The Arlington Institute

A Strategy: Moving America Away From Oil

Technology • Fuel • Efficiency

Office of Net Assessment
Office of the Secretary of Defense
Department of Defense

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I. Executive Summary

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?

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.

About 26% of the total energy consumption in the United States is used for transportation. Oil, 60% 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.

In sum, it looks like the world – led by the U.S. – is moving toward the day when hydrogen will replace oil as the major source of energy for transportation. The only question is how we get there. There are three major scenarios that describe possible energy environments of the next few decades: Awash in Oil and Gas, Technology Triumphs, and Turbulent World. Within the alternative vagaries of unlimited fossil fuels, new hydrogen-based technologies, or broad-based chaos that begs for change, a path must be planned that is based upon evolutionary change but will respond to revolutionary influences.

Where is this all going in the end? What does the world of transportation look like in, say, 2050? It's our guess that it's an all-electric world. Almost all vehicles (and most of the rest of our tools) will be electrically powered – the question is where and how the electricity is generated. Breakthroughs in generation, distribution and storage are almost inevitable and will eliminate all of the major problems associated with electricity today.

Keeping in mind possible technological breakthroughs that could leap over hydrogen fuel cells and produce electricity directly on a vehicle, we nevertheless jumped into the present methanol-ethanol-natural gas argument as a source for H2 and then assessed all of the major alternative vehicles that are presently under development.

There are a number of fundamental considerations that will always be major factors in any changes to a new energy source: political and economic feasibility, environmental impact, utilization of existing infrastructure, potential geopolitical disruption, et al. Using Think Tools™ technology, we arrayed all of these against all combinations of energy source/vehicle to isolate which options presented the best near-term, mid-term and long-term benefits. Always preserving the capability of rapidly accelerating the pace because of some major event or science breakthrough, a solid 15-year development path was designed.

The beginning of the strategy is already being played out: all manufacturers can now produce E85 engines (that can run on any combination of gasoline and ethanol up to 85% ethanol), with no changes in engineering and manufacturing cost. They should do so immediately. That would open up many hundreds of thousands of new vehicles to using ethanol, a domestically produced alternative fuel that can be distributed through the existing infrastructure with essentially no change at all.

An increasing number of manufacturers are producing hybrid electric vehicles (HEVs). Electricity is produced in an HEV from an internal combustion engine/generator set and stored in batteries. Either the engine or the batteries is then used for powering electric drive motors under the most efficient conditions. HEVs are the first step toward an all-electric vehicle, and if the engine were an E85/HEV engine it would at the same time be much more fuel-efficient while a larger portion of the fuel would come from North America.

Efficiency could be significantly increased above that gained from powertrain upgrades by integrating full-system design measures that take into consideration elements like aerodynamic drag, rolling friction, heating and cooling efficiencies, etc. The best example of this is the Hypercar® that has been developed in Colorado. Hypercar® design ideas combined with the HEV drivetrain could theoretically produce average fuel consumptions around 90 mpg.

The HEV/Hypercar® could easily be upgraded with fuel cells when they become commercially available. That would be a natural evolution along the developmental path to national independence, vehicle efficiency, and environmental friendliness.

All of these initiatives must be implemented while keeping in mind the larger objective of maintaining geopolitical stability. It would make no sense to solve our domestic energy problem by causing a number of equally significant, enduring crises in other parts of the world . . . that we then have to deal with for decades to come. We must take a holistic approach to dealing with this system.

II. Introduction

The United States is approaching an historic transition in terms of the major sources of energy that it will use in the future. There are good reasons to believe that within the next twenty years the U.S. will lead the world in moving from oil as the major source of fuel for the transportation into a new era that hopefully eliminates a number of the major problems that have always attended the acquisition and use of gasoline.

Drilling for oil, refining it, and the transportation, distribution, and the burning of gasoline in automobiles and other vehicles has always had negative environmental implications, but scientific studies in the last decade have increased the understanding of the role that this fuel plays in a number of global and regional problems. As we have learned more about these implications, public awareness and sensitivity to the pollution that attends our dependence on petroleum products has dramatically increased to the point where local and national governments have implemented new regulatory regimes designed specifically to encourage the transition away from gasoline to an alternative, more environmentally friendly fuel for the highway fleet.

