Issue 26, Number 1
January 2004

Geopolitics of Energy®

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Inside Geopolitics of Energy

- **Investing in Energy Poverty Reduction**
  by Robert Priddle

  Without adequate supplies of affordable energy, it is virtually impossible to carry out productive economic activity and improve living standards. Poverty becomes inescapable. Robert Priddle discusses the magnitude of energy deprivation worldwide, its characteristics and likely future trends. He goes on to discuss the financial challenge facing developing countries to meet their energy investment needs. Mr. Priddle concludes that the energy deprived regions, especially South Asia and Africa, will require subsidies if we are to achieve universal access to electricity by 2030.

- **A Strategy: Moving America Away from Oil**
  by John L. Petersen and Dane Erickson

  Recent terrorist events, along with instability in the Middle East, have again raised questions about the security of US energy supplies. In this article, John L. Petersen and Dane Erickson look at historical global energy transitions, catalogue America's current energy situation, explore potential new technologies, and envision a new, all-electric world. The authors then go on to posit a strategy that could dramatically and fundamentally change the shape of energy usage in the US in the next fifteen years.

Investing in Energy Poverty Reduction

*by Robert Priddle**

Every two years, the International Energy Agency publishes long-term projections of global energy supply and demand. Like all projections, these depend on key assumptions – economic growth rates, population growth rates, energy prices, constant energy policies – which may not be realised. They are not, therefore, forecasts of the energy future. Rather they are indicators, based on rigorous analysis, of how the energy future is likely to evolve if the basic assumptions are realised; and, to a degree, indicators of the policy actions needed if features of the projected future appear unacceptable and unsustainable.

These energy projections by the IEA have traditionally been published in the fall, in the *World Energy Outlook* series. In 2002, however, the publication date for one part of the analysis was advanced to the summer. This was done in order to provide a firm basis of fact and systematic analysis for the energy aspects of discussion at the World Summit on Sustainable Development. Kofi Annan, the Secretary General of the United Nations, had ensured that energy ranked on the Summit agenda alongside water, sanitation and the other essentials of life.

A unique feature of the IEA figures on this occasion was that they provided heads of state and government, for the first time, with a detailed picture, region by region, of the links between energy and poverty: the magnitude of energy deprivation worldwide, its characteristics and likely future trends. Previously, little more had been available than the broad generalisation that 2 billion people world-wide were, in some sense, victims of energy poverty. The objective was to arm governments to make better-informed choices towards solutions.

The results, when they came to hand, were shocking. They included the following:

- one quarter of the world population, 1.6 billion people, has no access to electricity today;
- if we go on as we are, that figure will still be 1.4 billion in 30 years time;
- over a third of the world population relies for cooking and heating on traditional biomass –wood, agricultural residues and dung;
- more people than today will be predominantly reliant on primitive biomass for these basic domestic purposes in thirty years time.

Without adequate supplies of affordable energy, it is virtually impossible to carry out productive economic activity or improve health and education. Poverty becomes inescapable.

This is where the issues of energy and sustainability really come together. Though sustainable energy has other dimensions, notably environmental, the future described in the IEA analysis cannot be described as sustainable.

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*Robert Priddle was Executive Director of the International Energy Agency from 1994-2002, where he contributed, on behalf of the 26 member nations, to a significant evolution in the relationship between oil producers and consumers as well as directing an extensive programme of research into all aspects of energy policy. His earlier career in the UK was concerned with many aspects of the relationship between government and industry. He continues to write and speak to an international audience on a consultancy basis. Mr. Priddle is on the editorial board of *Geopolitics of Energy*.

The Search for Solutions – Looking Below the Surface

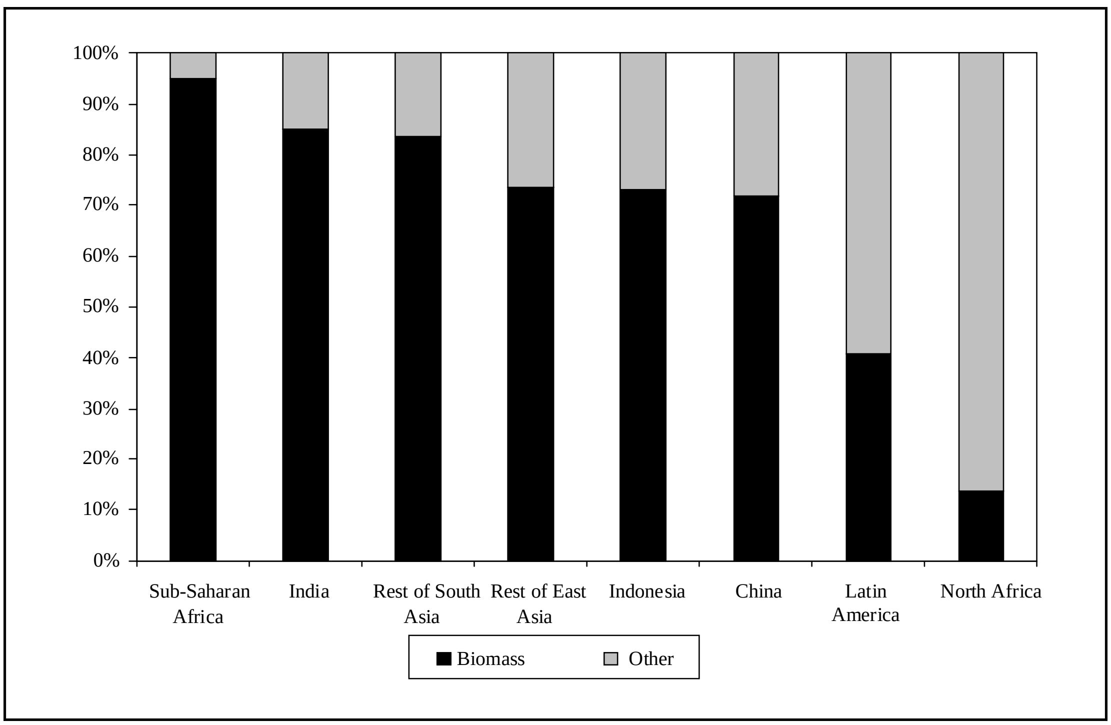
Four out of five people without electricity today live in rural areas. Their initial needs might well be appropriately met through distributed, renewable forms of energy. But it is too easy to slip into the assumption that the problem is one of rural poverty. The demographics are changing. Future population growth will be heavily concentrated in large cities. Urban access to electricity is a less formidable and costly problem; but it demands different solutions, usually involving large-scale centralized power plants.

It is also misleading to assume that the transition from traditional biomass to modern fuels is a straight-line process, involving the substitution of electricity for biomass. The reality is more complicated. Poor families with access to electricity often continue to use biomass for cooking and heating, or switch to kerosene or LPG. They use electricity selectively, for lighting and communications equipment.

