contains 115,000 BTU's per gallon so Butanol is virtually a 1 for 1 replacement. This translates into essentially the same mileage per gallon as gasoline while Ethanol gets fewer miles per gallon.

There is no need to manufacture special Flex Fuel vehicles since Butanol does not attack the piping etc. of the ICE. Ethanol is limited to around a 10% mixture with gasoline before ICE modifications are required.

Environmental Energy Inc. and DuPont/BP have published information on Butanol.

Note 4: See *Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf, 2006* published by the U.S. Department of the Interior Minerals Management Service. This report indicates there are approximately 420 Trillion Cubic Feet of natural gas technically recoverable from the Outer Continental Shelf. The economically recoverable amount of natural gas is considerably less and is estimated by region in the report.

Note 5: This is the difference between total consumption and imports: It includes items such as natural gas liquids. Actual domestic crude oil production in 2000 was 5.8 million barrels per day

Note 6 See *Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf, 2006* published by the U.S. Department of the Interior Minerals Management Service. The report indicates there are 86 billion barrels of technically recoverable oil from the nation's outer continental shelf. The report contains charts depicting the economically recoverable oil be region.

Note 7: The distribution of usage between segments, i.e., cars, trucks, heavy trucks, airplanes etc., is assumed to be the same in 2002 as in 2000. Passenger vehicles are the combination of cars and light trucks.

Note 8: Forecasts are based on hybrids obtaining twice the mileage as today's passenger vehicle. Presumably some vehicles will double their mileage using other technologies and these vehicles are included as Hybrids in the forecasts.

The forecast growth of hybrids in this report is very optimistic: J. D. Powers, for example, predicts that hybrids will only capture 3% of the market by 2010.

Passenger vehicles include light trucks.

Note 9: Current forecast of oil consumption in 2025 = 20.6 million barrels per day, of which:

- 9.4 million barrels per day is for passenger vehicles.
- 2.5 million barrels per day is for heavy trucks
- 1.6 million barrels per day is for airplanes.

Note 10: Approximately 13% of the 2004 acreage devoted to growing corn was dedicated to making ethanol.

Note 11: Approximately 250 million tons of corn stover are generated annually of which around 150 million tons have other agricultural uses leaving 100 million tons available as waste.

Note 12: It is conceivable that additional cellulosic ethanol could be produced in later years using other feed stocks such as switchgrass and industrial waste. This could increase the amount of cellulosic ethanol output by as much as .6 million barrels per day.

There are 30 million acres of underused farmland enrolled in the Conservation Reserve. Though much of it is too arid to grow corn it could be used to grow switchgrass. If all 30 million acres were used to grow switchgrass, total cellulosic ethanol production could be xxx million bbls/day.

Note 13: So called Flex vehicles are in production in Brazil where ethanol is widely available.

Note 14: While some technologies such as high pressure storage of hydrogen have been developed, there are many technologies that will evolve over time following the introduction of hydrogen vehicles. For example, storage of hydrogen on vehicles may ultimately be accomplished with hydrides or carbon nano structures.

For more comprehensive information on alternative technologies and the long range infrastructure requirements refer to *HYDROGEN TODAY, The current status of H2 and Fuel Cells with a review of alternatives:* And, *HYDROGEN*: *REALITY AND POLICY, The challenge and the alternatives.* Both papers are available at www.tsaugust.org

Note 15: Vehicles with both hydrogen storage and gasoline storage could reduce the problem of H2 fueling stations allowing for the use of gasoline when H2 fueling stations are not available: This tactic would reduce the savings in gasoline but might facilitate the introduction of H2 vehicles.

Note 16: One possibility for jump starting the installation of hydrogen fueling stations is through government-private partnerships. In this approach, separate corporations could be established between the federal government and each of the oil companies; the government would provide the funds needed for equipment and share 50/50 in profits while the oil companies would provide land, labor, management and marketing. A buyout provision would allow the oil companies to acquire the government's share in a manner that could allow the government to recover its investment.

This would solve the chicken and egg situation that currently exists; where vehicles need hydrogen while fueling stations need vehicles. Fueling stations, as free standing components of the system, are most amenable to interjecting a starting mechanism to resolve the chicken and egg dilemma.

Note 17: Whether hydrolysis units could become home appliances or fitted into cars for producing hydrogen by plugging the vehicle into an outlet at home will be determined by market forces.