At the same time that public pressure has increased for an alternative to oil for environmental reasons, the geopolitical issues associated with a major dependency on a raw material that is often found in politically unstable areas have come to a head, contributing in part to two Persian Gulf conflicts in the last dozen years.

The events of September 11th have galvanized many parts of the American government to think afresh about some of the underlying energy issues that make the Middle East particularly important to us all at this time. Perhaps a dozen independent studies are underway, all focused on moving out of oil to something else – soon.

This confluence of trends coupled with a broad spectrum of technological advances in the last decade have convinced a growing number of thoughtful analysts that we are on the verge of a major global energy transition from oil to something else. Most commentators believe that hydrogen will fuel the coming era and have given their efforts to trying to determine just how to facilitate the emergence of a hydrogen economy. In this report we consider the issue more broadly; certainly looking at all of the alternative paths to hydrogen, but also keeping in mind how other elements of the equation (like increased efficiency and other technological breakthroughs) could come together to reconfigure the future world of energy.

This then is a broad-based approach to accelerating the U.S. transition from a dependency on oil to a new primary energy source that eliminates the underlying issues associated with petroleum.

The Process

While the impetus for the report is geopolitical, the focus is technological. However, social, political, economic and environmental vectors are considered.

Commissioned by the Office of the Secretary of Defense/Net Assessment, the project is designed to:

- Consider the history of the dominance of major fuels and understand why and how the world transitioned to each new era
- Establish the present state of global fossil fuel reserves, projected usage, and availability horizons
- Determine the present state of development of both conventional and unconventional alternative fuel sources
- Develop scenarios of possible early transitions from oil dependency
- Explore the political and economic implications for the U.S. in each scenario
- Develop a strategy for transition out of the oil age and identify the policy initiatives that would be required to enable it

The project's structure is composed of a research segment, a workshop, and a final report.

The Research

Extensive research was undertaken to identify the history of fuel dominance in the developed world, the present state of global fossil fuel reserves, usage, and future availability, and to assess the development of conventional and unconventional alternative sources. Our objective was to establish a credible understanding of historical precedents in the energy area and begin to look into the future and identify plausible alternatives to the status quo.

Summaries of this research can be found in the Appendix.

The Workshop

January 7-8, 2003
At The Arlington Institute

As part of this project, The Arlington Institute held a two-day alternative energy workshop in January. Eleven experts in energy, national security, and politics convened at The Arlington Institute offices. The workshop was designed around the utilization of Think Tools™ technology, which provides an unequaled, robust methodology for developing scenarios and strategies. The workshop was structured to:

- Consider a broad spectrum of trends and surprise events that could significantly influence future energy scenarios
- Build a variety of scenarios of possible transitions away from oil dependence
- Identify the most effective options to be included in the strategy and how they might interact
- Identify the most effective strategies for achieving the most desirable scenarios

- Indicate the policy initiatives that would be required to execute the strategies
- Build a risk analysis of the most effective strategic option

The Report

This final report presents the complete strategy, details on the underlying logic, resources that are required, alternatives that were considered, the risks associated with the initiative, and a scenario that might also contribute to an effective energy transition.

About the Authors

John L. Petersen's professional involvements include long-range strategic and product planning and helping leadership design new approaches for dealing with the future. He has led national non-profit organizations; worked in sales; manufacturing; real estate development; and marketing and advertising, mostly for companies he founded. A graduate electrical engineer, he has also promoted rock concerts; produced conventions; and even worked as a disc jockey--among other things.

Mr. Petersen's government and political experience include stints at the National War College, the Institute for National Security Studies, the Office of the Secretary of Defense, and the National Security Council staff at the White House.

Petersen, the president and founder of The Arlington Institute, is a leading futurist who writes and thinks about high impact surprises – wild cards – that are global in scope, potentially disruptive, and intrinsically out of control. *johnp@arlingtoninstitute.org*

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1. **Jesse H. Ausubel** is Director of the Program for the Human Environment and Senior Research Associate at The Rockefeller University in New York City.

2. **Thomas P.M. Barnett** is currently both Assistant for Strategic Futures, Office of Force Transformation, Office of the Secretary of Defense; and Professor/Senior Strategic Researcher, Decision Strategies Department, Center for Naval Warfare Studies, U.S. Naval War College.

3. **Bruce Damer** is President and CEO of *DigitalSpace Corporation* and Director of *Contact Consortium*.

