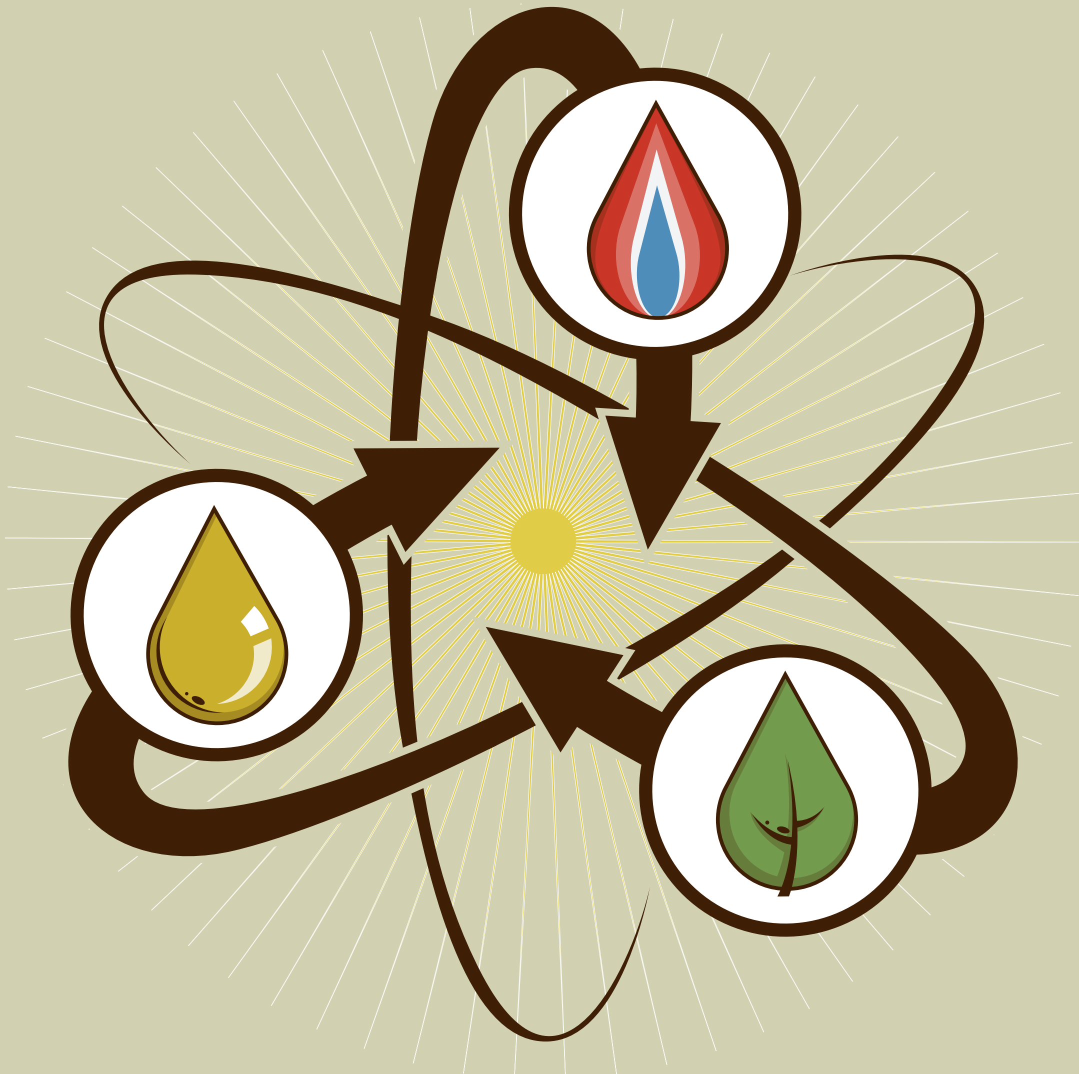

Energy

PRESENT & FUTURE

Common Sense
for Concerned Americans

By Robert P. Smith, Ph.D., P.E.

ENERGY

~

Present and Future

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Dedicated to all Americans: present and future. May my generation leave them a country that is prosperous and secure.

Acknowledgements: Friends and family who all helped and encouraged, or sometimes just tolerated, this engineer: Judy, Powl, Lana, Jason – many thanks.

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I. INTRODUCTION

Overview

This paper is about energy: how much there is, what types there are, how much is being used, who controls it, and what options are available to Americans.

The 2008 oil price spike sparked debate on the entire spectrum of energy alternatives. We are approaching the end of an era, and profound changes lay ahead of us. This paper summarizes facts about energy that can give us a better understanding of what we can expect in current and future energy options and what we should be doing to effect good energy practices and government policy.

Executive Summary

- Despite the recent fall in oil prices, the era of cheap oil is over. Nevertheless, the U.S. has extensive reserves of coal, shale oil, and nuclear fuel, and these can provide reasonably priced electricity and liquid fuels for at least the next 200 years; nuclear power even longer. Natural gas reserves are once again rising because of new technologies in extraction.

- The U.S. has abundant supplies of non-conventional oil. Shale oil and coal-to-liquids technology can produce gasoline and diesel fuel in the $3 per gallon range for many decades, with at least a 200-year supply.

- Conservation and utilizing energy efficiencies are always good practices. The U.S. is already becoming more energy efficient every year – and without mandated restrictions.

- The U.S. must have a reliable and affordable energy supply as a matter of national security. Economic growth will require adequate and economical sources of energy. Though well-intentioned, many environmentalists and certain congressional members are blocking practical energy alternatives simply because they are not perceived as “renewable,” without fully understanding the harmful consequences of this obstruction.

- The theory of man-made global warming is not based upon thoroughly vetted science. Data over the past decade indicates that no warming has occurred since 1998, and 2007 and 2008 are two of the coolest years in the past fifty. Historical and sunspot data indicate temperatures will decline over the next twenty years. Faced with mounting opposition from thousands of scientists citing fact-based research, global warming advocates are now adopting the term "climate change." Public policy formulated with global warming as its premise could be extremely counter-productive to economic growth.

- A new generation of more fuel-efficient vehicles will be on the market in 2010 and thereafter. Longer term, plug-in electric hybrids built from composite materials that can routinely achieve over 60 mpg will be safer and better alternatives for the future.

- Wind energy can provide a portion of electrical power, but its potential is limited. Wind is unreliable: it only generates electricity when and where the wind is blowing. Wind energy requires backup, such as coal, nuclear or gas turnbine, to make it reliable.

- Solar energy will have a place long term, but faces major challenges. Development of a cheap and efficient photovoltaic cell is needed, although Thin Film Photovoltaic technology shows promise. Large-scale solar power is unreliable – nights and cloudy days yield no power – but Solar Tower Power technology may be viable in the long term. The intermittent nature of both solar and wind power currently limits their reliability and hence their cost effectiveness.

- The U.S. Congress is blocking energy initiatives that could help the U.S. in cost and supply. These include:
  - Domestic oil exploration offshore, in Alaska, and on federal lands;
  - Coal-to-liquid fuels for secure military and domestic supply;
  - Permitting for shale oil development and recovery in western states;
  - Fast track permitting for nuclear plants.

- Carbon taxes and caps, combined with mandated requirements for "alternative energy" sources will drive up the cost of fuel and electricity. This will increase the cost of food, fuel, and utility bills. These higher costs will cause disproportionate hardship on those who can least afford it: middle class and lower income citizens.

Paper Format and Sources

The writing style of this paper is intended to make it as readable to the ordinary person as possible. The format often poses a question followed by an answer. This is not an academic paper. There are no footnotes or citations. The sources were authoritative books and technical papers on related subjects (listed at the end of paper); articles and publications such as the *Wall Street Journal*, *Scientific American*, the Rocky Mountain Institute, the Dallas Morning News and *The Economist*; and energy reports, technical papers, data sources obtained (and cross-checked) through the Internet from sites such as Energy Information Administration of the U.S. Department of Energy, and the International Energy Agency.

A series of tables at the end of this paper indicate the major energy reserves and which countries control them. These tables are:

Table 1	World Oil Reserves
Table 2	Oil Use in the U.S. by Sector
Table 3	World Coal Reserves
Table 4	World Natural Gas Reserves
Table 5	Natural Gas Exports and Imports
Table 6	Worldwide Uranium and Thorium Reserves

The Current Situation

Why is it important for Americans to educate themselves about energy right now?

Americans are in the process of making decisions with respect to energy that will affect the future of our nation. Those decisions include choices we make in the vehicles we purchase and how we operate them, where we set our thermostats and choose to live, the political pressures we put upon our elected representatives to support good policy, and based upon the response of those political candidates, who we vote for.

“Be careful what you ask for.” The results of the decisions we make in the months and years ahead will determine how effectively the United States will manage the changes that lie ahead and how we can remain the leading economic power in the world. Energy is the irreplaceable resource for a nation’s economic vitality, and therefore its national security.

America’s “Center of Gravity” is its economy.

What is America’s “Center of Gravity?”

In national strategy, a term called “Center of Gravity” is used. This term describes the single most important source of strength and power of a nation. For the United States, the Center of Gravity is its economy. Our economy is the engine that provides our high standard of living, the global reach of our trade and industrial commerce to cooperate and compete, our influence upon other world powers to promote stability, and the most powerful military in the world.

Our energetic and efficient economy ensures the freedom to pursue our way of life, which is the envy of the world. The fuel of our economy is currently fossil-based. High-flown rhetoric cannot alter the fact that the overwhelming majority of U.S. energy comes from oil, coal, and natural gas, and despite good intentions, this simply cannot be changed quickly. Adjustments to our energy use must come in time, but those modifications need to be based upon practical and responsible decision-making, not upon lofty aspirations that result in severe economic hardship and disruption, and in a realistic sense simply cannot be met.

> Because true economics rewards efficiency, America has become one of the most efficient users of energy in the world.

In late May 2008, in San Francisco, a presidential candidate stated that the U.S. cannot continue to consume 25% of the world's energy having only 3% of the world's population. Like many political statements, it was calculated to appeal to certain audiences, without explaining why the U.S. uses so much energy. Let's explore that for a moment. *The U.S. requires this energy because America produces 28% of the world's gross domestic product (GDP)*. Economically, the U.S. is very efficient – we use energy and innovation and leverage those two in place of human labor. This happens, not because the U.S. squanders and wastes energy, but because the U.S. uses this energy to produce high value goods and services very efficiently. *The U.S. cannot maintain its prosperity and national security without adequate and cost-effective energy resources.*

This paper will cover all forms of energy, but first, we will address oil. It is the most familiar and controversial energy source we use. When we speak of energy independence, we are actually implying *imported oil <u>dependence</u>*. The United States' vehicles and production lines depend upon the reliable flow of oil. It is the fuel our economy – our Center of Gravity – requires every day. There are ways to transition to a more secure energy mix over the next twenty years, but for now we are stuck on oil, so let's take a look at it.

II. OIL – THE LIFEBLOOD OF AMERICA'S TRANSPORTATION

Supply and Demand

What caused the recent spike in gasoline prices?

Experts do not agree on a single factor for the recent rise in oil prices. Rapidly increasing demand from substantial growth in the economies of China and India was an important driver. Although speculation and the weakened dollar have each played a part, the dominant factor in high oil prices is the increasing demand against a steady or declining supply of world oil. A tightening margin between supply and demand often causes price spikes.

As the 2008 recession accelerated and major financial failures occurred, economic growth slowed and the demand for oil decreased. This resulted in a relative oil supply glut steadily driving down oil prices to an amazing one-third of the price paid in summer 2008.

> It would be very shortsighted to assume that oil prices will not rise again.

There may be some temporary fluctuation in prices – even small declines in daily demand can cause oil prices to drop – but long-term, there is no indication that worldwide demand will stop increasing. The world market has indicated it is willing to pay $140+ for a barrel of oil. If one market sector decreases its demand, there is every reason to believe another sector will buy up that oil. Retail gasoline prices are lower than they have been in many years, but it would be very shortsighted to assume that oil prices will not rise again when the economy begins to recover and demand again increases.

Although there will be additional oil discoveries in the future, these new discoveries are balanced against declines in mature oil fields. Technology will undoubtedly discover ways to increase the yield from both existing and older fields, but a lot of this technology will result in higher extraction prices. Nations known as *petrostates*, states where large petroleum reserves are owned by the government, have not indicated a willingness or ability to increase supply. Many experts believe that the world's daily oil supply will not appreciably increase beyond where it is today.

Who is to blame for high oil prices?

If the object is to assign blame, there are plenty of candidates, including Big Oil, OPEC, speculators, the U.S. Congress, environmentalists, China and India, and we, the American consumers.

Big Oil. Blaming Big Oil may make some of us feel better, but it really doesn't get us anywhere. Slapping punitive taxes and regulations on oil and gas exploration companies will only add to the cost of producing fuel for the consumer, and it may make some of them relocate to friendlier shores, where their efforts and the taxes they pay and the people they employ are more appreciated. U.S. corporate taxes are already the second highest in the world.

Oil and gas companies are just companies owned by stockholders: about one in three Americans either directly own stock or have a financial interest in these companies because of pensions and mutual funds. These companies have a duty to their stockholders to run the company within the law and to make money for their investors. That is the way a capitalistic democracy works and that is what they are doing. The profits these companies make are not excessive in comparison with margins of other corporations. Big Oil companies do not control the price of oil. They own some oil fields – only about 10% – while about 90% of oil fields are controlled by *petrostates* like Saudi Arabia, Iran, Nigeria, Venezuela, and Mexico.

Big oil companies do not control the price of oil.

Why should these oil companies (or the petrostates) sell oil to U.S. service stations for a cheaper price when someone is standing behind them who will pay more? Nobody felt sorry for Big Oil when oil was $17 per barrel and they were losing money on many of their exploration projects. A lot of the problem with Big Oil finding more supplies – particularly in the U.S. – is that our congress will not grant permits to explore the most promising areas in our own country. Several politicians have claimed that oil companies are not drilling in areas where they have already been granted leases. This is obviously because exploration in those areas has indicated these areas cannot (yet) produce oil or natural gas profitably.

Incidentally, major oil companies are leading the way in investing in research for alternative energy sources. These include ExxonMobil, British Petroleum, Chevron, Royal Dutch Shell, and others. Tomorrow's breakthrough technologies for new energy may be the result of today's Big Oil research dollars, *which come from their profits.*

The U.S. Congress. During congressional hearings in the summer of 2008, several members of Congress used their positions of public trust to castigate oil company executives about fuel prices. This line of questioning seemed hypocritical when Congress restricted those companies from developing the most promising areas for cost effective supplies within the United States.

But we should not really expect otherwise. As many renowned economists, at least those who understand the power of a free-market, have reminded us through the centuries, resources are best distributed by market forces, not by government regulations and quotas. When government intervenes, it does so by enacting various mechanisms of control. Such controls will invariably make shortages worse, which the government seeks to remedy through additional controls. Eventually, government finds itself setting production quotas, programming the resource distribution, and rationing consumption. This is true for wheat in the Ukraine (1930s), shoes in China (1950s), or gasoline in the United States (1970s).