Reliance on biomass is not in itself unacceptable. Sustainable use of wood in an efficient stove remains a part of energy use even in OECD countries and is seen by many as a preferred form of energy use. And in India, even rich families very often retain a biomass stove to prepare their traditional bread.

But this is not the predominant picture. There is a close link between biomass use and poverty in most parts of the world.

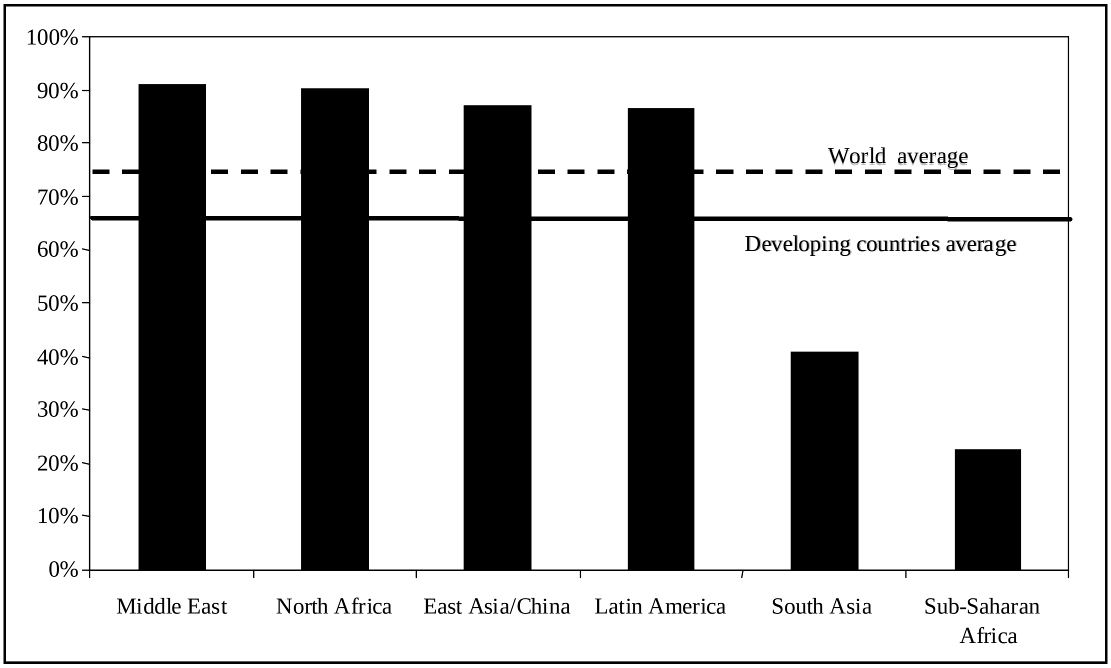
Figure 1
Share of Traditional Biomass in Residential Energy Consumption, 2000



Eighty percent of the total African population relies on biomass to meet basic domestic needs and in 2000 biomass accounted for 70 percent of residential energy consumption in developing countries. In rural sub-Saharan Africa, many women carry 20 kilograms of wood over an average distance of 5 kilometres every day. Traditional stoves burning charcoal and dung expose poor people, particularly women and children, to unacceptably high particulate and carbon monoxide concentrations in the home, giving rise to an estimate from the World Health Organisation that 2.5 million women and children in developing countries die prematurely every year as a result. In urban conditions access to biomass fuel becomes an increasing problem. As readily accessible sources become exhausted, poor people turn increasingly to any available combustible waste, often with serious health implications.

Lack of access to electricity remains the clearest indicator of fuel poverty – and, indeed, of poverty in general.

Figure 2
Electrification Rates by Region, 2000



Twenty-seven percent of the world's population in 2000 had no access to electricity. More than 99 percent of them lived in developing countries. Put the other way, the average electrification rate for the countries of the OECD and the transition economies is over 99 percent. More than 80 percent of those without access to electricity live in South Asia (Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka) and sub-Saharan Africa. In sub-Saharan Africa, only 23 percent of the population has access to electricity, the lowest electrification rate in the world.

Much has been done and is being done to bring electricity to those without supplies. In 1970, over half the world's people had no access to electricity. That figure was still 41 percent in 1990. Despite rapid urban growth in recent years, the absolute number of city dwellers without electricity has not risen above 250 million. That represents an achieved urban electrification rate in 2000 of 91 percent. Looking forward, too, there are high expectations of progress. 75 million additional people are expected to gain access to electricity every year for the next thirty years.

But this is not enough, for the simple reason that the expected growth in the world population will, if realised, almost match the rate of new electricity connections. That leaves us with the much bleaker, and unacceptable, picture of 1.4 billion people still deprived of access to electricity in the year 2030. 650 million of these will be located in sub-Saharan Africa and 680 million in South Asia. But numbers in South Asia will, at least, have peaked before 2010 and then be in decline, whereas the number in sub-Saharan Africa will continue to rise until 2025 before stabilising.

Quantifying the Financial Challenge

Not content with exposing these figures in 2002, the IEA has this year quantified, in the *World Energy Investment Outlook 2003*, the cost of delivering universal access to electricity by 2030. This has been done as part of a more general exercise to test the investment implications of the energy demand and supply figures forecast in the *World Energy Outlook 2002*.

The figures for achieving universal electricity access need to be seen in this wider context. Claude Mandil, the Agency's Executive Director, told the press on November 4th that the Agency had quantified the investment needed to sustain today's global energy supplies and provide for the projected two thirds increase in demand by 2030. Few people will be able to get their minds round the resulting figure – $16 trillion. But, as he said, no individual or organisation will have sole responsibility for mobilising that scale of finance; and it looks less daunting in relation to expected global GDP – 1 percent of global GDP over thirty years.

One of the most striking features of the analysis is the forecast distribution of investment requirements between the different energy sectors. Oil and gas each account for 19 percent of the total and coal for a diminutive 2 percent. The outstanding figure is the requirement for electricity investment: 60 percent of the total, over half of this in transmission and distribution. The 60 percent figure rises to 70 percent if the associated investment in primary fuel supplies for electricity generation is included.

But the second most significant finding of the IEA analysis is that developing countries, where demand and production of energy will increase most rapidly, will require almost half of global energy investment as a whole (even though the unit cost of capacity additions is generally lower than in the OECD), with the five largest countries in the world outside the OECD – China, Russia, India, Indonesia and Brazil – alone needing about a third of global electricity investment.

While the world's financial institutions will not blanche in the face of these figures, what will determine the energy sector's ability to compete for the available international capital will be the market conditions of the sector. Even the OECD countries are facing new uncertainties as market liberalisation introduces new unknowns to the sector.