Note 18: Edrive, a company dedicated to converting Prius Hybrids to Hybrid Plug-in vehicles, says; “the Prius can run in electric only 'EV' mode at lower speeds or when less power is needed. The result is EV driving and electrically boosted gasoline driving for the first 50 to 60 miles with a gasoline efficiency of 100 to 150mpg. After the 50-60 mile 'boosted' range, the vehicle performs just like a standard Prius until it is plugged in again”.

Note 19: Some commentators have referred to Hybrid Plug-in’s achieving gasoline mileage of 500 mpg. They make this claim by assuming the use of an ethanol gasoline mixture. This hyperbola may be true, but it distorts the actual gasoline mileage performance of Hybrid Plug-in vehicles.

Note 20: “In projecting consumer demand for hybrids, J.D. Power and Associates has assumed a $4,000 price premium for hybrids compared with traditional vehicles”: From 3/30/05 Automotive News.

Note 21: With a 90% learning curve the cost of the $10,000 battery would be nearly cut in half by 2025.

Note 22: In 2050 the computer projection on which this report is based indicates that hydrogen vehicles represent over 80% of all vehicles (except heavy trucks) and that total oil usage is 2.5 million bbls/day. Similarly in 2050 total oil usage is 3.9 million bbls/day when over 80% of vehicles are Hybrid Plug-in vehicles. At these low levels of oil usage it is entirely possible that ethanol or butanol could replace oil so that no oil would be used for cars, light trucks and SUV’s.

Note 23: Edrive states that “because of the configuration of the Prius, electric use is limited to 21kW and often less. At speeds over 34mph, the electrical contribution is more or less constant. You may find at 55mph that 1/4 of the power is coming from gasoline and 3/4 from electricity, but at 75mph the contribution may be 2/3rd gas and 1/3rd electric. Even though the electric contribution is the same in both cases, the gasoline contribution (and thus mpg) can be dramatically different.”

Note 24: The term "oil shale" refers to an organic material called kerogen, which is a precursor of petroleum. Typically oil shale contains between 5 and 25 percent kerogen.

Note 25: From statement by Mark Maddox, Principal Deputy Assistant Secretary for Fossil Energy, Before the Subcommittee on Energy and Mineral Resources Committee on Resources, U.S. House of Representatives, June 30, 2005

Note 26: ibid

Note 27: A report prepared by th Congressional Committee on Resources indicated that domestic oil production could be increased by 17.2 million b/d from various North American sources, including 4 million b/d from oil shale. It also included 6.1 million b/d of oil from Canada. By definition, Canadian production is foreign oil and would not be included in this report.

Note 28: See *Stabilizing CO2 in Atmosphere at Current Levels to Stop Global Warming* from www.tsaugust.org

Note 29: Electric scooters have been proposed by some as an alternative transport method for driving to work or running errands in the local community. Electric scooters (or golf cart like vehicles) were not considered here as it is doubtful that the public will accept such vehicles for everyday use.

Note 30: Comments re Tables:

a. The EIA reports that total gasoline consumption expressed as barrels of oil was 8.7 million barrels of oil and included gasoline used by boats etc.
b. It is assumed that there is no increase or decrease in miles driven.
c. It is assumed that cars are scrapped at 14.5 years of age. This may be a shorter life than recent history.
d. Hydrogen vehicle sales are increased 30% each year until they equal hybrid sales. Realistically, at some point around 2035 through 2045 hydrogen vehicle sales would increase at the expense of hybrid vehicles. Since the ratio of population to vehicles is fixed, the life of hybrid vehicles or the number of new vehicles sold each year needs to be reduced in the spread sheet formula after 2025. These are unknowns that are not accommodated for in the spread sheet. The tables are adjusted for year 2050 to show 7,250,000 fewer hybrid vehicles to reflect these factors.
e. Butanol production as measured by volume would be approximately the same as ethanol production. The miles driven per bushel of feedstock would be greater with butanol. Butanol has 42% more energy than ethanol. For the sake of simplicity the forecast assumes ethanol is a 1 for 1 substitute for gasoline though ethanol gets fewer miles per gallon than gasoline. Butanol, however, is a 1 for 1 substitute for gasoline so the forecasts are accurate for butanol.