The free market is a much better system for distributing limited resources. It rewards productivity and efficiency. It automatically prioritizes distribution based on true need; *the more urgent the need or more scarce the resource, the more superior market forces are in meeting that need*. So, as oil gets scarcer, Big Oil (or many times, Small Oil) is far more capable of meeting our need for energy resources than additional government intervention. Perhaps this is why many petrostates contract private western companies to do their most challenging work.

<u>Environmentalists</u>. Most Americans support conservation and good stewardship. We advocate protecting the environment with reasonable safeguards but are not extreme. We should maintain adequate rules for pollution control based upon real scientific data, not political hyperbole and media spin. When this happens, it is harmful to the prosperity and welfare of American citizens and does nothing to truly help the environment.

> We should maintain adequate rules for pollution control based upon real scientific data, not political hyperbole and media spin.

As an example, the U.S. Congress just added polar bears (Ursus maritimus) to the threatened species list under the Endangered Species Act. Perhaps they saw the photo showing a hapless polar bear standing on a small ice floe; never mind that polar bears can swim extraordinary distances in freezing waters, hence its species name, *maritimus*. The fact is, the number of these creatures has *increased* from about 5,000 to around 15,000 in the last twenty years. *They are not a species in decline*. But now, because of this counterproductive legislation, any entity including oil and gas companies whose activities can be seen to have a negative impact upon these non-threatened bears can be sued in court by environmental extremists. It is interesting that Canada, which has a much larger population of polar bears than does the U.S. in Alaska, has no such endangered status for these animals. An objective and rational person can only conclude that this decision was reached as a political expedient to reduce energy access to U.S. domestic reserves or to pander to the appearance of political correctness.

<u>We ourselves</u>. Americans are very hard working, industrious, and compassionate as a nation. But we have a very short attention span. It is the way we are. Yes, we should have seen the oil crisis coming when we bought all those gas guzzlers, but we had other things to think about. The good news is that Americans are innovative and adaptive. We are already developing and marketing alternatives to deal with price and supply and will continue to do so. But Americans need to educate themselves on energy in order to

intelligently direct goals and activities in the most productive way. We need to make rational, practical decisions, and to do so we must know the facts.

Who Is To Blame? Blame isn't going to get us anywhere. But we have to personally take charge of our energy future, or others with different agendas will mandate our options. We will then spend the future pointing fingers, and doing so without the energy we need.

What Could Be Worse Than High Oil Prices?

No oil. While we have seen an extraordinary price run-up especially in the last two years, there have been no long lines, and fuel has not been rationed. The only thing worse than high-priced gasoline is: no gasoline. This is an invariable consequence when governments attempt to excessively manipulate supply or demand through such things as price controls or production quotas.

> The only thing worse than high priced gasoline is:
> No gasoline.

How Much Oil is There?

No one knows for sure. The Saudis, with the world's largest reserves – about 25% of the world's total – maintain secrecy about how much remains or what their plans might be for additional exploration. Nevertheless, some estimates of these and other worldwide sources can be made based upon past data.

It is estimated that in terms of recoverable oil, there are six to eight trillion barrels for both conventional oil fields and other oil resources including shale oil, tar sands, and extra heavy oil. As many as 12 to 16 trillion barrels may be underground, but much of this may be economically or technically unfeasible to recover. As a matter of perspective, about 1 trillion barrels have already been consumed.

The amount of oil remaining is unknown, but further, there are reasons for owners to both under-report and over-report the reserves they believe they control. The amount of oil remaining will never be known with certainty, until it is almost all gone.

How Much Oil is Recoverable?

Currently, the industry recovers only about one out of three barrels for conventional oil and less for non-conventional sources. Nevertheless, technology is constantly improving methods to increase the extraction rate. This could expand the energy supply from oil.

Also, many petrostates are underdeveloped, using 1960's technology. Advanced techniques could vastly improve recovery. For example, some believe Iraq – with a modernized oil development program – could become second to Saudi Arabia in oil potential.

While we may complain about high oil prices, it is a double-edged sword. It does mean higher prices at the pump for gasoline, diesel, and jet fuel, but such prices also enable more expensive recovery techniques that increase the supply. These high prices also make alternative sources such as oil sands, oil shale, coal-to-liquids, and gas-to-liquids processes cost effective.

How Much Oil Is Consumed Worldwide?

Current world consumption is about 86 million barrels per day.

How Long Will the World's Oil Last?

Assuming there are 9 trillion barrels of economically recoverable conventional and non-conventional oil resources, including new discoveries and a conservative estimate of recovery efficiency of only one barrel of three in place, a quantity of 3 trillion barrels can be recovered. *At current world consumption of 86 million barrels per day, this oil supply would last about 96 years.*

If 1 trillion barrels have already been consumed, and 3 trillion barrels can still be recovered, then approximately 25% of the world's recoverable oil has been consumed. As technological improvements increase the recovery percentage, the total recoverable supply will increase. Using these figures, the world is approximately 30-40 years away from Peak Oil.

As their economies and national prosperity grow, China and India will continue to sell more and more autos, as well as other energy-consuming devices. Rising industry and commerce will demand more energy, including oil. China alone in 2007 was producing 14,000 new cars *a day* and by 2020 is expected to have 130 million vehicles. Between 2040 and 2050 China is projected to surpass the U.S. in numbers of cars.

> Declining production of mature oil fields will tend to push the price of oil upwards.

However, many experts predict that supplies cannot be increased significantly over current levels (new discoveries are only just matching declines in mature fields) while demand is steadily increasing. Daily supply cannot be ramped up because pumping too quickly could prematurely deplete the ultimate yield of a mature field by leaving some of the oil "stranded". *Limits to daily production will tend to keep pushing oil prices upwards because of the dynamic of supply versus demand.*

What does the term "Peak Oil" mean?

Peak Oil can refer to the historical point in time when either peak world production has been reached, or when half the world's recoverable reserve has been consumed. These two points are quite different and may be separated by decades. Neither of these definitions applies to the point when daily supply equals demand, because this could occur for many years – even decades – while production, supplies and prices are changing radically.

When we reach the point at which 50% of the world's economically recoverable oil has been consumed, oil will be a very expensive commodity in high demand. Peak Oil Reserve may occur decades after we have reached Peak Oil Production and world daily yield is in decline. Peak Oil, both in terms of maximum historic daily production and of 50% of total recoverable reserve is mentioned frequently in literature, but both these points are hard to define. This is because *new discoveries* will tend to push the total available supply upwards, and *new technologies* may permit increasing safe yield, thereby increasing maximum daily production. All the while, rising demand will consume oil at the maximum rate it can be produced.

Experts agree that price and daily production disruptions will continue to occur far in advance of the actual date when Peak Oil Reserve is reached. Some believe we have already reached the Peak Oil Production point and that new discoveries cannot outpace the production declines in existing mature fields.

Can the U.S. Curtail Its Increasing Demands for Oil?

We are already doing that. The U.S. consumption has been virtually flat at about 20 million barrels per day for the last five years and has risen an average of about one percent per year since 1988. In 2007 and 2008, U.S. consumption actually dropped slightly and will probably do so again in 2009. We have been able to do this during rising economic growth because of increased efficiencies in vehicle and oil use.

> The untold story is that the United States has become increasingly efficient for a long time.

Consider that the U.S. has been able to keep a modest rate of increase in oil consumption despite steady population and robust economic growth. This represents a continuing decrease in per capita and GDP oil use and an increase in energy efficiency. Despite all the negative hype, the quiet untold story is that the U.S. has been getting more efficient for a long time.

Where Does the Oil Consumed in the U.S. Come From?

About 35% of oil consumed in the U.S. is domestic. The largest suppliers in 2007 (in million barrels per day) were:

U.S.A.	7.50	Will continue to decline without additional development
Canada	2.27	Mostly oil sands, very reliable supply
Saudi Arabia	1.48	Many decades of potential supply
Venezuela	1.34	Unpredictable dictator could make this source unreliable
Mexico	1.25	Supply is reliable but declining
Nigeria	1.13	Occasional supply disruptions from terrorist sabotage.
Algeria	0.66	
Angola	0.51	
Iraq	0.48	Larger potential once stabilized
Russia	0.41	Larger potential but constant logistical/political challenges

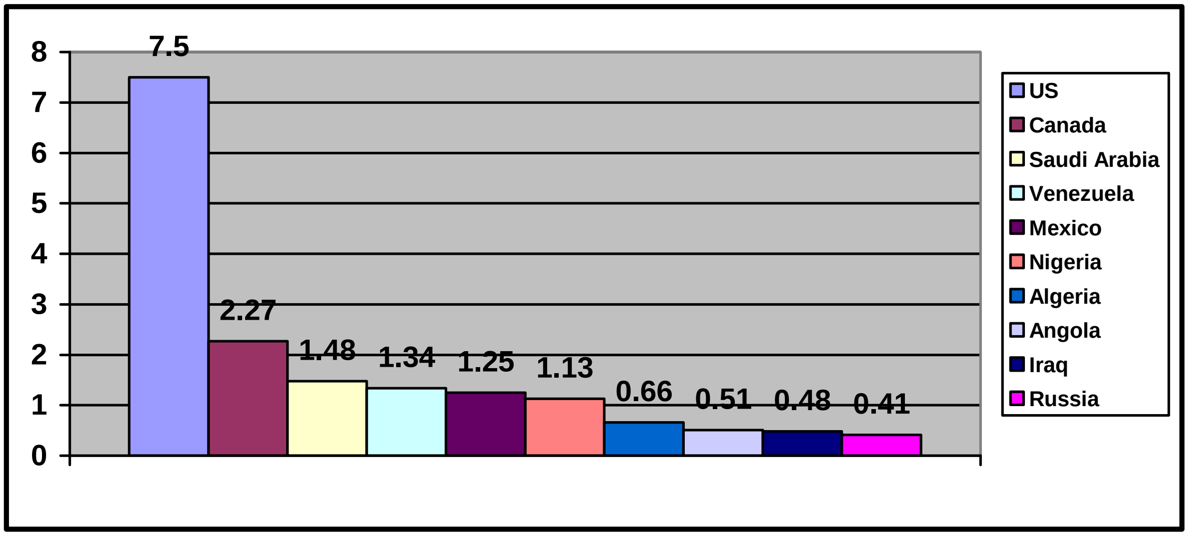

Figure 1. Top Ten Producers of U.S. Petroleum (million barrels per day).

In total, the U.S. imports oil from about two dozen countries, and imports are about 13 million barrels of oil per day, 65% of our total demand. A common misperception is that most U.S. imported oil comes from the Middle East. In fact, Mideast oil represents only about 15% of imports.

What Is the Risk to U.S. Security of Being Dependent Upon Foreign Oil?

There are two risks: (1) Cost risk and (2) Supply reliability risk.

<u>Cost Risk</u>. The mid-2008 run-up in oil prices has resulted in destabilizing effects on virtually every form of transportation, including airlines, truck transport, agriculture, and personal transport. The net effect results in significant cost inflation of services and products that are transported. High oil costs will continue to be a threat to economic growth and the budgets of everyday Americans until we develop a reliable source of energy at reasonably predictable prices. This will require an ultimate reserve significantly exceeding demand and daily availability controlled by market competition rather than a limited overall supply.

Supply reliability risk. The risk of losing any major supplier is probably low at this moment. Canada and Mexico should be considered stable, with many interests allied to the United States. Canada may actually be able to increase its exports of petroleum derived from oil sand somewhat, but Mexico's oil is government-owned, their production is not managed as efficiently as privately-owned supplies, and supply is beginning to decline. Venezuela, Nigeria and the Middle East are subject to potential interruption or cessation of supply. It is always a risk that one or more of these sources reduces or stops supply. A tightening of the supply-demand margin and more demand for oil will heighten tension and national competition. Such an interruption could come from terrorist-induced sabotage, overt government intervention, or a major accident in a foreign port, pipeline system, oil field, or refinery. Even a temporary interruption of several million barrels per day in U.S. imports could have a serious negative impact upon our economy and national security.

What About the Strategic Petroleum Reserve?

The Strategic Petroleum Reserve currently holds 707 million barrels of oil. This is equivalent to approximately 33 days of oil supply at current U.S. demand rates. However, only a portion of U.S. imports would likely be affected at any point in time, so the reserve would likely last longer. If, for example, oil supply from Venezuela (1.3 million barrels per day) were suddenly interrupted, the Strategic Petroleum Reserve could make up this portion of imported oil supply for about 18 months.

The important question from this theoretical exercise is: what set of circumstances could provoke an interruption from a major import source (Saudi Arabia, Nigeria, Venezuela, Iraq, Russia, Angola, etc.) and what other disruptions or interruptions might follow? If other less-reliable dominos in the chain of oil imports fall, then the Strategic Petroleum Reserve can make up supply for a much shorter time. Then, instead of having an interruptible supply for 18 months, the supply would last only 6 months. And when the Strategic Petroleum Reserve is consumed in that 6-month period, what then?

> In addition to the strategic reserve, the United States needs a secure source of domestic petroleum that can be ramped up quickly.

For the next twenty years or so, the U.S. needs a domestic supply of emergency oil that can be ramped up within a relatively short period of time – for example, six months. We have the potential to do that easily (coal-to-liquids or gas-to-liquids), but with Congress blocking real-time domestic energy alternatives, that capacity does not exist.

U.S. Oil Costs, Supplies, and Consumption

Can We Decrease Gasoline Prices By Drilling in ANWR and Offshore U.S. Coasts?

New oil field discoveries in the U.S. will improve supply somewhat, but may only marginally improve prices. This is because oil discovered in the U.S. is developed by private companies who, understandably, sell to the highest bidder. Any new oil supplies will flow into the world market – a bathtub that has many straws sucking on it. There is no reason for a private company to sell oil to American distributors if other international buyers are willing to pay more. It's a world market.

But assuming that ANWR (Arctic National Wildlife Refuge, located in northern Alaska) and U.S. offshore drilling proceeds, and that most of the oil discoveries there are developed by U.S. companies, then these sources would be *closer in distance*, thereby making the U.S. able to bid higher because of reduced transport costs. And if most of this oil could be purchased at competitive prices, these sources could provide *energy security* for at least a decade, maybe two, replacing other declining domestic supplies. Their chief value would not be to significantly reduce oil prices, which they could not do, but to provide a reliable supply in close proximity at current market prices.

Estimated reserves in ANWR are 15B (billion) barrels, but some experts doubt all this can be recovered. Estimated safe production is 1.3M (million) barrels per day, certainly nothing to sneeze at. Offshore drilling could potentially produce several times more oil and gas than ANWR, but at greater cost and risk. ANWR and offshore probably hold the greatest promise for significant fields of new oil and gas in U.S. territories. But it should be kept in mind that other U.S. sources are declining, so these may only hold the percent of domestic U.S. oil steady for the next 20 or so years.