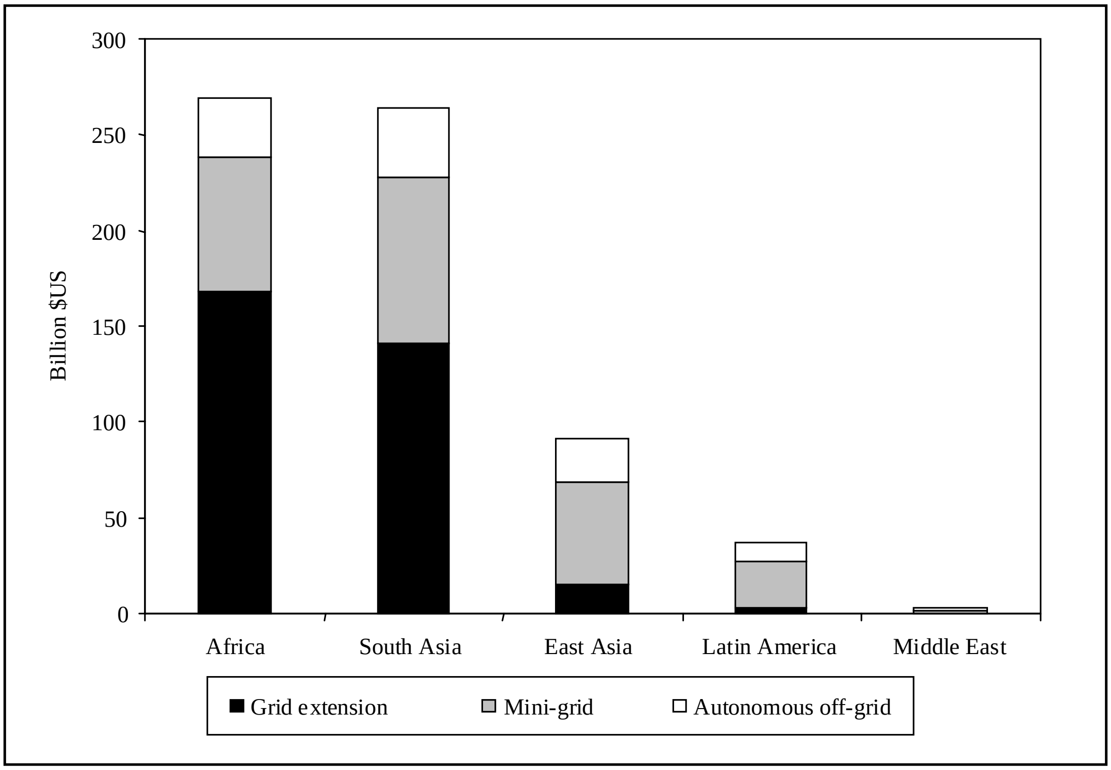
Developing countries face a challenge of an altogether different magnitude. There can be no guarantee that they will be able to finance the $5 trillion electricity investment needed even to meet the requirements of the IEA's Reference Case. Most of it will need to come from private investors. Poorly developed domestic financial markets are a major constraint, while the exchange rate risk is an important factor limiting access to international markets. The challenge is particularly stiff in Africa and India. Far-reaching reforms are urgently needed – particularly to make tariff structures more cost-reflective.

Financing Universal Electricity Access

In the face of these formidable challenges, it may seem vain to contemplate going further and financing universal access to electricity by 2030. But the IEA is not deterred and gives us a figure – $665 billion. In any other context, this figure would be totally daunting. But the IEA has accustomed us to large numbers; and at 6.7 percent of global electricity investment over the thirty-year period, the figure begins to look slightly less forbidding. It assumes a relatively modest level of supply to those newly connected, and one that builds up gradually, reflecting the income-generating effects of electricity supply. This exponential process means that only 10 percent of the additional investment would arise in the first half of the thirty-year period.

Increased demand is, however, inevitably again concentrated in the most vulnerable regions.

Figure 3
Additional Cumulative Investment Requirements in the Electrification Scenario Compared to the Reference Scenario, 2001-2030



Africa would need to add 25 percent to its supply and South Asia 17.5 percent. Only these regions would need to add to urban supply: all other regions already attain 100 percent urban supply by 2030. Africa and South Asia together account for nearly 80 percent of the additional investment needed to realise the goal of universal access.

The World Bank has this year announced a reversal of the policy of recent years, which had reduced the proportion of aid devoted to infrastructure projects. This extends some hope to this deprived sector, which is unlikely to appeal to private investors, in the absence of established markets, guarantees or (in sub-Saharan Africa) geographically-concentrated demand.

But perhaps the most relevant figure from the IEA is not a total investment figure, but an estimate of the subsidy needed to meet the basic electricity needs of 1.4 billion people: $1.1 billion per year. As an investment in social benefits for those who are simply too poor to pay a fully economic price, and as a contribution to future income generation, this seems to be the figure on which the governments of the countries of the developed world should focus. It seems a modest price to put in place one essential element of a sustainable future.

A Strategy: Moving America Away from Oil

*by John Petersen and Dane Erickson**

Context

Recent terrorist events have again raised new questions about the security of U.S. energy. In the light of Middle East regional instability, it is fair to ask: Are there any alternatives to the status quo? How might the U.S. hurry the inevitable shift in primary energy supply, which has happened many times before in history, to a more stable, clean alternative to oil?

About 26 percent of the total energy consumption in the United States is used for transportation. Oil, 60 percent of which is imported, provides nearly all that energy. To solve the problem of dependency on imported oil, changes must occur in the transportation sector.

About the Report

Commissioned by the United States Office of the Secretary of Defense/Net Assessment,[1] the impetus for the report is geopolitical, yet the focus is technological. However, social, political, economic and environmental vectors are considered.

The project's structure is composed of a research segment, a workshop, and a final report. The workshop was designed around the utilization of Think Tools™ technology, which provides an unequaled, robust methodology for developing scenarios and strategies. In addition to Arlington Institute staff, workshop participants included the following experts in energy, national security, and politics: Jesse H. Ausubel, Thomas P.M. Barnett, Bruce Damer, David Epstein, Amory Lovins, Juli MacDonald, Eddie Mahe, Irving Mintzer, Robert Nordhaus, Harold E. Puthoff, and Arnold S. Wasserman.

This study looks at historical global energy transitions, catalogues the present situation, looks into potential new technologies, envisions a new, all-electric world, and then posits a strategy that could dramatically and fundamentally change the shape of energy usage in the U.S. and the planet in the next fifteen years.

Historical Energy Transitions: Key Points

- The history of energy and major fuel transitions is the history of human evolution, innovation, and technological advancement itself. It is significant that in approximately one million years of human history[2], the world has transitioned to a new era of primary energy fuel four times, all of which occurred in the last three hundred years. Indeed, three of these transitions took place within the last century. A survey of the world's transition from wood to coal to oil to natural gas to nuclear power reveals that new fuels are being discovered and used at an exponential rate.