4. **David Epstein** is Deputy Director, Office of the Secretary of Defense/Net Assessment.

5. **Amory Lovins** is the CEO-research and co-founder of the Rocky Mountain Institute.

6. **Juli MacDonald** is an Associate at Booz Allen Hamilton.

7. **Eddie Mahe** is now with Foley & Lardner after founding The Eddie Mahe Company. Prior to that, Mahe was the Deputy Chairman of the Republican National Committee.

8. **Irving M. Mintzer** is Executive Editor of *Global Change Magazine*, a Senior Associate of the Pacific Institute for Studies in Development, Environment and Security, and a member of the Global Business Network.

9. **Robert Nordhaus** is with the Washington law firm Van Ness Feldman, and is currently the point of contact for the Transportation Work Group of The Energy Future Coalition, a U.N. and Turner sponsored energy project.

10. **Harold E. Puthoff** is currently Director of the Institute for Advanced Studies at Austin.

11. **Arnold S. Wasserman** is Senior Fellow for Design at The Idea Factory in Singapore and San Francisco.

Think Tools A.G.

1. **Robert Steele** is a Regional Vice President for Think Tools A.G.

2. **Adrian Taylor** heads the section handling utilities and public sector clients for Think Tools A.G.

III. Historical Energy Transitions

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[1], 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.

Mr. Jesse H. Ausubel, Director of the Program for the Human Environment and Senior Research Associate at The Rockefeller University in New York City, has made significant contributions to this field.

Below is an overview of the major transition in primary fuels. Listed after the overview are some significant key points about these transitions for consideration when thinking about future energy transitions.

Wood

Since the discovery of fire approximately 400,000 years ago, wood has been the primary source for cooking, warmth, and light. Up until the Iron Age around 700 BC, most mechanical energy was supplied by human and animal muscle. Although the water wheel was known to Byzantium as early as 200 BC, the first purely mechanical energy source drove a grist mill in 200 AD in Arles, France[2]. Wind mills began to become prevalent in the Arab world in the 9th century, and then later came to Europe in the 12th century. In sum, during this early era, wood heated homes, animals provided muscle, and wind and water propelled basic machinery.

Coal

First discovered in China around 1,000 AD and subsequently brought to Europe by Marco Polo about 1275 AD, coal originally was used in lieu of wood for heat and illumination purposes. In 16th century London, for example, coal began to take the place of wood in homes as deforestation made wood scarce and expensive. However, there were technological challenges to coal. For example, coalmines penetrated the water table and therefore the water needed to be pumped out to extract the fuel.

Everything changed when Thomas Newcomen invented the first steam engine in 1712. This provided reliable power for mechanical pumps and began a revolution in the capability and potential of machinery. Because steam engines provided as much power

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

as dozens of horses at a fraction of the cost, they were "soon powering locomotives, factories, and farm implements."[3] In addition, the spread of coal had political and economic implications worldwide. Countries with large coal deposits, such as the United States, Britain, and Germany, became dominant industrially, and thus economically and politically as well.[4]

Oil

Oil made its rise in a similar way as coal – first as a substitute for a current use, and then became the major energy source as the fuel for a new technology. In the latter half of the 19th century, oil began to be reformed into kerosene and used as an illuminant. Once oil was struck in Pennsylvania in 1959, New York investors started to see that oil would be a better source for light than whale oil because it would be easier, quicker, and cheaper to refine.[5]

But of course there were two main reasons for the dominance of oil in the US, which began at the start of the 20th century. First and foremost was the invention and mass production of the internal combustion engine, which created an insatiable demand for oil that obviously has yet to subside in the 21st century. Secondly, it became evident that an energy system of fluids was more advantageous than a system of solids.[6] Despite the fact that oil was more expensive per unit of energy than coal, it was much cheaper to transport. Even as late as 1955, the cost of transporting liquid fuel energy was "less than 15 percent of the cost of transporting an equal amount of coal."[7]

Natural Gas

Just like oil before it, for most of the 19th century natural gas was used almost exclusively as a fuel for lamps. However, after emergence of electricity and oil, natural gas had no major role in the US energy system. Around the 1890s, most cities began to covert their street lamps to electricity. For years it was considered a "useless, inconvenient by-product of oil production"[8] because despite large reserves of it in the SW, there was no way to transport it to market.