Should We Be Drilling in ANWR and Offshore?

Absolutely. Although these oil sources should be regarded as temporary bridges to the future, we need those bridges.

Can We Lower Gas Prices By Reducing American Consumption?

Only marginally. The U.S. consumes only 25% of the world's oil, so 75% of world consumption is not within U.S. control. There are only 300 million of us in America, while there are billions of others in the world, in growing economies, who want oil to power their growing industries and the motor vehicles they are buying – recall the increasing auto sales in China and India. Reduction in U.S. oil consumption can only happen gradually, and international markets have shown other consuming nations will buy up any excess production capacity at current prices or even higher prices. The excess we do not consume just gets bought and used by someone else. Demand keeps pushing upward, and since supply of conventional oil cannot be increased, new sources only replace declining existing fields.

As individuals, how can we reduce fuel costs?

Each of us can reduce our gasoline bill by buying and using less. The best advice is to purchase more fuel-efficient vehicles, and more options will be available in the future as ingenuity provides greater efficiencies. That subject is covered in a section ahead. It is helpful to keep in mind that the prospects look good for continued oil supply in the next several decades, and if we make the right choices for the next hundred years.

Oil Independence, Electricity, and Transportation

Is Energy Independence Possible?

Yes, but that will take time. The U.S. has enormous energy reserves, but developing those within a free market will present challenges. For the near future the U.S. must recognize our current dependence upon imported oil while developing economically sound solutions for future liquid fuel supplies. Also, there is the question of whether the U.S. needs to be completely energy independent. If adequate supplies of reliable energy are available from imported sources, then paying more for a domestic supply would not make good economic sense. The important thing is to have adequate energy alternatives available should a supply of outside energy be suddenly threatened or interrupted.

Energy independence is not within the immediate future, but any improvement in reducing imported oil dependency will help make the U.S. more energy secure and keep energy costs as low as possible. A reasonable and attainable goal would be to reduce our imports from the current 65% to only 50% in the next 10 years. This would require development of oil from ANWR and offshore discoveries and development of a robust coal-to-liquids (CTL) program. These new liquid fuel supplies, combined with savings from greater efficiencies in transportation and other domestic petroleum uses, could significantly decrease the U.S. dependence upon imported energy.

> Energy independence is within our reach, but it will take time.

In order to become energy independent, we must have the abundant U.S. energy reserves available to utilize. If the U.S. is to remain the world's dominant economic and military power, we cannot be in a vulnerable position with respect to energy. We must remain self-determinant without the threat of foreign energy supplies being used to blackmail the U.S. to another nation's will. An example of this possibility is happening in Europe now. Germany and several other European nations have become heavily dependent upon natural gas supplied from Russia. The threat of price increases or a supply shut-off has been used to influence Russia's European "customers." More discussion on the Russian natural gas play is in a section to follow.

Can the U.S. Become "Totally Electric" for Energy Supply?

It's possible, but not very likely. There will always be a significant demand for liquid fuels, even in the distant future when most of the fossil fuels are gone. Why? Because for aircraft and long distance vehicle use, only liquid fuel provides high energy density for making efficient long distance trips. Certainly in the next 50 years, liquid fuels will be in high demand. They will probably be around forever.

We need two types of energy: liquid fuels for cars, trucks, and airplanes, and electricity for homes and industries. We are in good shape with respect to electricity because we have ample long-term supplies of coal and nuclear raw material. U.S. oil reserves peaked in the 1970's and global oil reserves, from which we get most liquid fuel, will approach peak in the next 10-20 years. But there are solutions for the renewable generation of liquid fuels for the future.

While liquid fuels will always be needed, the balance of energy must continue to shift more toward electricity. A major challenge will be to expand and strengthen our electrical power grid to deliver greater amounts of electric power and to develop more interconnections and critical redundancy to respond to local power outages. These improvements will require major investments over many decades to expand our electric power delivery capability.

In a world of high oil prices, what are our transportation alternatives for the future?

Americans didn't heed the warning signals in the 70's and car makers continued to make the vehicles we preferred to buy and so here we are. Twenty years ago, Honda made a small car that got over 40 mpg. Its sales were flat, so the manufacturer responded to the marketplace and stopped making them.

> Energy usage will shift to greater consumer use of electricity, especially as plug-in hybrids become more popular. But adequate liquid fuels will always be needed, such as JP-8 for aircraft and military.

No one expects Americans to stop traveling, but we need to be driving more fuel-efficient vehicles. Just doing that will keep reducing America's oil consumption. Greater efficiency is consistent with free-market principles, reducing costs of goods and services, thus allowing the same dollars to purchase more.

Detroit has finally gotten the message. GM and Ford are making big changes in their product lines, converting light truck and SUV lines over to fuel-efficient models. Honda, Toyota and Nissan are already in the lead in this trend. GM has poured enormous investment into the development of the Chevy Volt, a plug-in gasoline electric hybrid.

The electric car is coming, and the ultimate car of the future is the plug-in electric hybrid. This is a vehicle that is plugged in overnight, will operate for trips on most days entirely from electric power, but has a small gasoline or diesel engine that kicks in for extended trips. These autos are mechanically simple and more efficient than the existing hybrids because the drive is entirely from electricity: there is no transmission, and the motor/generators are in the wheels. For more detail on future cars, see a separate section to follow, “Transportation Concepts for the Future.”

JP-8 is jet fuel (JP stands for “jet propellant”). The military now uses only JP-8 for all its vehicles: aircraft, tanks, and trucks. A well-developed technology exists for coal-to-liquids processing that is cost competitive at today’s oil prices. Synthetic JP-8 can be made from this process. A production and supply program from our vast coal reserves could be established that would allow U.S. companies to competitively bid for contracts to supply the military and airlines at stable prices over long time periods. *A reliable source of fuel for military and air transportation use is a matter of national security.*

What about the T. Boone Pickens energy plan?

The plan proposed by billionaire T. Boone Pickens is innovative and worthy of consideration. It proposes wind as 20% of our electricity power in 10 years, and natural gas as a substitute fuel for transportation, replacing imported oil. But the Pickens plan has several significant concerns.

Most experts agree that wind should be integrated into the electric power generation mix to the extent it is economically viable. The problem with wind power is it is intermittent. You get power only when and where the wind blows. In the Great Plains wind corridor that Pickens refers to, the wind is highest at night, when electrical demand is lowest, and fades significantly in the afternoon, when demand is at a high.

> To achieve the necessary reliability needed for a power grid, wind turbines must have backup power.

To make wind reliable, there must be backup power. If backup power is sufficient to meet peak demand when winds may be calm, the same capital cost investment is required as if there were no wind power. *Electricity cannot be stored within the grid; it must be used as it is generated.* To make wind power a reliable segment of the power grid, a method to store the energy generated when winds are at a peak (night) for release when winds are low (day) must be developed. Also, power must be available during sustained periods of calm or low wind. There may be ways to do this in theory, but they would require additional capital cost investment, and no such plans have been proposed. As it stands today, wind can only provide a small segment of the electric power generation mix. More discussion of wind and its future is in a section below.

The second major part of the Pickens plan is a significantly increased use of natural gas to replace oil as a transportation fuel. Natural gas can be used as transportation fuel in two modes: compressed natural gas (CNG), or gas-to-liquids conversion (GTL).

Mr. Pickens proposes CNG. Some vehicles (typically city or gas utility vehicles) use natural gas, but they have a shorter range and are restricted to a small radius of operation so they are close to the special natural gas fueling source. There are only about 500 CNG fueling sources open to the public in the entire United States, as of this writing.

The possibility of CNG does have a significant upside for the consumer: it can be refueled at home through current residential natural gas service. But it should be noted that home installation of a compressor for CNG auto refueling is an additional cost. There are a few vehicles currently on the market that can run on both gasoline and CNG (two fuel systems, same engine).

Using natural gas for corporate fleet vehicles or municipal/utility vehicles may have some value and reduce the need for gasoline and diesel fuel. This may be practical if there is a centralized refueling point and the anticipated vehicle range is moderate. But converting a large part of the consumer public to natural gas as auto fuel would likely require a significant overhaul of our service station infrastructure, even with home refueling capabilities taken into consideration. *Also, a major shift to natural gas for transportation would increase its demand, making its relative price higher for other conventional uses, such as home and commercial heating, and peaking electric power generation.*

III. GLOBAL WARMING

The issue of Global Warming has become closely linked to fossil fuel energy use. Proponents of the man-made global warming theory have proposed that carbon dioxide (CO_2) emissions from burning fossil fuels can produce a dangerous increase in the earth's temperature. Because of the abundance of fossil fuels in the U.S., any long-term energy policy must thoroughly evaluate the validity of this theory – through solid scientific inquiry – and enact policy that ensures U.S. energy security.

Three Questions

When addressing the issue of Global Warming (renamed in recent years to Climate Change) there are three questions that should be answered:

1. Is Global Warming actually occurring?
2. If so, is the warming primarily due to the activities of mankind?
3. Assuming the answers to questions 1 and 2 are yes, are the scientifically predicted consequences of Global Warming severe enough to warrant drastic and costly changes in the behavior of mankind?

Is Global Warming actually occurring? Ten years ago a majority of scientists would have agreed that the answer to question 1 is almost certainly yes. Today, with no warming in the last decade and decreasing temperatures in 2007 and 2008, many experts have changed their positions. Historically, the earth is nearing the end of the most recent (Holocene) interglacial warm period, and may again be trending towards a cooling period. Sunspot data indicate that the next 20 years will be of lower solar intensity, producing cooler global temperatures.

If there is Global Warming, is mankind the cause? Numerous respected scientists are on both sides of this issue. But because of the failure of predicted outcomes by global warming advocates to match observed conditions, the role of CO_2 in warming now appears to be insignificant. In contrast, analysis of temperature variations over long historical periods indicate that natural causes, and not man-made CO_2 increases, dominate global climate changes.

If Global Warming exists, and is predominantly caused by mankind, are the consequences severe enough to warrant changes in how we behave? The consequences of Global Warming – whatever the primary cause – do not warrant the drastic regulatory changes that many extreme environmentalists have advocated.

The most widely quoted information comes from the United Nations' Intergovernmental Panel on Climate Change (IPCC). The IPCC estimates that over the next 100 years, the global temperature will have risen on average 0.6C (1.2 degrees Fahrenheit). Should this increase occur, average temperature increase would not be experienced equally everywhere. Much colder regions would warm more, and warmer regions would warm very little; also, land would warm more than the oceans. Areas that have colder temperatures, e.g., Canada, would benefit by having longer and warmer growing conditions more favorable to food and fiber crops. The IPCC report estimates that ocean levels will rise approximately one foot in one hundred years.

Warming or Cooling?

Contrary to the IPCC's predictions of continued warming, historical data and analysis of current solar activity indicate the earth is due instead for a multi-decadal cycle of global cooling. *Ironically, a long-term cooling trend should be of far greater concern to the welfare of mankind than continued warming.*

The earth has gone through repeated warming and cooling for millions of years, with solar cycles being the driver. American Indian ancestors crossed from eastern Asia to Alaska when the ocean levels were much lower, following the end of the Ice Age, some 18,000 years ago. As can be seen in Figure 2, in the last several millennia we have had five major episodes of climate change:

Roman Warming:	200 BC – 500 AD
Dark Ages Cooling:	500 – 900 AD
Medieval Warming:	900 – 1300 AD
Little Ice Age:	1300 – 1800 AD
Modern Warming:	1800 – present

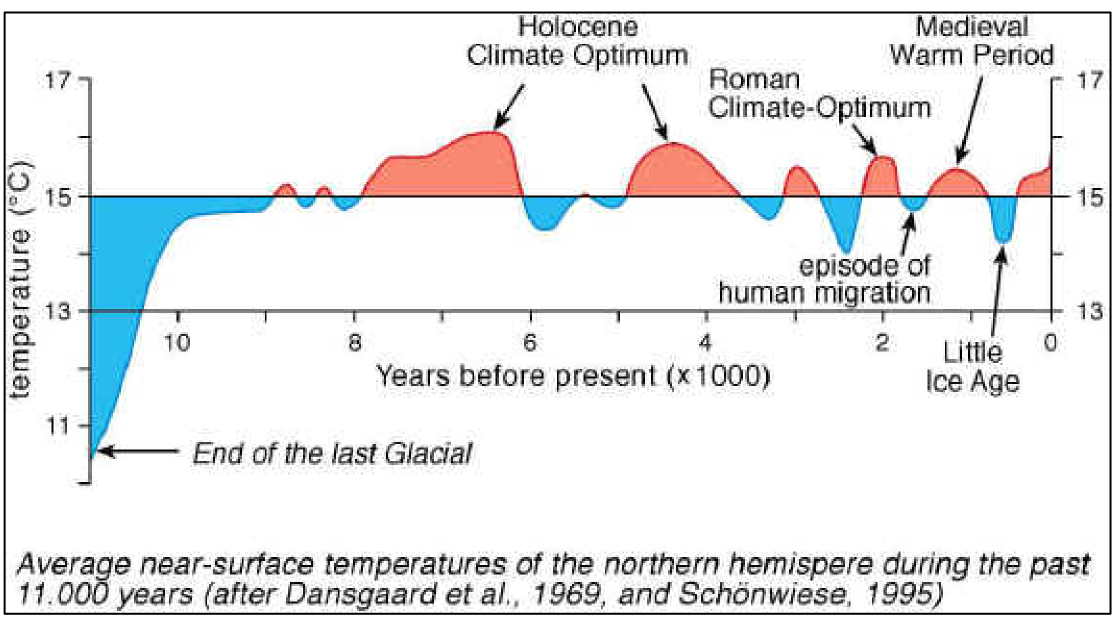

Figure 2. Warming and Cooling Periods within Recorded History

Warming episodes create better living conditions for mankind, and cooling periods produce great hardship, sometimes with catastrophic consequences. Shortened and colder growing seasons caused repeated famines in the British Isles and northern Europe. 1693 was possibly the worst winter in Europe, resulting in millions of deaths from disease and starvation, including about 10% of the population of France.

The most recent warming trend, at the end of the 500-year-long Little Ice Age, began in the early-1800s. Contrary to media hype, temperatures have not been recently accelerating. The greatest amount of increase in the preceding 200 years occurred in the first half of the 20th century and 1934 was the warmest year on record to date. Average daily temperature in the last decade has been relatively flat, perhaps even a slight decrease.

Periodic temperature cycles have been the historic norm.