- The military can lead the way for society to transition to a new source of energy. A prime example of this was when the U.S. Navy was the first to go to oil powered ships before World War I. This first step by the Navy was a major endorsement for oil and provided the needed confidence for private shippers to transition to oil as well.

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- Decarbonization Trend – Decarbonization, or the gradual decrease in the amount of carbon in each energy source, is both important for the environment and seems to be a trend in the progression of historical energy transitions. From wood to coal to oil to gas to nuclear power, each source has less carbon in its chemical makeup, and therefore emits fewer greenhouse gases (GHGs) into the atmosphere.

Energy Source	Chemical Makeup	# of C Atoms to Each H
Wood	HC10	1 Hydrogen = 10 Carbon
Coal	HC2	1 Hydrogen = 1-2 Carbon
Oil	CH2	1 Hydrogen = 1/2 Carbon
Natural Gas	CH4	1 Hydrogen = 1/4 Carbon
Nuclear (Uranium)	U	N/A

Source: Jesse Ausubel, "Where is Energy Going?".

- Energy transitions are tied directly to technology innovation. The use of coal did not become prevalent until the invention of the steam engine, and the use of oil did not become prevalent until the invention of the internal combustion engine. Similarly, the use of natural gas was dependent on improved pipe making that resulted from WWII.

  The United States has attempted projects to decrease its reliance on imported oil many times in the past. Consider the period of time following the oil crisis of the 1970s. The United States made a concerted effort to decrease its dependence on foreign oil, and as a result from 1979-1986, the U.S. decreased energy intensity, increased fuel economy, and lowered imported oil from 46 percent to 28 percent of total consumption.[3] This success was largely due to the fact that new U.S. built cars became 7 miles per gallon (mpg) more efficient from 1979-1985.[4]

  However, progress has come screeching to a halt since the mid 1980s as policy-makers shifted to a supply-centered focus, consumers favored inefficient Sport Utility Vehicles (SUVs) throughout the 1990s, and the political environment disallowed increases in CAFÉ (Corporate Average Fuel Economy) standards. Today, CAFÉ standards for a passenger car are 27.5 mpg, which have not increased since 1986 [5], and SUVs are exempt from this regulation because they are classified as light trucks. Indeed, new American cars average 24 mpg, a 20-year low.[6]

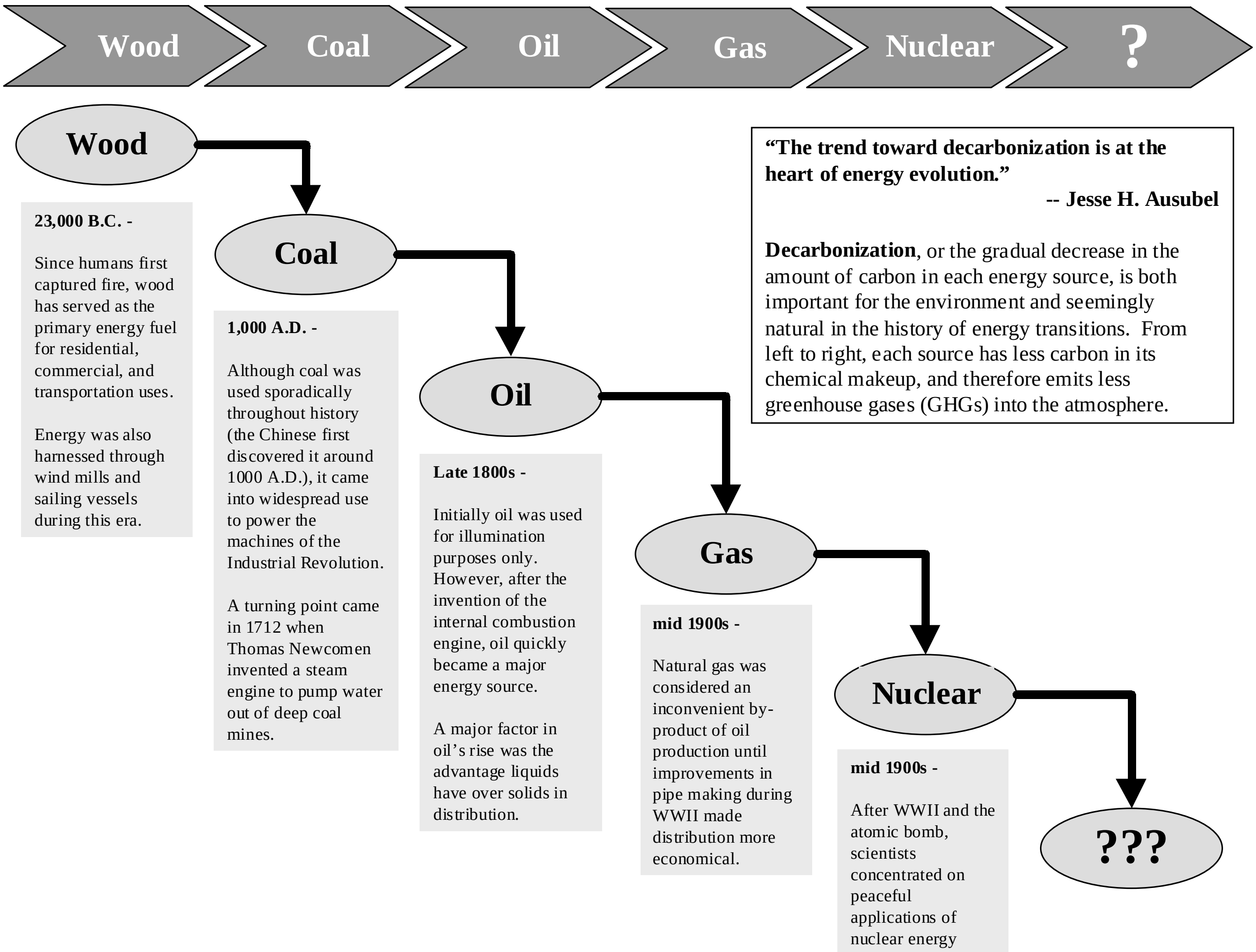
  In a basic sense, each new form of energy did not have to directly compete with its predecessors because new supplies created new demands and altogether more consumption. This led to a legacy of waste and inefficiency that we are still trying to overcome today. As such, each new energy era did not render the prior fuel obsolete. In the United States today, all five of these major fuels continue to play a role in the US energy system.

Observations on the Current US Energy System

- Fossil fuels (coal, oil, and gas) comprise approximately 85 percent of the energy source in the US.

- Almost 2/3 of all energy is lost through inefficiency or waste. In particular, the electrical system and transportation sector are two high impact areas needing improvements in efficiency.