There are many potential causes for global temperature change, including solar cycles that vary over tens of thousands of years, the earth's orbital dynamics, and ocean temperature patterns that oscillate over decades. The causal factors for some of these changes are not yet well understood; yet periodic temperature cycles have been the norm throughout the earth's history. Scientific data supports a pattern of large glacial cycles over a period of approximately 100,000 years (see Figure 3), with cycles of lesser magnitude every 800-1500 years and smaller multi-decadal oscillations of 25-30 year durations. The Ice Age, when ice sheets several thousand feet in depth covered Canada and the northern tier of the United States some 25,000 years ago, was near the end of a major glacial cycle.

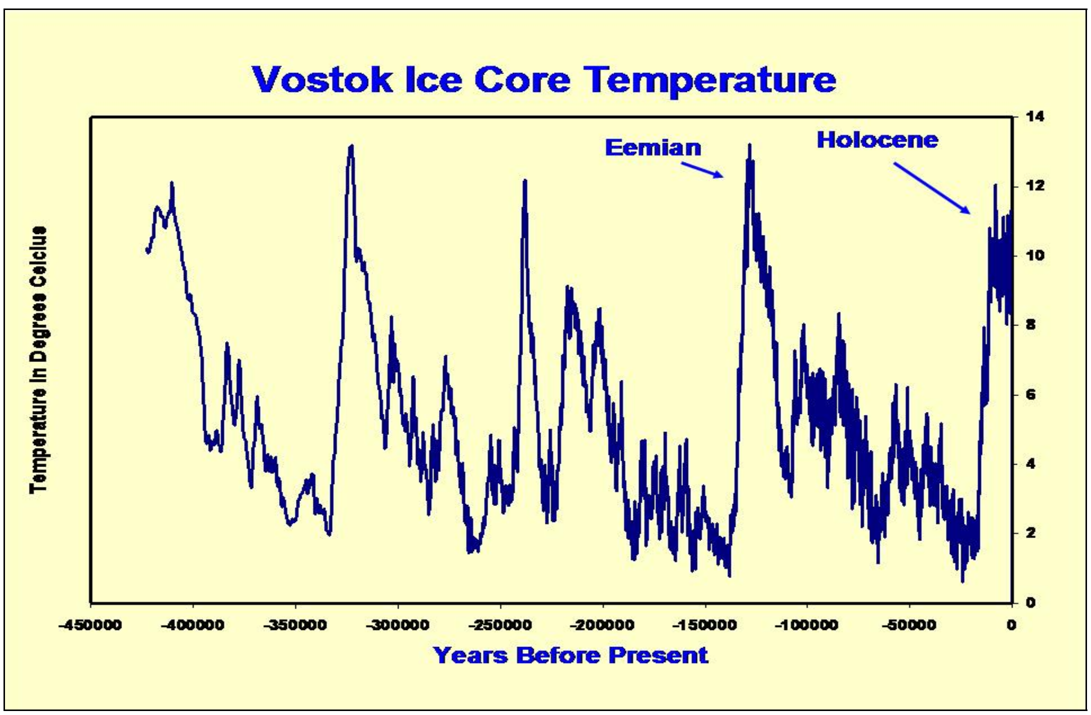

Figure 3. Temperature Variation within Recent Epochs

There is disagreement among scientists on whether or not Global Warming is predominantly driven by increasing CO_2 emissions from mankind's activities.

The reason one hears so much support from mainstream media for man-made global warming is because those reporting on the issue are misinformed or uneducated about the facts. For example, they fail to report that while Arctic ice has been decreasing, Antarctic ice mass is *increasing*. Alarmists who point to shrinking glaciers fail to note that glaciers have shrunk, disappeared and reappeared for the last ten thousand years, in response to normal fluctuations in the earth's temperature.

> With no warming in the past decade, many scientists have changed their previous position. Historical data and current solar measurements actually indicate a period of long-term global *cooling*.

Our media are not always a reliable source for good information. Because a sensational story with dire consequences will capture more public attention than one of good news, they tend to look for and over-report bad news while ignoring the other side of an issue. Remember the "ozone hole" hysteria? Supposedly there was a big hole in the ozone layer at the South Pole. It was growing every year and we would all eventually be cooked to death by ultraviolet rays. Why isn't it a story anymore? Because it never was a real problem. It is another example of how *a few scientists put forth a theory unsubstantiated by careful scientific studies, and the media locked onto the dire theme*.

<u>Recall Question 3: If Global Warming exists, and is predominantly caused by mankind, are the consequences severe enough to warrant changes in how we behave?</u> The costs of implementing treaties or programs to control CO_2 emissions are astronomical and produce little improvement. The Kyoto Protocols – a treaty to impose severe penalties upon carbon dioxide emissions – were predicted to only postpone the same level of global warming by several years, at a cost of hundreds of trillions of dollars and considerable hardship on mankind. The U.S. Senate voted 96-0 to reject this bad idea. Australia agreed with the U.S. in rejecting the Kyoto Treaty, and many of the participants, including Canada, Japan, Spain, Portugal, Greece, Ireland, Italy, New Zealand, Finland, Norway, Austria, and Denmark have failed to meet any of the treaty's requirements for carbon dioxide reductions, and have no prospect of doing so. The U.S., which has not signed on to the Kyoto Protocols, is actually reducing CO_2 emissions more effectively than any of these European nations.

Real Climate Change

Man-made global warming theory is based upon projections and assumptions. The projections are based upon short-term temperature records (less than 100 years) and computer models. The major assumption of global warming is that carbon dioxide is a significant greenhouse gas and that increases in atmospheric CO_2 concentration are a major driver of global temperature increase.

The problem with the man-made global warming theory is that global temperature and CO_2 have shown no significant correlation except for a very narrow period of time in the twentieth century. In other words, there is no long-term data base supporting CO_2 as a significant driver of measurable temperature change.

The IPCC-proposed 0.6C rate of temperature increase per 100 years does not differ greatly from the 0.5C rate constructed by E. Bryant using data from 1850 to 1997, that were predominantly within statistical 95% confidence limits and Akasofu analysis using data from 1880 to 2000 (see Bryant and Akasofu references). The 0.5C trend is based upon historical data from natural causes. The important conclusion is that the temperature increase from 1800 through 1945 *predated substantial increases in atmospheric CO_2 and was entirely from natural causes*, yet the trend line from 1945 through 2008 – the period of IPCC's concern – is virtually identical.

Scientists have investigated the role of carbon dioxide as a potential greenhouse gas and found that it does have an effect on increasing temperature, *but it is miniscule*. This small effect is greatest at extremely low concentrations – less than 100 ppm – but carbon dioxide's effect is inversely exponential (i.e., it diminishes rapidly at higher concentrations). At current atmospheric concentrations (380 ppm) and higher, the effect of CO_2 on temperature is so small that it is swamped by natural variability and cannot be distinguished. The insignificant role of CO_2 on global temperature and climate change from natural and not man-made causes has been well documented. Perhaps this is why statements from over 700 prominent international scientists in the U.S. Senate Minority Report on Global Warming (March 16, 2009), and a petition of over 32,000 scientists have questioned the process and refuted the theory of man-made global warming.

> There is no long-term data supporting the theory that CO_2 is a significant driver of temperature change.

If longer historic periods of temperature and CO_2 variation are studied, patterns emerge. These temperature and CO_2 records are based upon isotope data from Antarctic and Greenland ice cores and ocean sediments dating to 800,000 years ago. The temperature patterns from this time period predate any impact mankind has had on global temperature. These records indicate that increasing temperature can cause a release of more dissolved CO_2 from oceans, but this release follows by hundreds of years and is an effect, not a cause. Other time periods show no correlation at all.

More recently, sunspot data has been recorded over the past two hundred years, along with measured temperature records. All of the historic temperature data indicate long term temperature cycles of approximately 100,000 years, mid-term cycles of 800-1,500 years, and shorter cycles of 30 years.

These cycles are primarily driven by solar intensity, as indicated by sunspot activity. Greater solar intensity reduces cosmic ray flux, which in turn reduces low cloud formation, and this leads to more warming. Conversely, reduced solar intensity allows increased cosmic ray flux, which increases low cloud formation. More low clouds reflect more solar radiation, leading to cooling, which promotes more polar ice. More polar ice causes additional reflection and even more cooling.

Sunspot activity indicates that the earth entered a multidecadal oscillation some ten years ago, and this cycle of cooling will continue for another 20 years. The rate of cooling may be moderate or severe. If moderate, temperatures will be similar to the 1945-1975 cool period. If severe, temperatures will be much, much colder. A severe period of very cold temperatures similar to the Little Ice Age could have a significant effect upon agricultural production. Northern agricultural zones, such as Canadian wheat farms, could experience crop failures and reduced production. Areas further south would experience a shorter growing season and some reduced production.

Life's Carbon Footprint

Carbon is the essential building block of all life on earth. In addition to its presence in rocks, plants, and fossil fuels, it is an irreplaceable constituent of all animals, including humans. It is the structural foundation of every cell in our body, yet it seems that carbon has become, in the eyes of the media, another environmental culprit and a political target.

> Carbon is the essential building block of all life on earth. It is not "dirty" and is not a pollutant. CO_2 is simply carbon's oxidized form, and according to historical records, we are actually CO_2 impoverished today.

Carbon dioxide (CO_2) is simply carbon's oxidized form. CO_2 is released when animals exhale and when hydrocarbons (fuels) are burned to produce energy. That same CO_2 released into the air becomes an essential nutrient to plants, without which they could not exist. The carbon cycle – exchanging carbon between oceans, the atmosphere, plants, and animals – has been going on for hundreds of millions of years. As discussed above, carbon's role as a greenhouse gas is miniscule and cannot even be distinguished as an influence on temperature among other major influences such as solar intensity.

Media informs us that "never in the earth's history has the concentration of carbon dioxide been so high." This is not correct. In fact, throughout the first 99% of the earth's history, the concentration of carbon dioxide was much higher than today. By historic standards, we are CO_2-impoverished today.

Here are a few facts about carbon dioxide:

- 186 billion tons of CO_2 enter the earth's atmosphere each year from all sources and only 6 billion tons are from human activities. The 180 billion tons of non-human CO_2 come from biological activity in the oceans, volcanoes, and decaying land plants.
- CO_2 is odorless, colorless, and tasteless. Plants require CO_2 to grow and they emit oxygen as a waste product. Carbon dioxide is a nutrient to plant life and all life can benefit from more of it. All life on earth is carbon-based. When plant growers want to stimulate plant growth, they *increase* the carbon dioxide concentration in their nurseries.
- The current concentration of CO_2 in the atmosphere is 385 parts per million, less than 4/10ths of one percent. One wonders how there is even enough for the plants to survive.
- CO_2 that goes into the atmosphere does not stay there but is continually recycled by terrestrial plant life and earth's oceans. As the earth cools, more CO_2 is absorbed in the oceans; and as it warms, more CO_2 is released into the atmosphere. It has been so for millions of years.
- A review of temperature and CO_2 over the last 600 million years demonstrates no measurable relationship. There have been periods where CO_2 concentrations and temperature were similar to today, and other periods where they were quite different. It is difficult to argue that CO_2 is a greenhouse gas that will produce a thermal runaway when the Late Ordovician Period (450 million years ago) produced a CO_2 concentration of 4400 ppm – 12 times higher than today – and the earth was in an Ice Age!

Ironically, the Global Warming debate has caused many in the scientific community to study atmospheric CO_2 and the carbon cycle with much greater academic and scientific rigor. As a result, increasing numbers of credible scientists are following a trail of logic trending away from Global Warming:

Given that carbon is an essential element of life and is wholly beneficial to our environment;

Given that CO_2 is simply part of nature's carbon cycle that is essential for all plant life, and that increased CO_2 does not really cause Global Warming;

One must conclude that -
Carbon dioxide in any atmospheric concentration that could be produced by using the earth's economically recoverable fossil fuels would not cause increased temperatures, yet it would actually improve agricultural production;

Further -
In the event that the earth is indeed entering the next Ice Age in the next few hundred years, an increase in CO_2 and the resulting increased food production may be a very worthy goal to achieve, one of real benefit to mankind and our environment.

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IV. America's Current Resources and Options

Conventional Energy Sources

Oil. Perhaps the most versatile energy source, oil has very high energy density, and can be economically refined into many useful products from fuels to plastics. The U.S. oil reserves peaked in 1970, and since then supplies have been on the decline. The United States still provides some 6 million barrels per day of *conventional* oil supply from domestic sources, but it is being sucked up faster than new sources can be developed. Our domestic supply of conventional oil is falling by the day. One answer is to just keep drilling, principally offshore and in ANWR. These potential supplies can and should be explored and utilized to help get us through the middle years to avoid slowing down or choking our national economy. But they can only slow the worldwide supply/demand equation. T. Boone Pickens is right: we should pursue multiple energy sources, including drilling for oil. It will provide temporary help, but it should only be regarded as a bridge to a future independent from imported oil. See Table 1, Worldwide Reserves of Oil, and Table 2, Oil Use in the U.S., at the end of this paper.

> The United States is the Saudi Arabia of coal. Coal has unmatched energy density among the fossil fuel sources.

Coal. The biggest advantage of coal for the United States is its abundance. Often termed "the Saudi Arabia of coal," the U.S. has approximately a 250-year coal supply at current usage rates. *Coal is the largest source of electric power generation in the United States*. With older conventional power plant designs, coal power generation has relatively high pollutant emissions and is a high CO_2 source. The IGCC process (Integrated Gasification Combined Cycle) is an advanced coal power generating process. IGCC plants could be used to generate electricity from coal with higher efficiency, lower pollutant emissions, and CO_2 sequestering. Such power plants would be more expensive than conventional coal-fired plants (CO_2 sequestering increases capital cost by approximately 35%), but could economically co-produce liquid fuels (see "Coal-to-Liquids" paragraph below), thereby lowering overall combined capital and operating costs. These plants follow the "clean coal" concept and should be a major part of U.S. electrical power generation for at least the next 50 years.

Should supplies of natural gas and nuclear raw material become depleted in 30-50 years without economically viable renewable energy being developed and implemented, there would still be reserves of coal to provide new power sources for electricity. It is hoped that solar and wind technology will have developed cost effective reliability by that time, foregoing the need to fall back on coal, but if coal is needed, it is there. See Table 3, World Coal Reserves.

Natural gas is relatively plentiful in the United States, and has many advantages due to its exceptional versatility. It burns cleanly, and is the most environmentally-friendly fossil fuel. It can be compressed as vehicle fuel, or can be converted into synthetic liquid fuel by the Fischer-Tropsch method (i.e., Gas to Liquids; see "Non-Conventional Fossil Fuels," below).

Natural gas production in the lower U.S. 48 states has increased. Following 9 years of no net growth through 2006, an upward trend began and has continued for the last two years. This has resulted from improved technology that allows economic production of resources in deep water and large "unconventional" resources. A large portion of unconventional production resulted from the development of horizontal drilling that permits extraction from tight shale formations. This horizontal drilling technology also allows drilling under sensitive or highly urbanized areas without disturbing the surface. A large portion of the famous Barnett Shale lies under the City of Fort Worth.

The future for natural gas looks promising at this time. Shale formations in the lower 48 states are widely distributed and contain large amounts of natural gas, although these shale formations are slightly more expensive to drill, complete and produce.

> The great value of natural gas lies in its versatility. It is simple and relatively pure. As production technology improves, more natural gas is being made available.

Because it is relatively clean, stable and easy to transport through pipelines, the best use for natural gas is for home, commercial, and industrial heating, and electric peaking power. Natural gas could have some use as compressed fuel for utility vehicles in metropolitan areas where they can be refueled frequently. Used in this way, natural gas can continue to provide reliable energy for many decades – longer if technology provides more natural gas development.

Russia holds the world's largest reserves of natural gas, about one third of world supply. The Russians are exporting their natural gas to nearby countries by pipeline and to faraway places like India as liquid natural gas (LNG). Even while global oil and gas prices increased since 2006, the Russian economy has been in decline. Capital has been fleeing the country because of government strong-arm takeovers of industries, and Russian political, economic and military intervention in neighboring countries such as Ukraine and Georgia. The Russian stock market declined over 60% in fall 2008, and new potential investors are understandably wary.

Germany and other European nations are now relying heavily upon Russian natural gas for energy. Russia has used this energy dependency to influence European support for

Russian objectives. Support of membership of Georgia and Ukraine in NATO was withdrawn by Germany when Russia threatened natural gas price increases and/or supply interruptions. This example demonstrates how energy supply can be used as extortion against a "customer" nation. The U.S. Center of Gravity, our economy, cannot be allowed to be weakened by reliability of energy sources from other nations. It should be pointed out that a portion of our imported oil – about 400,000 barrels per day – comes from Russia. While this only represents about 2% of our total daily supply, an interruption of this supply could cause market and supply disruption. See Table 4, Worldwide Reserves of Natural Gas, and Table 5, Natural Gas Imports and Exports.

Nuclear power is attractive because of its efficiency and low environmental impact. The U.S. has fair reserves of uranium raw material. Australia and Canada have the largest reserves of uranium in the world. Uranium is cost competitive with coal on a daily operations basis, but nuclear power plants are more expensive to construct. Nuclear power generation is the single best source of significant non-CO_2 electric power generation available in the world today. Estimated world reserves of economically recoverable nuclear fuel – including uranium and thorium – for conventional nuclear plants vary, but are sufficient for at least 100-200 years at current usage rates.

> Nuclear power is the most efficient source of electric energy generation today.

Critics of nuclear power claim potential problems with radioactivity from waste material or converting this material to nuclear weapons. However, waste material from conventional nuclear reactors is low-grade, and although it must be sequestered when spent, it poses no problem with long life, extreme radioactivity, or potential for nuclear weapons in its natural state. Waste nuclear fuel does not require a large or complex containment structure. Conventional expended nuclear material can be safely stored below ground and three feet of water blocks the radiation. All the waste produced so far in the U.S. would only cover a football field about five yards deep. Refinement of conventional nuclear reactor waste would require an extremely high level of technological capability to be reprocessed into weapons-grade material; in short, it wouldn't be worth it.

> Second generation nuclear reactors could provide power for thousands of years.

It is entirely possible that the estimated life cycle of nuclear facilities could extend well past the estimated 40-60 years of current planning. To date, no nuclear plant has been shut down due to maximum licensed lifetime being reached. New nuclear plants are designed for a minimum of 60 years, and may be able to be refurbished, thereby extending the useful life for several more decades. Even if the cost of nuclear fuel were to significantly rise in 50 years, the effect on overall cost is small once the plant's capital cost has been paid off. Under such circumstances, nuclear power could prove itself to be the most reliable and cheapest long-term electrical power source.

There is another source of nuclear energy beyond conventional reactors: the Fast Breeder Reactor (FBR). Conventional nuclear waste can be reprocessed and used in FBR reactors (plutonium oxide mixed with uranium oxide). This second generation nuclear reactor technology would exponentially expand the power potential; i.e., the raw material supply would increase from around 100 years to tens of thousands of years. Thus nuclear power could be "stretched" by extending the first generation waste as a raw material for second generation fast reactors. Several challenges are presented by this method: these reactors would be more expensive than conventional reactors, and would produce a byproduct waste that is more easily processed into nuclear weapons-grade material. However, adequate security measures for the safeguard of weapons-grade material have been developed and in practice at U.S. military facilities across the country for over half a century.

> Security standards for handling weapons-grade nuclear materials have been in practice by the U.S. military for many decades.

Many nations have constructed and operated experimental FBRs, including the U.S., India, France, the U.K., Russia and Japan. It should be expected that as conventional fossil fuels reach peaks in the next 50 years, and economical reserves of uranium and thorium peak, that some nations will – no matter the objections of other nations – endeavor to develop and build fast reactors in order to provide electrical power generation. They may do this if they have no other energy alternatives. It would be good international policy for nations to share technology with each other to ensure safe and reliable reactors and methods for secure sequestering of waste, including ensuring non-proliferation to terrorists. See Table 6, Worldwide Reserves of Uranium and Thorium

Earth's Internal Nuclear Reactor

The core of the earth is hot – many people are aware of this – but just how hot and why? Temperatures at the earth's core reach 7,000 degrees Centigrade, about 1,500 degrees hotter than the sun's surface! Some of this heat comes from gravitational pressure and leftover heat from the earth's violent formation and past collisions. But at least half of the earth's internal energy is produced by radioactive breakdown of thorium and uranium, the same process that nuclear power reactors undergo.

We are indeed fortunate that this process is going on, for it is the power source of the earth's molten core and the resulting magnetic fields which produce the magnetosphere that extends far out into space. The magnetosphere diverts the solar wind streaming from the sun, a force that would, without magnetic protection, eventually strip away the earth's atmosphere. These nuclear forces are at work every minute, powering earth's internal energy reactor and thereby keeping the planet safe for its inhabitants. Think of it as a giant nuclear reactor right beneath our feet.

Non-Conventional Fossil Fuels

Oil sands. Bitumen is the "oil" in oil sands deposits. Bitumen is extracted and then converted into syncrude. The syncrude can be converted into conventional oil and at prices from $25 to $50 per barrel, this raw material is cost effective enough to recover and process into oil. Canada has 81% of the world's oil sands, exports syncrude worldwide, and is currently the largest source of foreign oil to the U.S. If fully developed, Canada's oil sands could supply the entire daily oil demands of the U.S. (some 20 million barrels per day) for the next 40 years. Canada is the most stable source of imported oil to the U.S.

Shale oil. The term "shale oil" is a misnomer, the material is a calcareous mudstone known as marlstone. The marlstone does not contain oil, but an organic material called kerogen, a primitive precursor of crude oil. Kerogen is processed into synthetic shale oil. The U.S. has over 50% of the world's recoverable shale oil and is the largest single source. It is found mostly in Utah, Wyoming, and Colorado. Royal Dutch Shell[*] and Chevron are currently pursuing shale oil development methods.

There are two methods for recovery and processing shale oil: underground mining and *in situ* recovery. Royal Dutch Shell is developing methods for *in situ* recovery. Briefly, its process utilizes ammonia pipes that freeze groundwater in place, forming a wall that protects from contamination. Then electric heaters warm the rock (650-700 degrees), converting the kerogen into shale oil, taking about two years. The resultant shale oil is then pumped to the surface.

Royal Dutch Shell's process avoids several major problems with underground mining, including much lower site remediation cost, lower water usage, and a far higher recovery rate of oil. Production is expected to start 10-15 years after development begins.

> The potential for shale oil is *enormous* – three times the reserves of Saudi Arabia, but at a higher cost.

The potential for shale oil is <u>enormous</u>. U.S. reserves could yield up to 800 billion barrels, over three times the current reserves of Saudi Arabia. This is equal to a 100-year supply for the U.S. at its current daily usage. If the U.S. is able to significantly reduce its demand for oil by improved efficiency in vehicles, shale oil could provide liquid fuel for the U.S. for up to 200 years or longer. In 2004, the breakeven price for oil production for shale oil was $55-70 per barrel; this is probably higher today, but still economical.

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[*] In order to differentiate the terms Shell Oil from shale oil, we have used Shell's traditional corporate name, "Royal Dutch Shell."

Shale oil alone could be the United States' bridge to the next generation of liquid fuels. The biggest obstacle to shale oil development will be resistance from environmentalists and blockage of progress in the U.S. Congress because shale oil is a fossil fuel.

Coal to Liquids (CTL) and Gas to Liquids (GTL). Coal or natural gas can be converted into liquid hydrocarbons including gasoline, diesel, and aviation fuel. The Fischer-Tropsch process was developed by two Czech scientists. It was later industrialized by Germans in the early 1930's to convert coal into synthetic diesel and aviation gasoline fuel that provided over 50% of Germany's WWII military needs. Several projects in the U.S. have utilized this process and recently, coal-synthetic jet fuel was manufactured to power a B-1 bomber that was successfully flown at supersonic speed. This test was part of a project to explore the creation of a source for fuels from U.S. coal for ensuring an independent and secure fuel supply for the U.S. military.

Coal-to-liquids produces cheaper synthetic fuel than gas-to-liquids because the cost of coal per BTU is cheaper than natural gas. But because natural gas is "cleaner," the GTL process creates fewer pollutants and lower net CO_2 emissions. For this reason, individuals in Congress have blocked the establishment of a program for a secure CTL fuel supply for the U.S. military.

The large coal reserves in the U.S. could provide enormous fuel supplies utilizing the coal-to-liquids process. This process becomes cost effective in the $45-80 per barrel range including CO_2 sequestering costs. Similar to shale oil, CTL supplies could provide the indispensable bridge to future sustainable liquid fuels.

> Coal-to-liquids and gas-to-liquids could provide diesel and aviation fuels for hundreds of years.

Methane Hydrate. Methane hydrate (also referred to as methane clathrate or methane ice) was identified in the 1960-70 era as a potential fuel source. This substance consists of methane trapped within ice crystals located under sediments in the ocean floor and in permafrost. Methane hydrates are believed to form by migration of gas from depths along geological faults, followed by precipitation, or crystallization, on contact of the rising gas stream with cold sea water. Significant deposits are located off some continental coastlines of the world, including offshore locations of North and South Carolina, and the states of Washington, Oregon, and California. The largest potential methane hydrate reserves available in any one area of the world are estimated to be along the coastline of Alaska.

The extent of worldwide methane hydrate is thought to lie somewhere between the total of the world's natural gas reserves and the entire total world fossil fuel reserves. In either case, the potential is huge. At this time, the amount of this resource that is economic to recover is not well defined, and methods for its extraction have not been developed.

Because of this, extraction costs cannot yet be estimated, but it does appear that technology for recovery of this resource will be developed in the future.

Distributed Power Generation

Most electric power is generated far from its point of use. Citizens in metropolitan areas do not want power plants located next door, so most large power generating plants are far away from the people they serve. Extensive power grids can span many hundreds of miles.

There are three deficiencies related to long distance separation of power generation and point of use. The first is that more energy is consumed with longer transmission lines, the line resistance being proportional to its length.

The second is that the longer a transmission line is, the greater risk of it being damaged, for example, in a storm, or intentional damage (vandalism or sabotage). In the case of major damage, the line is broken and the generating plant is unable to transmit power into the grid or to a particular point of use.

Finally, longer transmission lines from major generating sources require greater infrastructure investment because of heavier wire, large and numerous towers, and the purchase of right of way in transmission corridors.

Distributed power generation is the practice of locating power generation near to the point of use. In such a case, there are many more generating units and they are smaller in power output. This confers the advantages of low line loss, reduced infrastructure cost, and lower risk of power interruption because of damage to transmission lines. Also, because there are more units, the risk of total power loss in an area is reduced; i.e., if one unit fails, there may be others not too many miles away that can increase output to take up the slack until the failed unit can be put back into service.

> Solar panels on rooftops is an example of *distributed generation*.

One particular example of a distributed power generation method is the use of solar panels on rooftops to provide some of the power for a residence, thereby reducing its demand from the grid. Such a setup might be particularly useful in an area of high solar intensity where the sunlight is greatest during periods of high demand (Phoenix, Arizona, for example) to assist with power for air conditioning. Until now, the high cost of photovoltaic (PV) cells have made such installations prohibitively expensive for most homeowners, but technology is continuing to make improvements in both installation techniques and improved efficiencies in PV cells. Recent advances in Thin Film

Photovoltaic technology provides lower cost PV capability, and some utilities are offering rebate programs to reduce cost of installations.

Another example of distributed power generation is the use of stationary fuel cells, such as the Solid Oxide Fuel Cell (SOFC). These units will accept almost any kind of hydrocarbon as a fuel source, from fuel oil to methanol. SOFCs operate at very high temperature (1000-1700 degrees F) and when combined with a heat recovery mechanism (steam turbine to generate more electricity, hot water for industrial or residential use), the efficiency is up to 90% with few emissions because the fuel is electrochemically converted; i.e., no combustion. A 250 kW unit would be adequate to serve a small community or apartment complex. Such units could be uniquely suitable for remote installations outside major power grids. The major disadvantage of SOFC units is they require hydrocarbon fuel, which will almost certainly continue to increase in cost and the installed cost is $1200-2500 per kWh.

Coal or nuclear power will almost certainly remain the cheapest electrical power source for a very long time. It is very difficult to surpass the cost efficiency gained with economies of scale from large power generation facilities.

Renewables

Renewable sources have potential to supply future liquid fuel and electric power requirements. They are highly attractive because they are non-polluting and they will never run out. Together they can become the long-term solution to an energy-independent America.

> Renewables and Biofuels start with photosynthesis. So any release of CO_2 is simply the return of CO_2 that was captured a few years previously by plants – a natural part of the carbon cycle.

Why Would Renewable Fuels Not Create More CO_2?

Renewable fuels, by definition, are fuels that are created and re-created in current time. Examples are hydrogen, ethanol, butanol, biodiesel, and wood pellets. Because these fuels are created by processes that are solar-derived, they capture carbon from the atmosphere as these fuels develop. For example, burning wood grown in forests may cause some local smoke and air pollution, but the release of CO_2 is simply a return of carbon that 10-50 years ago was removed from the atmosphere by photosynthesis to biologically create wood fiber. Accordingly, when these energy sources are oxidized (or burned) they are only returning the CO_2 to the atmosphere that they recently borrowed from it.

These same principles can be utilized to create biofuels. Biofuels start with photosynthesis: the power of sunlight on chlorophyll to create carbohydrates. The carbohydrates are either used directly as fuel, or are converted to hydrocarbons with further processing. Hydrocarbons result in cleaner and more energy-dense fuels than carbohydrates.

What about Hydrogen as a Fuel?