Historical Energy Transitions

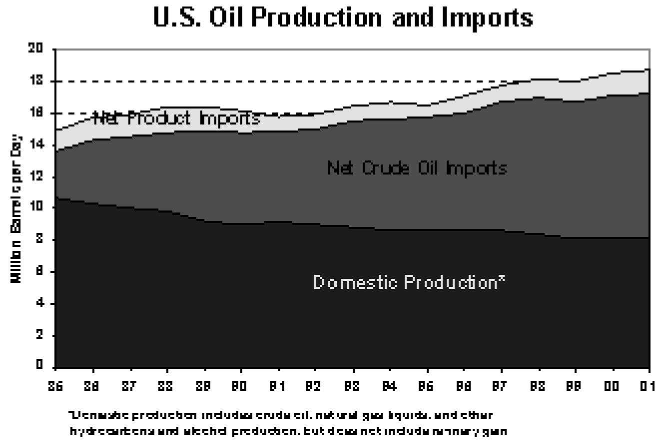


SOURCE: The Arlington Institute, 2003.

- Mostly based on the internal combustion engine, the transportation sector averages 20 percent efficiency.
- Electricity averages 30 percent efficiency from generation to consumption. The efficiency decreases in the distribution and then decreases even further in its end usage because there is currently no practical way to store electricity.
- Oil, 60 percent of which is imported, provides nearly all the energy used for transportation.

Transportation Supply

Consumption is increasing in the U.S., domestic production is decreasing, and imports are increasing (see below).



Source: EIA.

A survey of the origins of US imports reveals some interesting facts. The Middle East provides 25.6 percent of U.S. total crude oil and products imports, of which Saudi Arabia accounts for 14 percent and Iraq 6.7 percent. Overall 52 percent of our imports come from the Western Hemisphere, of which 15.4 percent originates in Canada, 13.1 percent from Venezuela, and 12.1 percent from Mexico (see below).

Noteworthy Countries	Crude Oil (000s barrels)	Crude Oil (% of imports)	Total Crude Oil and Products (000s barrels)	Total Crude Oil and Products (% of imports)
Middle East	976,445	28.7	1,109,076	25.6
Saudi Arabia	588,075	17.3	606,753	14.0
Iraq	289,998	8.5	289,998	6.7
Venezuela	471,243	13.8	566,996	13.1
Canada	494,796	14.5	667,374	15.4
Mexico	508,715	14.9	525,557	12.1
Total	3,404,894	100.0	4,333,038	100.0

Source: EIA Petroleum Supply Annual 2001.

Transportation Demand

Approximately 70 percent of oil in the United States is used for transportation. The demand for oil in transportation mainly goes toward the internal combustion engines of highway vehicles. Sixty-three percent of the oil consumed is used in light vehicles (37 percent in cars and 26 percent in light trucks such as vans, pickups, and SUVs), 5 percent to mid-size trucks, and 14 percent to heavy trucks. Outside of highway vehicles, about 1 percent is used to drive buses and all public transit, 9 percent toward aircraft, 6 percent to ships and boats, and 2 percent to railcars[7].

The remaining 30 percent of oil that is not used for transportation is divided into three places: 6 percent is used in buildings (of which 2/3 is residential), 8 percent is for industrial fuel, and 17 percent is used as industrial feed stocks such as asphalt and petrochemicals[8].

The Changing Context: Wild Cards

We are living in a time fraught with change and uncertainty – a time of greater (and accelerating) scientific and technological achievement than any in history. We have bigger environmental problems than any time previous and the developed world is now being threatened by a diffused, international terrorist threat. This is an environment that is ripe for big surprises –

low probability, high impact events called wild cards. These are the kinds of events that could reasonably contribute to a *Turbulent World* scenario. It is useful to consider what the effect of wild card events might be in such a context.

If a wild card is too big (e.g. Antarctic ice sheet breaks loose and slides into the ocean like a huge ice cube, raising the average ocean level more than 100 ft. and swamping all major seaport cities), it produces extraordinary fear and concern for personal safety that tends to dwarf concerns such as what an energy policy should be for shifting off of oil to hydrogen. An event that is too small (some would argue that 9/11 hasn't changed behavior as much as they thought it might), allows the resiliency of human nature to shake off the experience and revert back to familiar patterns.

When a wild card is big enough to make a difference but not so large as to produce large-scale panic, it generates a vacuum: the status quo evaporates and there is an obvious need for finding new, better approaches to supplying basic needs. Such an event could significantly influence America's progress toward a new energy era.

There are three general types of these wild card events: geopolitical events, technological breakthroughs, and environmental disasters.

- ***Geopolitical Events***: Major terrorist activity (e.g. large nuclear or biological attack) is the most likely possibility that would accelerate or decelerate the move toward an alternative to foreign oil. In the right conditions, the fall of the government of a major oil producer might produce a similar response.

- ***Technological Breakthroughs***: New discoveries that either produce and/or store usable energy many times more efficiently than current technologies would obviously effect the U.S. energy equation. There are a variety of potential breakthrough areas (nanotechnology methods, magnesium batteries, high efficiency photovoltaics, et al.).

- ***Environmental Disasters***: Global warming and rapid climate change-related events could cause a major focus on the pollution that is produced by our present system. The most likely occurrence would be a significant precursor event that the scientific community could directly and credibly relate to a future event of far greater magnitude if we didn't change our approach to energy.

The Future: An All-Electric World

If one steps back from the details of the present state of energy production, looks at larger technology trends that are in place, and at the same time factors in some ideal characteristics that one would want in, say, 2020-30, one interesting possibility emerges—an "all-electric world". Consider these issues.

Present Technology Trends

All major automobile manufacturers are working on fuel cell powered automobiles, which combine oxygen and hydrogen in a chemical reaction to produce an electrical current. Significant government policies and regulations are in place driving a movement that should have all manufacturers having zero-emission fuel cell cars in their product line in about ten years.

Similar trends exist in the maritime area. The U.S. Navy has made a policy decision to only build electric drive conventionally powered ships in the future. Major commercial ship owners have made similar decisions. For many of these ships, gas turbines drive generators that supply the electricity, but in the end, they are electric ships. The question is only how the electricity is produced.

The same is true for trains. All modern train locomotives are powered by electricity whether generated onboard by diesel generators or accessed directly by overhead wires or "third rails".

Emerging Technology

Electricity is not now the most cost-effective approach for heating and cooling of living and working space. But, if there were a way to economically generate cooling from electricity it would immediately open up an extraordinary new market sector for electricity since the distribution infrastructure is already in place. Such a technology is emerging.[9]

New solid-state devices are on the verge of being able to produce both heat and cooling directly from electricity at efficiencies of 60-70 percent. If these new products come into the market sometime soon it would have the potential of revolutionizing the market for using electricity for conditioning the environments of buildings of all types as well as automobiles and other vehicles. This, along with using electricity for motive power, would make it the predominant source of energy for the developed world.