Hydrogen as a fuel may be seen as ideal inasmuch as its combination with oxygen in a combustion or fuel cell process yields a final waste product of harmless water vapor; i.e., no pollution. But there are many practical problems with using hydrogen as a source of fuel, particularly for powering motor vehicles. First, hydrogen – the lightest element – has a very low energy density, so it must be compressed to extremely high pressures to sufficiently condense it to power a vehicle for any useful distance.

Creating a source of elemental hydrogen is not simple either. The hydrogen must be either stripped from a hydrocarbon source (oil, natural gas, or coal), or it must be derived from electrolyzing. If one is to strip hydrogen from a hydrocarbon, why bother? Instead, the hydrocarbon itself could be used as fuel more efficiently.

Creating hydrogen with electric power to break apart hydrogen from water (electrolyzing) requires a significant amount of energy (about 25% energy loss). Compressing requires an additional 15% energy loss. In addition to other small process losses, the hydrogen in a fuel cell only converts 40-50% of the available energy. In the end, 65-80% of the initial electrical energy used to create the hydrogen fuel is lost, so it is a relatively inefficient process.

By comparison, a plug-in diesel hybrid electric vehicle would have only a 20% loss of the initial electrical energy to provide power to the vehicle; i.e., 80% energy efficiency.

BIOFUELS: Ethanol, Butanol, Biomass-to-Liquids, and Biodiesel.

Ethanol. Once regarded as the fuel of the future, ethanol has increasingly come under criticism as a long-term solution for liquid fuels. Although ethanol has become the gasoline additive that replaced MTBE, it has a very high cost and corn-based ethanol production ability is limited without diverting corn production for food.

> The market viability of ethanol has increasingly come under criticism.

Ethanol from corn has been challenged as requiring more energy to produce than it generates and causing food products from corn to rise in price. Another problem with ethanol is that it does not contain as much energy as gasoline or diesel, so one must fill up more often, and 100% ethanol is very corrosive to engines.

If current efforts are successful in developing methods for producing ethanol from cellulosic sources, and at much lower cost, it could become a significant source of liquid fuel.

Butanol. Biologically-produced butanol has several advantages over ethanol. It is less corrosive to engines, it is easier to mix with gasoline, it can be transported via pipeline (ethanol must be transported by truck or train), and it is more energy-dense than ethanol. It has one major drawback: it is more expensive to produce, about 50% more expensive than ethanol.

DuPont and BP are working jointly to develop cost-effective production techniques. Butanol is currently produced from wheat because there is an excess of wheat in the UK where the research is being conducted, but it can be made from any form of sugar. There is current research into how butanol can be made from cellulose or biological waste products such as paper pulp or corn waste.

Biomass-to-Liquids (BTL). This process is the production of fuels from waste wood and other non-food plant sources using the Thermal Conversion Process (TCM), in contrast to conventional biodiesel production, which may be primarily based upon food crops. BTL originates from renewable sources, including wood waste, straw, grain waste, crop waste, garbage, and sewage sludge. The primary challenge to economical production of BTL is that these facilities require huge storage and staging areas, and high transportation costs to move feedstocks to a central plant. One solution to the feedstocks transportation and storage cost problem would be to develop decentralized TCM processors located at sites where the feedstocks are created: sawmills, agricultural centers, and municipal waste facilities. The resulting fuels created could then be transported efficiently in liquid form.

BTL is in the early pilot plant stage of development. BTL may become viable as a more satisfactory economic and ecological alternative for disposing of waste, so that its high production cost can be offset by avoiding conventional waste disposal methods.

Bio-Diesel. Biodiesel is the production of a motor fuel similar to conventional diesel from biological processes. Although it may seem novel to consider food oils as motor fuel, the first diesel engine (invented and built by German Rudolf Diesel in 1892) was designed to run on peanut oil.

Current sources for biodiesel use a variety of feedstocks including soybean oil (U.S.), palm oil (Malaysia), and in Europe, rapeseed (canola) and sunflower oil. These feedstocks undergo an esterification process, which removes glycerin and allows the oil to perform like traditional diesel fuel. The problem with the above feedstocks is similar to ethanol from corn – they are not inexpensive and all these are also food crops, so that producing fuel for transportation is competing with food at the supermarket.

Perhaps the most promising technology is the production of biofuel from algae. Recalling that petroleum is merely biological matter that has stewed underground for millions of years, producing oil from microorganisms doesn't seem as far a stretch. Royal Dutch Shell is researching the production of oil from algae. Some algae can double their weight three or four times per day, others can generate 15 times more vegetable oil than traditional biodiesel feedstocks such as palm and rapeseed. Chevron is researching the compatibility of biologically produced fuels with conventional fuels, and other companies are conducting research and development into biofuels.

Perhaps the most promising bio-diesel feedstock is production of fuel from algae.

There are two current approaches: using shallow ponds, or the ocean itself as the growing area for the algae; or using a closed environment with the algae contained in plastic tubes. The first approach has the advantage of cheaper cost for the growing area, but it is subject to contamination and competition from other invading organisms that do not produce oil. The second approach keeps the selected algae isolated in an ideal environment with optimal sunlight contact, but the growth facilities are more expensive.

It can take a ton of algae to produce just two barrels of vegetable oil, so much of the current research is focused on driving down production costs and boosting productivity by finding algal strains that reproduce quickly and produce a lot of oil.

To culture optimal algal strains and develop growing facilities that will produce even a small commercial fuel supply on a cost-effective basis will require several decades of research and development. But the promise of a source of high quality liquid fuel that is carbon neutral, environmentally friendly, and does not compete with other food and fiber crops has enormous potential for the future.

Hydropower, Wind, Solar and Geothermal

Hydropower. These include conventional reservoir hydropower, tidal, ocean currents, wave action and other ocean movement dynamics. The hydropower we are all most familiar with is from inland reservoirs. While this type of hydropower can provide some contribution and can be highly reliable for baseload power supply, its contribution is small compared to overall electrical demands, and there is not much potential for expansion.

But, tidal power generation can provide a significant contribution to the energy mix in certain areas. Some examples are Nova Scotia, Ireland, Great Britain, and some areas in China. An advantage of tidal power generation is complete predictability; but like wind, a method of power storage is needed to enable reliable electrical power generation whenever it is needed.

Wave energy can be harnessed to generate power. But except in certain areas, wave action is fickle and can probably only provide supplemental power into an existing grid that has a reliable baseload capability. Although hydropower can make a significant contribution to electrical power in certain areas, it is expected to provide no more than 10% of global electrical power generation.

Pumped hydroelectric power has some potential, and is proposed as an adjunct to wind or solar to make those sources more reliable. It is discussed below in wind power.

Wind. Wind has great potential, but has the drawbacks of limited locations and unreliability during calm periods. A cost-effective power storage scheme could improve the outlook for wind energy.

> Wind power can make a great contribution to meet electric power demand, but to become independently viable it needs a cost-effective means of energy storage.

Four conceptual methods for energy storage are compressed air, pumped hydroelectric power, flywheels and flow batteries. Air could be compressed during periods of wind activity and released when needed to power turbines to generate electricity. Subsurface caverns have been suggested as compressed air storage containers.

A second concept would be to use wind power – when supply exceeds demand – to pump water to a higher elevation, then later to release the water to flow through hydroelectric turbines. The third concept would be to use excess wind power to spin up massive flywheels, and later use the flywheel inertia to generate electricity.

The fourth concept is the use of a flow battery to store energy. A flow battery can be energized similar to a conventional lead-acid battery. The energy is stored in the liquid electrolyte, which is pumped through a reactor cell to release the energy. Flow batteries can be rapidly "recharged" by replacing the electrolyte liquid (similar to refilling a fuel tank) while simultaneously recovering the spent material for re-energizing. These conceptual systems would require excess wind generation capacity to build up the stored power for release when power demand increases and winds are inadequate to meet demand.

Wind power can make a significant contribution to electric power needs. By comparison, wind energy has a potential exceeding five times that of hydropower. If a practical method for storing power generated from wind can be developed, wind could provide more than half the power needs for areas of the country where it is most favorable.

An aspect of wind energy that is not getting much attention is the amount of space required to generate a significant amount of electricity. A large coal or nuclear power plant is relatively compact in comparison to the amount of electric power provided, but a large wind farm would require an enormous amount of space. This may not be of great concern offshore or in remote rural sites, but could be problematic in more highly populated urban areas.

Cost is the biggest concern with wind as a resource in providing energy. In order to be a major source, wind must be reliable, so energy storage during times of high winds becomes a necessity to provide continuous power during periods of calm. Wind power alone is about the same total cost (capital, plus operating and maintenance) as coal and nuclear power (see cost comparison and discussion in a section to follow). Adding the necessary energy storage capability such as compressed air, pumped hydro, flywheels, or flow batteries *will add significant cost to the total package*. At this time, no cost projections of these four energy storage methods are available.

Solar. Solar is the Holy Grail of energy, and by strict definition, most of our energy is solar-derived. Even oil and gas began with biomass generated from photosynthesis millions of years ago. But solar energy in this discussion refers to what the sun offers in the here and now.

Solar has the biggest future potential, but it will also take the longest time to develop into a major segment of national electric power generation. Solar power has so far offered the most promise and delivered the least. Other than small calculators and a few projects here and there, solar has not come through with cheap, high-efficiency energy conversion into electricity. The silicon cells that power our calculators are probably not going to get us there.

> Solar has the biggest potential, but may require the longest time to develop – and so far, solar has promised the most, and delivered the least.

Solar power has to overcome the obstacle of developing a cheap photovoltaic (PV) cell, but also (similar to wind energy) storing electric power for release at times when it is not producing, such as night and on cloudy days when full solar generation is not possible.

A conceptual land-based solar power system could provide 50% of the electrical requirements of the entire United States. Solar collectors would be located in unused lands in Arizona and New Mexico – where solar incidence is highest and the number of cloudy days is lowest. This collection system, using current-day PV cell technology would require an area approximately 100 x 100 miles in size. Further improvements in PV technology could reduce the area required. Excess energy generated during the day could be used to compress air, which would be stored in caverns and later released through turbines to generate electricity during the night or cloudy days. As with wind energy, pumped hydro, flywheels, and flow batteries are also possible energy storage options. The generation system could be linked to other areas of the U.S. by using ultra-high voltage DC transmission lines. Right now, it is a conceptual approach, and at least 50 years away. But with technological improvements, it could eventually be achieved.

In addition to photovoltaic electric power generation, Concentrating Solar Power (CSP) has advanced as an alternative method. CSP technologies use the heating power of sunlight to develop energy rather than direct conversion to electricity. From four different original design concepts for CSP, over the last twenty years the Parabolic Trough and the Power Tower have emerged as the leaders. Although both these concepts continue to be evaluated, the Power Tower appears to be more attractive in terms of projected unit cost and, more importantly, its ability to efficiently store energy for later generation of electricity to meet demand at night and on cloudy days.

The Solar Power Tower requires a field of flat, moveable mirrors (called heliostats) to focus the sun's rays upon a receiver in a tower. The receiver acts as a furnace to heat molten salt to approximately 1000 degrees Fahrenheit. Molten salt has very high efficiency heat storage and transfer properties, although oil is also being evaluated as a heat storage medium. The stored heat is used, when needed, to power high efficiency steam turbines to generate electricity. Despite the fact that the solar energy is not directly converted to electricity, Power Towers have very high solar-to-electrical conversion efficiency.

The Solar Power Tower offers today's best land-based solar power generation alternative.

Several Solar Power Tower demonstration plants of 10-megawatts size have been operated in the U.S. from 1982 onwards. Similar-sized plants have subsequently been constructed and operated in Spain and Israel, and a new 900-megawatt plant is scheduled for construction in Southern California. Currently, the projected cost of power generation from the Solar Power Tower is approximately $0.12 per kWh, when deployed in sufficient production quantities to achieve economies of scale, and in appropriate locations with high solar incidence. Studies project lower electric power costs – in the range of $0.06 per kWh – when sufficient numbers of generating plants have been built, operated, and improved. The Solar Power Tower offers today's best land-based solar power generation alternative.

There is another solar avenue being pursued: space solar power (SSP). Lightweight PV panels could be placed in earth's orbit and then deployed to collect solar energy. Here the sun's intensity is greatest (five times the intensity as on the earth's surface) and in space, the sun never sets. The generated power could be transmitted to earth by microwave or laser beams, which can penetrate clouds with no more than 10% loss of energy.

The Japanese – with no significant energy resources of their own – are banking heavily on space-based solar energy. They intend to launch a pilot plant system in 2010, a 250-

megawatt prototype will begin beaming energy in 2020, and a gigawatt-sized station in 2030. Their goal is to produce reliable electricity at 6.5 cents per kilowatt-hour, but this cost does not include the formidable capital cost of getting such power stations into orbit, assembled, and operating. The Japan Aerospace Exploration Agency (JAXA) leads the effort, and has proposed joining with NASA and the European Space Agency to pool resources for the development of this program.

The principal obstacles are reducing weight of the system's components: thin film photovoltaics, high temperature superconductors, and infrared lasers to transmit the power to earth. The power to payload ratio at a few hundred watts per kilogram is still far too low and scientists are working on developments to cut the system's weight to reduce the formidable cost of launching them into orbit. Success of implementing such a program will also depend upon more efficient earth-to-orbit space transportation systems that can significantly reduce the cost of getting the infrastructure into space.

Geothermal Power. Geothermal power offers two broad ways of harnessing the benefits of the earth's underground temperature. One is shallow and the other is deep. The first way is by using the near constant underground temperature of 60 degrees Fahrenheit to help mitigate our energy use in buildings and houses via *geothermal heat pump technology*. The second is by using the very hot temperatures of the earth's core as a source of *geothermal power generation*.

Geothermal Heat Pump Technology. Geothermal energy can be used for home heating and cooling. Ground temperature in the subsurface tends to be constant year round: about 60 degrees Fahrenheit.

Equipment that controls the temperature and humidity within a house or building and supplies hot water and fresh air must exchange energy (or heat) with the outdoor environment. Equipment using the ground as a heat (energy) source and heat sink consumes less energy because the earth is cooler than outdoor air in summer and warmer in winter.

Heat pumps are always used in Geothermal Heat Pump (GHP) systems. They efficiently move heat from ground energy sources or to ground sinks as needed. Although heat pumps consume electrical energy, they move 3-5 times more energy between the building and the ground than they consume while doing so. With continued technological improvements, the energy multiplier effect is predicted to rise to 6-8. This has the effect of reducing the energy required for heating and cooling to a small fraction of current heating and cooling systems.

In order to access the ground's heating and cooling effect for most homes and buildings, ground heat exchangers in vertical borings into the ground would be required. Construction of the borings and heat exchangers would be relatively straightforward during new home or building construction, but could be difficult or very expensive to retrofit into existing structures. GHP installations would represent a higher initial expense than conventional HVAC systems, but could provide a rapid return on investment based upon savings in energy costs. GHP is widely practiced in some European countries and is gaining acceptance in the U.S. Geothermal Heat Pump technology should be regarded as a significant opportunity for conservation and energy savings for new construction of homes and buildings.

Geothermal Power Generation. As discussed in the previous section "Earth's Internal Nuclear Reactor," the temperature of the earth increases with depth. The high temperatures of the earth's interior can be used as an energy source, and geothermal power is economically competitive with other energy sources in certain locations in the world. Locations with economic potential are Iceland, the Philippines, and some areas in the western United States.

Geothermal power is utilized by drilling several thousand feet into the ground, extracting a brine-saturated solution at about 500 degrees Fahrenheit and pumping to the surface. The brine solution is flowed through a heat exchanger that powers a steam turbine to produce electricity. After the heat exchanger, the brine solution is returned to the subsurface formation.

The western United States has a theoretical economic potential of approximately two quads of electricity. (One quad equals one quadrillion British Thermal Units) The current total U.S. electricity demand is about 30 quads, so this would represent a potential energy sector of 7% of total national demand.

Current U.S. geothermal power generation is close to that of wind, but wind is gaining in share. It should be noted that geothermal power, once developed, is highly reliable; i.e., it is available at all times. This is in contrast to wind power, which is available only when the wind is blowing in sufficient strength to provide current power demand.

In a few areas, geothermal is cost competitive with wind, coal, and nuclear power, but in most areas, geothermal would cost in the neighborhood of 15c per kilowatt hour, which is twice as much as wind, and three times as much as coal power. It is possible that geothermal power could be cost competitive with wind power because it would not require backup energy to make it reliable.

Comparison of Coal, Natural Gas, Wind, and Nuclear Power

The principal electrical power sources for at least the next 50 years will be generated from coal, natural gas, nuclear, and wind. Wind as a power source was previously discussed, and is listed here in comparison to other conventional power sources.

NEW GENERATING CAPACITY COST COMPARISON
(2004 Dollars per Megawatt hour)

Cost Element	Coal	Natural Gas	Wind	Nuclear
Capital	30.4	11.4	40.7	42.7
O&M	4.7	1.4	8.3	7.8
Fuel	14.5	36.9	0.0	6.6

Source: Energy Information Administration, Annual Energy Outlook 2006, DOE/EIA-0383(2006) (Washington DC, February 2006)

Figure 4. New Generating Cost Comparison

The above table, provided by the Energy Information Administration, illustrates the relative costs of these major electrical power generation sources. However, only a life-cycle cost analysis can provide a true long-term cost comparison of all these methods of generation. This analysis is important when electric power generation facilities are built to operate over very long time periods. For example, natural gas is by far the cheapest (and quickest) source to install, it is also by far the most expensive in terms of fuel cost. But when a facility's capital cost bonds have been paid off, the most significant cost factors become operation and maintenance (O&M) and fuel. At such a point in time, coal, wind, and nuclear become the preferred sources over natural gas. Wind's fuel cost is zero, its capital costs are high, and the reliability and location problem of wind energy must be overcome to make it a viable source. Again, wind energy only works when and where the wind is blowing.

Nevertheless, we should infer the following from this cost comparison of sources:

- Natural gas plants are cheapest to construct, fuel is costly and supply is more limited than coal or nuclear, so natural gas should be used only for peaking and emergency power, not baseload.

- Coal plants are cheaper and faster to construct than nuclear. Coal is abundant and relatively cheap, so it is very good for cost effective baseload energy.

- Nuclear takes longer to get permitted and built, but fuel is cheap, and nuclear is ideal for cost-effective baseload energy. There are hundreds, perhaps thousands, of years of nuclear fuel supply.

- Wind can provide a portion of electric power needs, provided the problem of reliability (calm periods) can be solved. But making wind energy reliable by providing energy storage facilities *can significantly increase its capital cost.* No data are available on the costs of wind energy storage facility options.

V. TRANSPORTATION CONCEPTS FOR THE FUTURE

Transportation consumes two-thirds of all oil in the United States, most of which is used daily on our highways by cars and trucks. See Table 2, Oil Use in the U.S. by Sector.

Public transportation will undoubtedly solve some of our future transportation needs, but individual vehicle transportation – personal autos – has become not only a convenience, but a perceived necessity to our way of life. We want our cars, but at the same time, we know that we will ultimately be forced – by economics or scarcity of supply – to use much less fuel.

> The mass-produced automobile was clearly one of America's great contributions to the world, allowing a vast increase in individual freedom and productivity.

Automobiles. Can technology help us solve the problem of retaining the freedom and convenience that personal automobiles provide us, yet dramatically reduce the associated fuel demands? The good news is that technological concepts already exist that can do this. And these autos of the future will be accepted, not because they are an unavoidable consequence, *but because they are better*.

Seeing how improvements can reduce fuel requirements with little or no mileage or personal comfort reduction requires an understanding of the energy basics of the automobile.

<u>Important factors impacting automobile fuel efficiency:</u>

- Only about 12-17% of the energy in fuel actually reaches the wheels; the remaining 80-88% is lost as heat and noise in the powertrain.
- The remaining ~12% that reaches the ground is consumed by three tractive loads: about 1/3 heats the air that the auto pushes aside (aerodynamic drag), about 1/3 heats the tires and road (rolling resistance), and about 1/3 accelerates the car, then heats the brakes when the car is slowed.
- Aerodynamic drag increases in proportion to the cube of the driving speed, doubling between 55 and 70 mph.
- Vehicle weight is responsible for the largest consumption of energy. Two-thirds to three-fourths of fuel consumption is weight-dependent.

- Steel is the predominant structural material in cars. Steel is relatively cheap, but is very heavy and it is expensive to design and build the dies and stamping forms. Steel requires finishing and painting, one of the largest cost factors in auto production.

- Internal combustion engines – both gasoline and diesel – run most efficiently at high power, yet these engines spend most of the time operating at low power. The reserve power is needed for acceleration, yet is used only a fraction of the time. This creates inefficiency in fuel use, and requires a heavier engine, adding to the vehicle's weight.

- Diesel engines are about 25-30% more efficient than conventional gasoline engines, yet the gasoline engine is the predominant type used in American cars.

<u>Technical improvements that can dramatically improve fuel efficiency:</u>

- Lightweight vehicles made from composite materials

- Hybrid engine technology

- High efficiency diesel engines – 25-30% less fuel, longer lasting and lower maintenance cost

- Improved aerodynamics

- More efficient tires

- More efficient accessories

- Highly efficient batteries that weigh less

The above improvements can boost an automobile from 25-30 mpg to the 60-75 mpg range, with *no compromise in performance or safety*. SUVs and light trucks can also significantly improve fuel efficiency by implementing the above factors.

<u>Fuel efficiency factors:</u>

Aerodynamics. Aerodynamic drag is determined by multiplying the car's frontal area times its drag coefficient. The drag coefficient depends upon how far back smooth laminar flow occurs before it breaks up into turbulence. A vehicle's shape, smoothness, wheel well design, underbody protrusions, mirror extensions, body seams, etc., affect its aerodynamic drag. One item that has gone without improvement is the underside of the car, where the irregular shape causes immediate laminar breakup into turbulence. One fourth of a car's aerodynamic drag is caused by the irregular underside, so making this surface smooth can greatly improve fuel efficiency.

Rolling Resistance and Improved Tires. Rolling resistance depends only slightly on speed, but mainly on the product of the car's weight (how hard it presses down on the tires) times the tires' coefficient of rolling resistance. Better tire designs and materials can reduce tires' rolling resistance.

Tire makers are developing much lower rolling resistance designs without compromising safety or handling. Regulations may soon require tire manufacturers to display the resistance factors on tires to enable buyers to select the most efficient models. These improvements will be available on self-sealing and run-flat models, so using these tires can avoid the space of carrying a spare and jack. Lighter autos will enable lighter weight tires and wheels, which reduces rotating inertia, equivalent to a 2-3% weight reduction.

Acceleration. Acceleration is directly proportional to the car's weight. This is represented by the power needed to accelerate the car and to climb hills. The acceleration energy is dissipated as heat when the brakes decelerate the car. (Electric hybrid autos recover some of that deceleration energy, an efficiency gain.)

Lightweighting. As stated, a car's *weight* is responsible for 65-75% of its energy consumption. The largest fuel-saving opportunities can result from reducing vehicle weight. Cars are about half steel, and steel is heavy. Substituting lighter materials with equal strength will greatly improve efficiency.

The largest fuel-saving opportunities can result from reducing vehicle weight.

Composite Materials. Composites whose polymer resins contain embedded glass, or carbon fibers, are the most promising materials for future structural materials. Carbon composites – long used in aerospace and racing cars – are stronger and tougher than steel, but one-third as dense (even in finished composites, no painting required), and their strength can be directionally oriented to match load paths to save the most weight. The biggest obstacle to rapid adoption of composite materials is cost, but even this picture is improving. Composite parts are more expensive per pound and per part, but composites are lighter and require fewer parts than steel designs. Adoption of carbon fiber has already begun to occur with U.S., Japanese, and German auto makers including these in roofs, hoods, and other parts. A very important consideration is that *lightweight cars made of composite materials are not necessarily smaller* than their heavier counterparts and can include full-size sedans, SUVs and light trucks.

Lightweighting and Safety. How does a lightweight vehicle – manufactured using carbon fiber composite materials – match up against a traditional heavyweight in a collision? Besides immunity to fatigue and corrosion, carbon-fiber composite materials have impressive crash absorption. This results from three factors:

- Optimally shaped carbon-fiber composite structures can absorb an order of magnitude (10 times) more crash energy per pound than steel or aluminum.

- These composite structures crush relatively smoothly, not jerkily as metal does, achieving up to 2 times the energy-absorbing crush stroke of metal.

- A light, but extraordinarily stiff, beam can surround the passengers and provide a protective barrier.

Traditional wisdom informs us that a heavier car is safer to be in, but more dangerous to be struck by. Crash testing indicates however, that a car that's bigger but not heavier *is safer for people in both vehicles*, because extra crush length absorbs crash energy without adding the aggressiveness of weight. Weight is hostile, but size is protective. Racing car drivers have survived spectacular crashes at speeds exceeding 200 mph in carbon-fiber composite cars.

Future Transportation Improvements:

Hybrids. The term "hybrid" refers to the combination of a traditional internal combustion engine with an electric motor. But there are several different concepts of hybrid vehicles. The hybrid most commonly seen today is a traditional internal combustion-style automobile with an electric motor assist. The electric motor – with a large battery – provides more power for acceleration, and uses generators to recover energy during braking. This setup enables a smaller engine – which runs closer to its capacity – to operate more efficiently.

Another type of hybrid is the Plug-In Electric Hybrid, expected to appear on the U.S. market in 2010. This design is predominantly electric-drive. The car's batteries are charged by plugging into an electrical outlet, and it operates over a limited range – for example 40 miles – from electric power. The motor/generators are in the vehicle wheels and there is no transmission or drive train. This saves a great deal of vehicle weight, and increases the power efficiency. These vehicles have a small internal combustion engine that drives a generator to provide backup electric power if the electric batteries reach a discharged state after driving maximum range on electricity alone.

> CNG vehicles share a similarity with electric hybrids: they offer consumers the ability to refuel at home.

Compressed Natural Gas (CNG) and CNG Hybrids. CNG has been used as transportation fuel around the world since the 1950's. Natural gas is compressed to a pressure of 3000-3600 psi and is used just like gasoline or diesel in an internal combustion engine. The few differences from gasoline and diesel only lie in the storage and delivery of the fuel. CNG infrastructure requires a natural gas utility pipeline, compressor, and dispenser to deliver the fuel to the vehicle. Natural gas is relatively clean, can use existing automobile engines for heavy duty and light duty, and has a distribution infrastructure already in place.

A key advantage for consumers is, with proper gas plumbing and a compressor kit, CNG vehicles can be refueled at home. In this respect, it enjoys the same consumer convenience as a plug-in electric hybrid. In its current form, it would be well suited for short- and medium-range form of individual transportation, or as a short-range fleet vehicle, such as used by a local utility or municipality. With greater availability of commercial refueling points or gas stations, it could become more popular as a primary means of transportation for individuals.

CNG vehicles are manufactured and distributed worldwide by Ford, General Motors, Mercedes-Benz, Volkswagen, Mitsubishi, Nissan, Hyundai, Honda, and Fiat. Few of these manufacturers have effectively penetrated into U.S. consumer markets. The Honda Civic Gx CNG is perhaps an exception. Recently, Toyota announced its 2009 Camry CNG-Hybrid, combining compressed natural gas with advanced batteries and an electric drive.

Battery Technology. The demands required of car batteries for hybrid and plug-in electric autos far exceed the modest requirements of the traditional lead-acid battery of the past. Batteries for the new generation of hybrids and electric autos must store much more energy, be able to be charged much more quickly without risk of overheating, and must be much lighter in weight.

The new generation of lithium chemistry batteries (lithium ion, lithium polymer, and lithium sulfur) has a specific energy (watt-hours per kilogram) of three to ten times traditional lead-acid batteries. Instead of a 900 lb lead-acid battery, its lithium equivalent would weigh about 100 lb and be much smaller.

With today’s technology, a plug-in diesel electric hybrid could have a range of 60 miles on batteries alone (sufficient for about 80% of trips on average), coupled with a small diesel-driven generator to power the electric system for longer-range operation.

Heavy Trucks. Class 8 trucks (18 wheelers and their kin) currently consume over 11% of total oil and average 6.2 mpg of diesel fuel. Current efficiency improvements could almost double this rate to 11.8 mpg, and with further innovations, boost efficiency to ~16 diesel mpg equivalent. Some of the specific needed improvements are:

- Increase from 5 to 6 axles as in Canada and Europe, improving efficiency and container-ship and rail-freight transfers

- Adopt engine system improvements such as variable-pitch turbos, turbo-compounding, displacement on demand, variable valve timing, common-rail, piezo-injectors, 42-V electric systems, conversion of hydraulics to electrics, better lubricants, camless diesels, hybrid drive, and homogeneous charge compression ignition

- Apply known aerodynamic improvements

- Use lighter, stronger, and more durable tractor and trailer materials

- Develop and adopt superefficient wide-based single tires

- Make air-conditioning and other auxiliary loads electrical rather than shaft-driven and power with an efficient auxiliary power unit

- Medium Trucks can utilize many of the above innovations for efficiency

Trains. Although trains are far more efficient than most other forms of transportation, improvements can be made to further increase efficiency. Experts estimate that up to 66% improvement can be achieved by following innovations developed by the Swiss, who are highly reliant upon rail transport. More advanced propulsion concepts, exceeding 310 mph, could replace short- and intermediate-distance air travel. High-speed rail transport would not be subject to the same potential delays and interruptions from adverse weather that often plague air travelers.