The Structure: An All-Electric World

By definition, this all-electric world would not be an extension of the present, with all of the currently familiar sources and methods operating in just more effective or efficient ways, but would necessarily be a different world. In general, what we are envisioning here would be a place where the generation of electricity would come from any of a number of sources – all of them very low in pollution byproducts. Sources would include some of the renewable approaches that are familiar today (wind, solar, tidal and wave, et al.) as well as more exotic sources that would be invented between now and then.

The electricity production would almost certainly be more decentralized than the present, with increased amounts being generated at the location of use (aboard vehicles, in homes, etc.), rather than at some central power plant.

There would be significant increases in the efficiency of:

- generation (photovoltaics with 70% efficiency, for example),
- transmission (very high temperature superconductivity),
- storage (magnesium batteries, etc.), and
- use (much lower per capita requirements).

In general, breakthrough technologies would produce sources and devices that were much smaller than today. Personal electrical generation sources would be a distinct possibility (portable fuel cells for computers are now on the market). Superconductivity, for example, would result in motors and other components that were much more compact and lighter than what we find today. With microelectromechanical (MEMS) advances the requirements for similarly very small, highly portable energy sources would proliferate.

This would be a world where electricity was everywhere – produced and carried on people (for health monitoring, communication, computation, environmental control, etc.), generated in/on all forms of transportation (from personal to mass), powering freestanding structures (like bus schedule signs at bus stops). Burning fuels to produce heat and then converting it to other useful forms of energy would be as outmoded as the steam engine is today.

Strategy Considerations

These basic considerations shaped all of the deliberations and assessments throughout the strategy development process.

1. The strategy must be sensitive to the inevitable domestic and international politics that will attend any changes as fundamental and far-reaching as these.

2. We must allow for technological breakthroughs in the coming decade and the strategy must allow for that possibility.

3. The present fuel infrastructure should be utilized as much as possible because of the extraordinary cost and effort that would be expended to put a new one into place.

4. This strategy will only work if it is fundamentally driven by economics – if the incentives are in place to make it work. In some cases it may be the government's role to make or increase the incentives in order to accomplish a larger good, but the underlying system is based upon incentives and economics.

5. One should not try to swim upstream – a great deal of time and resources have been invested in exploring and planning for a hydrogen economy, so much so that essentially all car manufacturers are planning for fuel-cell powered cars by 2012 or so. The U.S. Government has made hydrogen a priority as well, so our strategy will take that into consideration, while allowing for the possibility that some surprise might happen that could bypass hydrogen as the prime energy carrier for transportation.

6. The intrinsic resilience of facilities must be a consideration in this time of heightened security. Centralized and decentralized production are important aspects of resilience, as are distribution and retail access of fuels.

7. Resilience of energy flows must be one of the central considerations of this strategy. The objective of this exercise is to craft an approach that increases the certainty of energy by considering more resilient sources, production methods, vehicles, etc.

8. Efficiency must increase. This is not just about finding alternative sources of fuel so that we can continue our wasteful ways. One of the quickest approaches to decreasing our dependency upon foreign oil is to adopt efficiency initiatives.

9. Decreasing the environmental impact of our transportation system is also a key consideration.

10. A successful strategy will encourage the domestic economy. Political and business support will increase if local jobs are part of the equation.

Strategy

A three-phase strategy is needed to revamp and renew the U.S. transportation sector. Within this strategy are three main ideas:

- First, vast improvements in efficiency must be made, mainly through hybrid gasoline-electric vehicles and new lightweight designs.
- Second, the US should invest in a new large-scale initiative to produce bio-fuels as an alternative supply source, mainly through cellulosic biomass.
- Third, in the longer term, these bio-fuels can be used as a feedstock for fuel cells.

Below is the three-phase strategy. Each phase is broken into general objectives – the optimal vehicle technologies, fuels, and efficiency tools that would be used during this phase – and more specific policy steps on how to achieve the overall objectives.

Phase I (1-5 years)

Efficiency is the quickest and easiest first step toward extracting the U.S. away from oil, especially imported oil. Quite different from conservation, which is doing less with less, efficiency is about doing more or the same with less. And making small improvements in the efficiency of our oil consumption can have a dramatic impact on our overall oil needs. A Rocky Mountain Institute study suggests that a 3.25 mpg increase in the U.S. light-vehicle fleet would displace all current Persian Gulf imports.[10]

Today, technology has begun to leapfrog the political quagmire. Hybrid gasoline-electric vehicles offer the same individual transportation flexibility and capability as internal combustion engines, but with a significant increase in efficiency. With systems that alternate their source of power between gasoline engines and electrical motors, the cars currently on the market are capable of attaining between 48 and 64 mpg, more than twice the mpg of a regular vehicle.

Further development and widespread use of hybrid cars should provide the main thrust of efficiency. Promoting hybrid vehicles nation wide could decrease overall consumption of oil in a fast and significant way. Hybrid technology could fully replace the need for Persian Gulf oil if 27 percent of cars were 48-mpg hybrid electric, or 15 percent were ultralight hybrid SUVs.[11]

Vehicles that can run on an mixture of 85 percent ethanol and 15 percent gasoline (E85) won't make a large impact in the system until cellulosic biomass is produced at a large enough scale. However, pushing these vehicles out into the market will create a demand for the fuel, and make the transition easier – at no additional cost. Ethanol vehicles and flex-fuel vehicles cost no more to the manufacturer or the consumer.

By the end of the 2008, this strategy determines as broad objectives that all replacement vehicles off the assembly line are hybrids or E85 vehicles, the fuels used are gasoline and ethanol, and the major efficiency improvements come from Hybrid vehicles.

- Vehicle Technology – All Replacement Vehicles are Hybrids or E85 by 2008
- Fuels – Gasoline and Ethanol
- Efficiency – Hybrid Electric Vehicles (HEVs)

The objective of all replacement vehicles to be hybrids or E85s by 2008 is ambitious, yet attainable, through the five steps stated below:

1. Heavy tax incentives for consumers who buy hybrids and E85
2. Tax penalties for both production and consumption of non-hybrids and non-E85s
3. Marketing for hybrids and E85s
4. Increase taxes on fuel to add incentive for more efficient cars
5. Government purchase and investment in hybrids and E85

Phase II (5-10 years)

The second aspect of this three-part strategy centers on new fuels. Our assessment suggests that bio-fuels offer the U.S. the quickest avenue to alternative sources of energy; both clean and home grown, renewable fuels are available as alternative sources today. Ethanol produced from corn currently makes up about 1 percent of the fuel consumed in the U.S. today.