Airplanes. Airplanes, which are principally commercial jet aircraft, consume about 1.5 million barrels of oil per day, about 8% of total U.S. oil consumption. Similar to autos, weight is the most critical fuel factor. Use of composite materials in aircraft is currently only about 3%, but could easily be increased to 50%, greatly reducing aircraft weight with no loss in strength. Regional service aircraft are 40-60% less efficient than long-haul planes because of their short stages (typically less than 600 miles), which have a lower ratio of more-efficient cruise flight than lower altitude, climb-out, and ground modes. As stated above, improvements in high-speed rail transport could economically displace short- and intermediate-distance air travel with no loss in time.

> Diversifying sources to include synthetic aviation fuels (GTL/CTL/BTL) may provide the additional fuel price stability needed for airlines. With volatile fuel costs buffered by market-friendly diversification, airline companies can make the leap to the next generation of airframes.

Efficiencies in air transportation are expected to continue beyond the 80% improvement already achieved in recent years. This is driven by an anticipated increase in demand of nearly 3 times the seat-miles of today's fleet average by 2025. *But these improvements depend upon developing and acquiring more efficient aircraft.* If the fragile economic condition of airlines persists, exacerbated by fluctuating fuel prices, the turnover to more efficient aircraft will occur slowly. Strapped airline companies cannot currently afford a new fleet of aircraft with the best new technological improvements when they are struggling just to stay in business. Diversifying fuel sources by developing synthetic fuels may be the answer.

Military. The U.S. military (Navy, Air Force, Marines and Army) consume about 1.5% of total U.S. oil. Although the total is small, its importance is disproportionate. All the lethality of our military depends upon getting a weapons system to the area where it is needed, and this requires fuel.

When the Army deploys, over 70% of the tonnage is fuel. Over 60% of Air Force fuel is used not by fighters or bombers, but for airlifting people, material – and fuel. Many of the same innovations in improving efficiency of personal autos will be required to improve military system efficiency – with a premium on weight reduction.

The military has steadily simplified its fuel requirement by moving to engines for all its vehicles and fuel platforms that require one type of fuel: JP-8; i.e., jet fuel. Improving reliability and security of fuel systems in the military has been underway for more than a decade.

> A misunderstanding of the Global Warming theory is denying the Air Force ultra-clean and reliable synthetic fuel derived from U.S. coal.

The military has actually been ahead of the general public in awareness of this problem. The Air Force has been trying for the last 5 years – for national security reasons – to obtain a dedicated and secure source of domestic aviation fuel. One option that has been tested and approved is fuel processed from domestic coal by the coal-to-liquids process and provided by U.S. companies. This would represent a reliable source that does not compete with the private sector, but this initiative has been consistently blocked by Congress because of environmental objections. The coal-based fuel would represent an increase in CO_2 emissions over regular oil-based jet fuel. Thus, a misunderstanding of Global Warming theory is denying the Air Force from obtaining ultra-clean and reliable synthetic fuels derived from abundant U.S. coal.

What are the Effects of Transportation Improvements?

The sum total of improvements in transportation efficiency summarized above could cut U.S. oil demand dramatically in the next 10-20 years. These reductions could, in combination with development of U.S. shale oil and advances in bio-generated or synthesized liquid fuels, enable the U.S. to be energy independent in two decades, for all practical purposes. *These changes would entail no reduction in economic growth, no risk to national security, and no loss of personal transportation convenience.*

VI. HOW TECHNOLOGICAL TRANSFORMATIONS HAPPEN

Most significant technological changes begin as someone's idea. From there it gets tested on a very small scale; i.e., **Bench Scale**, as in a laboratory. If the concept is successful, it may proceed to the **Pilot Plant** scale, where the entire process is set up and run to get data on continuous performance, and identify areas where efficiencies can be achieved. Because pilot plants are small, they can be easily shut down to modify or rebuild stages, and then run again to observe the effects. In a complex process, this repeated modifying and tweaking may be done dozens or even hundreds of times and be conducted over a period of many years. A successful pilot plant operation will identify the best design for a larger scale plant, and provide a scale of magnitude of the economics required. The Pilot Plant phase is very important because it is often here that the process is refined from non-economic to an efficient one, so it can compete in the marketplace.

The next step in technological development is the **Demonstration Plant**. At this stage, the process is a smaller full-scale operation to demonstrate the economics and process data that can be expected of a full-scale operation. Potential problems and improvements are sometimes not identified until the operation is running at full scale. Because a Demonstration Plant is limited in size and economics, the cost of any inefficiencies have reduced impact, and the improvements learned at the Demonstration Plant scale can be incorporated into the next step: **Full Scale**.

Even Full Scale operations can require a considerable period of time before enough plants are built to represent a significant percentage of the whole. Major technological transformations take 12-15 years to go from 10% to 90% adoption. If the time to go from Pilot Plant to Demonstration Plant is also a decade and major adoption requires another 12-15 years, then major change may not occur for 20-25 years after the original concept is proposed.

> Technology transformations usually take 12-15 years to become fully integrated into an industry and the broader marketplace.

An example of this process is the development of biodiesel fuel from algae. There are currently several pilot plant operations working to develop and improve this process. It may take a decade or more for sufficient biological and process development to occur in the Pilot Plant scale before it is economically justified to build a Demonstration Plant. Biodiesel fuel from algae is a process that holds enormous promise for the production of clean, CO_2 neutral liquid fuel, so these scientific development operations are of great importance. Nevertheless, we are only in the beginning stages of this technological transformation.

When a political candidate or an environmentalist states that we should abandon conventional energy because we can be totally converted to "clean renewable" energy in ten years if we would only try, you can be assured they are either lying or ignorant. To try to force such a result could result in enormous economic damage. The replacement and conversion of major infrastructure, process, and factory assets cannot be done that quickly.

For example, Boeing or Airbus may develop a highly efficient new airliner, but it may be 15 years before older planes are completely replaced in the fleets of our airlines. It takes about 15 years for 90% of the autos to be replaced.

Wind energy is only at a beginning level of impact on the total of electrical power generation, and it has great potential for cheap electrical power, but it has several major obstacles to overcome. It is doubtful that wind energy can supply more than about 10% of our electricity in the next 10-15 years because even if its technical obstacles are overcome, it just cannot be ramped up faster than that.

We must use existing fuel supplies as we transition to future technologies. Those existing energy sources are bridges to the future, and to maintain America's Center of Gravity – the strength and vitality of our economy **–** ***<u>those bridges are essential</u>****.*

VII. RECOMMENDATIONS – Strategy for the Future

The following recommendations have the goal of the most reliable and cost effective energy sources for Americans for the longest period of time. The recommended approach is to continue to research and develop new technologies for the long term, but in the near future, utilize established and proven technologies that are most economical. This will provide the greatest opportunity for prosperity and security for the largest number of people, and will avoid economic hardship for middle-class and lower-income citizens. It is possible that wind and solar may *never* be cheaper than nuclear power.

These recommendations are premised upon the established evidence that man-made global warming is not occurring, and the historically low levels of carbon dioxide in the atmosphere now and in the future pose no threat to the earth's climate.

Recommendations for U.S. Energy Policy

Two Timeless Principles

- <u>Continue to Conserve.</u> Conservation makes sound economic sense and is consistent with free-market principles. It should always be practiced and promoted. Examples of current conservation options include buying more fuel-efficient vehicles, and where appropriate, installation of solar panels and geothermal heat pumps in homes.

- <u>Continue to Support the Free Market.</u> The free-market is the most efficient and effective system of allocating scarce resources to the greatest need. Most of the major technological breakthroughs in America have come from private enterprise, not government programs. Its reliance on scientific processes has proven to be superior to that of government bureaucratic processes, and its focus upon economics ensures that scarce funds are used most efficiently.

Five Near-Term Recommendations

- <u>Oppose Carbon Caps and Taxes.</u> Carbon caps and taxes are a non-solution to a non-problem. These financially punitive measures will ultimately be borne by the consumer in the form of higher costs of products and services because of more expensive energy. Energy taxes and restrictions will be most burdensome for those least able to afford higher living costs: middle-class and lower-income citizens.

- <u>Oppose Alternative Energy Subsidies:</u> Government financial supports of alternative energy methods, also described as "sustainable," "renewable," "green," etc. should be limited to research and small-scale projects. Private enterprise already invests in promising future technologies in the most cost-effective way. Large-scale government subsidies and regulations distort the true economics of alternative energy options and are counterproductive.

- Continue Coal Power Generation. Existing coal power generating plants should continue to be operated throughout their economic useful life. The capital cost of a power plant is a major cost factor, and coal is relatively cheap as a fuel.

- Fast-Track Oil and Gas Exploration. Government should expedite the permitting process for conventional fossil fuel exploration and production, especially on federal lands and offshore. Continued bureaucratic obstruction distorts the market's ability to efficiently meet the needs of American consumers.

- Use Natural Gas Wisely. Natural gas is extremely versatile and has an existing pipeline infrastructure. It is clean with comparatively few contaminants and negligible waste. It is an ideal on-demand fuel for: domestic and commercial heating; as a compressed gas fuel for municipal and industrial vehicles; as a feedstock for plastics, polymers and gas-to-liquids; for electric energy generation during peaking and emergency demand. Because of its high fuel costs compared to coal and nuclear power, natural gas is disadvantaged as a fuel for baseload electrical power generation.

Four Long-Term Recommendations

- Shift to Electric Power. Over the next century, the United State should shift from fossil fuel energy use toward electric power. While there are ample raw materials for several hundred years of liquid fuels, the world reserves of nuclear fuel can provide many more centuries of power than fossil fuels.

- Support New Nuclear Plants. Standardization of nuclear power plant design can lower capital cost, improve reliability and maintenance costs, and increase safety. Long-term electrical demand should include significant nuclear power generation capacity.

- Promote Shale Oil. Shale oil should continue to be developed as a potential liquid fuel source. Shale oil can be America's bridge to future development of renewable liquid fuels.

- Promote Coal-to-Liquids and Gas-to-Liquids. Viable coal-to-liquids and gas-to-liquids programs should be developed to provide a secure fuel supply for essential aviation needs. Utilizing America's abundant coal and gas supplies to provide a reliable source of aviation fuel for the military and commercial aviation has national security implications.

Table 1 - Major Worldwide Reserves of Oil (billions of barrels)

Country	BBbl	Comments
Saudi Arabia*	262	Approximately 20% of world total, may be at peak
Iran*	136	
Iraq*	115	Projected to surpass Iran with modern technology
Kuwait*	102	
United Arab Emir.*	98	
Venezuela*	80	May be at peak
Russia*	60	Trend: government taking over private energy companies
Libya*	39	
Nigeria*	36	
Kazakhstan*	30	
China*	16	
Mexico*	12	Underdeveloped and declining
United States	12	Offshore and ANWR fields would increase reserves

* Indicates oil sales controlled by government

Canada oil sands	315	81% of world total, now largest U.S. oil import source (economic when oil exceeds $30 / bbl)
U.S. Shale Oil	750	50-75% of world total, could supply U.S. for 200 years (economic when oil exceeds $70 / bbl)

Table 2 - Oil Use in the U.S. by Sector

(All data are percentages)

Transportation, total		67.8
Cars		23.3
Light trucks		16.9
Heavy trucks		11.3
Airplanes		8.1
Ships and boats		3.7
Military		1.5
Rail freight		1.3
Buses / Public Transp.		1.2
Other transportation		0.5
Industrial Fuel	12.3	
Industrial feedstocks	11.7	
Buildings	7.7	
Miscellaneous	0.5	

Table 3 – World Coal Reserves
(millions of short tons)

Country	Anthracite / Bituminous	Sub-bitumin. and Lignite	Total	Comments
United States	125,412	145,306	270,718	27% of world total
Russia	54,110	118,964	173,074	
China	68,564	57,651	126,215	
India	99,302	2,601	101,903	
Australia	42,549	43,982	86,531	
South Africa	53,738	-0-	53,738	
Ukraine	17,939	19,708	37,647	
Kazakhstan	31,031	3,448	34,479	
World Total	530,438	470,475	1,000,912	

High quality hard coal (anthracite/bituminous) essential for steel production.
Lower quality coal such as lignite is suitable for coal-to-liquids processing.

Table 4 - Worldwide Reserves of Natural Gas
(trillion cubic feet)

Country	Tcf	Comments
Russia*	1,680	27% of the world reserves.
Iran*	974	Russia and Iran together control 42% of world reserves.
Saudi Arabia*	240	
United Arab Emir.*	214	
United States	204	Advanced technology may double or triple proved reserves.
Nigeria*	182	
Venezuela*	152	
Iraq*	112	Use of U.S. technology may increase reserves.
Kazakhstan*	100	Russia controls most export pipelines
Turkmenistan*	100	Russia controls most export pipelines
Indonesia	98	
Norway	82	
China*	80	
Maylasia	75	
Uzbekistan*	65	
Egypt*	59	
Canada	58	U.S. imports gas from Canada
Kuwait*	55	
World total	6,183	

Table 5 – Natural Gas – Imports and Exports

All units in millions of cubic meters

EXPORTS

Country	**Amount**	**Comments**
Russia	182,000	
Canada	101,900	Most exported to United States
Norway	78,100	
European Union	76,480	
Algeria	62,000	
Turkmenistan	58,000	
Netherlands	50,210	
Indonesia	29,600	
Malaysia	29,060	
Qatar	25,990	
Trinidad Tobago	21,030	
United States	19,800	
Australia	12,900	
Uzbekistan	12,500	

IMPORTS

Country	**Amount**	**Comments**
European Union	361,500	
United States	117,900	Most imports from Canada
Germany	86,990	Most imports from Russia
Japan	77,600	
Italy	70,450	Most imports from Algeria
Ukraine	57,090	
France	47,020	Most imports from Russia
Russia	37,500	
South Korea	35,860	
Spain	31,760	
Turkey	25,480	
Netherlands	22,080	
Belarus	19,310	
Belgium	17,270	
United Kingdom	15,840	

Table 6 –
Worldwide Reserves of Uranium

Country	Metric Tons	Comments
Australia	460,000	
Canada	426,000	
Kazakhstan	254,000	
South Africa	186,000	
Brazil	112,000	
Namibia	110,000	
Uzbekistan	109,000	
United States	102,000	
Niger	94,000	
Russia	75,000	

Worldwide Reserves of Thorium

Note: Knowledge of Thorium reserves is poor because to date demand and exploration has been low. The U.S. Geological Survey data are shown below, however, it is acknowledged that Brazil and India may actually possess the world's largest reserves.

Country	Metric Tons	Comments
Australia	300,000	May be overestimated
India	290,000	May be underestimated
Norway	170,000	
United States	160,000	
Canada	100,000	
South Africa	35,000	
Brazil	16,000	Probably much larger
Malaysia	4,500	
Greenland	?	May have 54,000 metric tons

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