In addition, this process is very energy inefficient as it takes nearly as much energy to produce the ethanol as is consumed in the end.

However, a new process of producing ethanol from cellulosic biomass (plant material) is becoming a highly attractive option. Highlighted by James R. Woolsey and Richard G. Lugar in Foreign Affairs,[12] this process can take any organic material and produce ethanol through new biocatalysts – genetically engineered enzymes, yeasts, and bacteria. This means not only the corn, but corncobs can be processed, as well as switch grass and other materials formerly unused. Several specialists, including Dartmouth engineering professor Lee Lynd, say that just the nation's agricultural and forest residues could produce enough ethanol to replace eight percent of the nation's gasoline. In addition, to mow the grasses of historically unused cropland for conservation purposes, and process them into ethanol could displace up to 25 percent of the nation's gasoline needs.[13]

While already far along in development, most companies pursuing this technology expect to make it commercially available by 2007 (e.g. Cargill Dow). This process could eventually displace significant amounts of the oil currently consumed.

Phase II broad objectives consist of all replacement vehicles becoming hybrids, E85, or E85 Hybrids by 2010, that the major fuel consumed is Ethanol, and that major efficiency improvements come from Hybrid and HyperCar® lightweight designs[14].

- Vehicle Technology – All Replacement Vehicles are Hybrids, E85, or E85 Hybrids by 2010
- Fuel – Ethanol
- Efficiency – HEVs; Hypercar® Design

Phase II broad objectives are attainable through the following steps:

1. Research and development (R&D) money to cellulosic biomass technology (into ethanol)
2. Incentives to promote storage, distribution, production infrastructural changes
   a. Storage – water tight storage containers
   b. Distribution – change seals on current infrastructure
   c. Production – increase ethanol production
3. Subsidize ethanol production to keep costs down
4. Marketing/encouragement for fuel changes
5. R&D into E85 Hybrid vehicle
6. R&D into Hypercar® Design

It should be noted that a technology of potential significance in this strategy is an E-85 hybrid engine. Not only would this vehicle reduce the demand for imported or produced oil, but it would also make the transition to ethanol much easier and faster. Instead of having to replace the entire 20 million barrels of oil consumed a day in the U.S., perhaps only as little as half of that would need to be produced. This is the importance of efficiency.

At the time of publication, there were not any companies pursuing this technology and the National Ethanol Vehicle Coalition was only aware of a few university studies on the idea. Nonetheless, this technology is very worthwhile in an ethanol transition.

Phase III (10-15 years)

At most levels, fuel cells have been deemed the new engine which will carry the U.S. to the next energy era. Fuel cells act like a battery, yet will eventually replace the internal combustion engine.

The third piece of this strategy is to use these new biofuels (mainly ethanol) as feedstock for fuel cells. This will open the door for the fuel cell and hydrogen future, even as pure hydrogen is seen as the better option down the road.

There are two ways biofuels can be used for fuel cells. One is to use the ethanol directly in the fuel cell. This process has already been researched, and has been achieved in stationary form (a PAFC by United Technologies). However, research still needs to be done in this area, as it has not been achieved for a smaller, more portable fuel cell.

The second option is to transform the ethanol into hydrogen at the site of fueling. Then the advantage of a liquid fuel can be utilized in distribution of the fuel, yet direct hydrogen fuel cells can be used in the vehicles themselves.

Currently, methanol is considered the most convenient liquid fuel for fuel cells, and can be produced from a number of different sources. The processes that convert ethanol from cellulosic biomass materials would be the same processes to produce methanol.

Phase III broad objectives include making fuel cell vehicles mainstream, allowing most of the feedstock fuel to be methanol and ethanol, and hybrid fuel cell vehicles and Hypercar® designs to make up the efficiency contributions.

- Vehicle Technology – Fuel Cell Vehicles and Fuel Cell Hybrid Vehicles become mainstream
- Fuel – Ethanol; Methanol
- Efficiency – Fuel Cell Hybrid Vehicles; Hypercar® Design

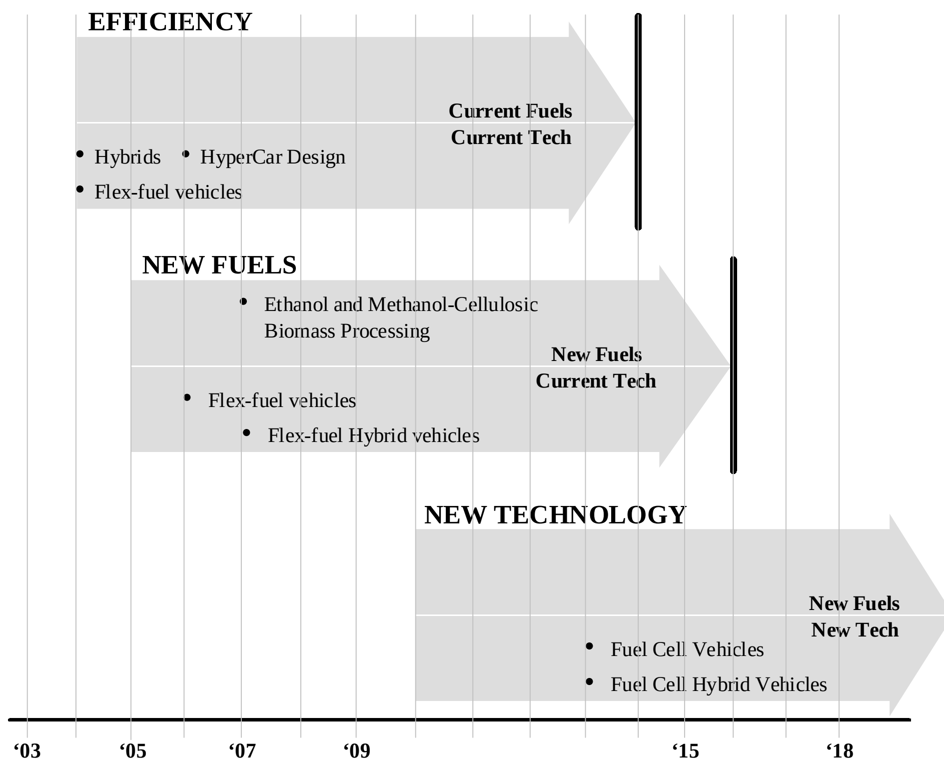
The following policy steps will advance the U.S. into Phase III:

1. R&D into Fuel Cells that run directly on Ethanol
2. R&D into Fuel Cells and Methanol
3. Incentives to promote storage, distribution, production infrastructural changes
    a. Storage – water tight storage containers
    b. Distribution – change seals on current infrastructure
    c. Production – increase ethanol/methanol production through cellulosic biomass
4. R&D into Fuel Cell Hybrid Vehicles[15]
5. Incentives and Tax Breaks for Fuel Cells
6. R&D into onsite reformation stations

In summary, our analysis suggests that E85 vehicles and hybrids have the potential to make the most significant impact in the near term with essentially no design or manufacturing changes by car manufacturers. In the mid-term, hybrid electric vehicles using E85 engine/generators with battery augmentation come into their own and finally, the same electric vehicle platform could be used, replacing the E85 engine with a fuel cell.

It is interesting to note that other knowledgeable individuals have reached conclusions that are consistent with this perspective. In particular, recently Timothy Wirth, C. Boyden Gray, and John Podesta, former senior government officials, proposed as part of a comprehensive energy strategy that the number of hybrid vehicles should be rapidly expanded and that ethanol derived from cellulosic biomass would be the best alternative fuel to power the cars and trucks[16].

Approximate Timeline for Moving America Away From Oil



Source: The Arlington Institute.

<u>General Benefits to this Strategy</u>

There are 10 general major benefits to this strategy:

1. It uses existing infrastructure to move the U.S. away from oil in the most expedient fashion.
2. It moves the U.S. to energy independence – fast.
3. It uses the shorter-term solution – alternative biofuels with existing infrastructure – as a stepping-stone to the longer fuel cell and hydrogen solution.
4. It uses renewable fuels.
5. It is politically viable because of a strong agricultural lobby.
6. It creates jobs in rural areas.
7. It upends the U.S. trade deficit. (Imported oil currently accounts for more than 20 percent of America's trade deficit.)
8. It uses the newest technologies.
9. It will contribute no net carbon dioxide to the atmosphere.
10. It is flexible enough to allow for new technologies and discoveries to arise in the next decade that will alter or accelerate this transition.

<u>Strategic Benefits to the Military</u>

The strategy of a move toward an increase in the utilization of gasoline-electric hybrid engines, Hypercar technologies, bio-fuels, and fuel cells among military vehicles could have profound positive impact on the U.S. military forces. Major benefits include:

- *Increased Range and Mobility* – Gasoline-electric hybrid engines are able to go up to twice the distance on the same tank of fuel, without sacrificing performance. This makes the vehicles more agile, capable of covering more ground in less time.

  The positive effects in range and mobility can also be seen on the larger scale. An armored division currently uses about 600,000 gallons of fuel a day[17], which means large refueling vehicles and infrastructure must be on hand at all times. The less fuel needed, the less refueling vehicles and infrastructure needed, and the more range and mobility of the entire division.

- *Decreased Costs* – Amory Lovins of the Rocky Mountain Institute estimates that a comprehensive fuel efficiency plan for the military could save upwards of ten billion dollars a year.[18] These funds can then be reallocated toward other endeavors.

- *Increased Capabilities for Surprise and Reconnaissance Purposes* – Gasoline-electric engines and fuel cells are significantly quieter than internal combustion engines — virtually noiseless — allowing U.S. forces to sneak up on enemy targets or pass by unnoticed, at certain speeds.

Conclusions: Compensation for Oil Producing Countries

It is of significant importance for the United States to rapidly move toward energy independence in the near future. Our lack of energy independence makes our economy and way of life vulnerable to global instabilities through potentially disrupted supply and distribution chains. The money we spend on foreign oil too often goes to fund the same terrorists with whom we find ourselves in conflict. This strategy posits the most expedient way for the U.S. to move away from oil, and even more quickly, away from imported oil.

However, in this era of globalization, the world has become too small and interconnected for any country to think it can behave with ambivalence toward the rest of the world. An isolationist stance regarding energy policy is strictly untenable.

By creating a strategy that makes oil less useful, on one hand we posit a solution to a very important problem, but the consequences around the world, and especially in the Middle East, cannot be ignored. Middle East problems would certainly multiply if oil rapidly lost its value as would similar problems in a number of other countries that are highly dependent upon oil exports to provide economic and political stability.

There are some who suggest that if the transition were slow enough, a Middle East, Nigeria and Venezuela free of oil wealth would actually create opportunities for true economic development to occur. These pundits suggest that history shows that countries rich in oil create and sustain large gaps between the rich and the poor. They say the oil acts as a hindrance to the country – keeping the elites content enough to maintain enough stability without opportunities, money, and education trickling down to the majority. If the demand for oil gradually decreased over a period of several decades, the foreign oil producers could anticipate the change and begin investing in other potential resources and industries, such as minerals, food, and pharmaceuticals, thus averting a long-term crisis.

The other side of the argument is that if oil were to suddenly lose its value, the oil producing countries could become very unstable with anarchy breaking out in the most oil dependent countries. Potentially, there could be a redistribution of power as old regimes fall, and new regimes are created. A scenario not too dissimilar from this is included in John Petersen's, "Out of the Blue; Wild Cards and Other Big Future Surprises" where all fossil fuels become obsolete.

The implications of this possibility are vast. Will chaos break out? Will old regimes fall, countries collapse, and new borders drawn? Will the change present an opportunity for democracy to take hold in countries never seen before?

The answers are not clear. But the questions are very important, and serious scenario development in this area is a requisite next step. The reality of a world much less dependent on oil appears to be just around the corner.

Endnotes

[1]The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of Defense position, policy, or decision.

[2]Grathwohl, Manfred. World Energy Supply. Berlin, New York: Walter de Gruyter & Co, 1982.

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[7]Lovins, Amory. "Energy Security Facts" Rocky Mountain Institute 2 June 2003 http://www.rmi.org/images/other/S-USESFbooklet.pdf

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[9]Cool Chips™ represent a new development for cooling, refrigeration, and thermal management. One of the first industrial applications of nanotechnology, Cool Chips use thermotunnel technology to deliver up to a projected 55% of the maximum (Carnot) theoretical efficiency for heat pumps. Conventional refrigerators operate at up to 45% efficiency and current thermoelectric systems (Peltier Effect) operate at 5-8% efficiency. http://www.coolchips.gi

[10]Lovins, Amory B., "Energy Security Facts" Rocky Mountain Institute 2 June 2003 http://www.rmi.org/images/other/S-USESFbooklet.pdf

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[12]Lugar, Richard G., and R. James Woolsey. "The New Petroleum." Foreign Affairs. Volume 78 (Jan/Feb 1999): 87-102.

[13]Ibid.

[14]http://www.hypercar.com/ — HyperCar® technologies utilize breakthrough design and engineering capabilities. They allow vehicles to substantially increase efficiency without sacrificing safety or comfort through lightweight advanced composite structures.

[15]http://www.ford.com/en/vehicles/specialtyVehicles/environmental/fuelCell/focusFCVHybrid.htm

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Publication Date: January 23, 2004

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Publisher: Canadian Energy Research Institute, #150, 3512 - 33 Street NW, Calgary, Alberta, Canada T2L 2A6
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