Improvements in metals, welding techniques, and pipe making during WWII made pipeline construction much more economically feasible. Subsequently in 1947, the oil pipelines Big Inch and Little Inch were sold to begin transporting natural gas from the SW to the NE United States. In the coming decades, thousands of miles of pipelines were built, and soon natural gas became a staple in the U.S. energy system.

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[3] http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=74
[4] http://www.utpb.edu/scimath/schafersman/env-sci/env-law/chapt-9.html
[5] Ibid.
[6] Ausubel, Jesse H. "Where is Energy Going?" The Industrial Physicist. February 2000: 16-19.
[7] Rhodes, Richard. "Energy Transitions: A History Lesson." http://cer.ucsd.edu/cernewsjun02.pdf
[8] Yergin, Daniel. The Prize: The Epic Quest for Oil, Money, and Power. New York: Simon & Schuster, 1991.

Nuclear

In the 1930s, Europeans Otto Hahn, Fritz Strassman, Lise Meitner, and Niels Bohr collaborated to discover that firing neutrons into uranium created a surge of excess energy, which confirmed the theoretical work of Albert Einstein. Bohr came to the United States and shared the discoveries with Einstein, who then, enlisted by the American scientific community, wrote a letter to President Roosevelt summarizing the potential of nuclear power. In 1939, Roosevelt authorized the government funding of atomic research, which signaled the race between the Germans and the Allies to develop the atomic bomb.

After WWII, the US also worked on peaceful applications of nuclear power. Although the 1946 Atomic Energy Act made atomic energy an absolute monopoly of the federal government because of security reasons, the 1954 Atomic Energy Act reversed this decision and allowed private industries to own and operate reactors. The 1954 act in large part was a response the news that the Soviet Union had started a nuclear power program, and the US did not want to be left behind.

Key Points

- The military can lead the way for society to transition to a new source of energy. A prime example of this is when the 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.

- 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 less greenhouse gasses (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 = ½ Carbon
Natural Gas	CH4	1 Hydrogen = ¼ Carbon
Nuclear (Uranium)	U	N/A

(source: Ausubel "Where is Energy Going?")

- Preadaption Trend – Preadaption[9] is the concept that one source is substituted for another for an existing use on a smaller scale, but only until a new technology is

[9] Rhodes, Richard. "Energy Transitions: A History Lesson." http://cer.ucsd.edu/cernewsjun02.pdf

discovered where this new source becomes more and more prevalent. This can be seen in the transition from wood to coal and coal to oil.

In the transition from wood to coal, coal was first used for the same end use as wood – mainly heat. However, the invention of steam power gave way to entirely new uses of coal in mining, transportation, and manufacturing. In the transition from coal to oil, oil was first used as a substitute for illumination in the form of kerosene. Later, the invention of the internal combustion engine allowed oil to become a staple of energy for years to come.

It is a strong possibility that preadaption will play a large role in the future of energy transitions. As long as ingenuity and innovation continue to produce new technologies at an exponential rate, there is a better than fair chance that these new technologies will use fuels and sources that are currently being used as a substitution for other sources. This preadaption of a source often eases the infrastructural changes that are needed with a new source.

- Energy transitions are tied directly to technology innovation. Coal did not become prevalent until the invention of the steam engine, and 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. A lesser-known attempt occurred after WWII with The Bureau of Mines Synthetic Fuel Project in the city of Louisiana, Missouri[10].

  In 1952, Report of Investigations 4942 included a quote that sounds very similar to what has been echoed since September 11:

The increasing demand for gasoline and oil and the rising cost of finding new petroleum, coupled with America's growing dependence on imports and the unsettled international situation, have continued to emphasize the importance of [synthetic liquid fuel].

Originally pushed by President Truman, this project tried to capitalize on synthetic fuel research seized from the Germans after WWII, and attempted to utilize the vast amounts of coal in the United States. Despite claims that the technology had potential to make fuel at 11 cents per gallon, the Eisenhower administration terminated the program because it "wasn't competitive." The availability of cheap, foreign oil made synthetic oil irrelevant and uneconomical.

- In a basic sense, each new form of energy did not have to directly compete with its predecessors. This led to a terrible legacy of waste and inefficiency that we are still trying to overcome today. There are two reasons for this lack of competition.

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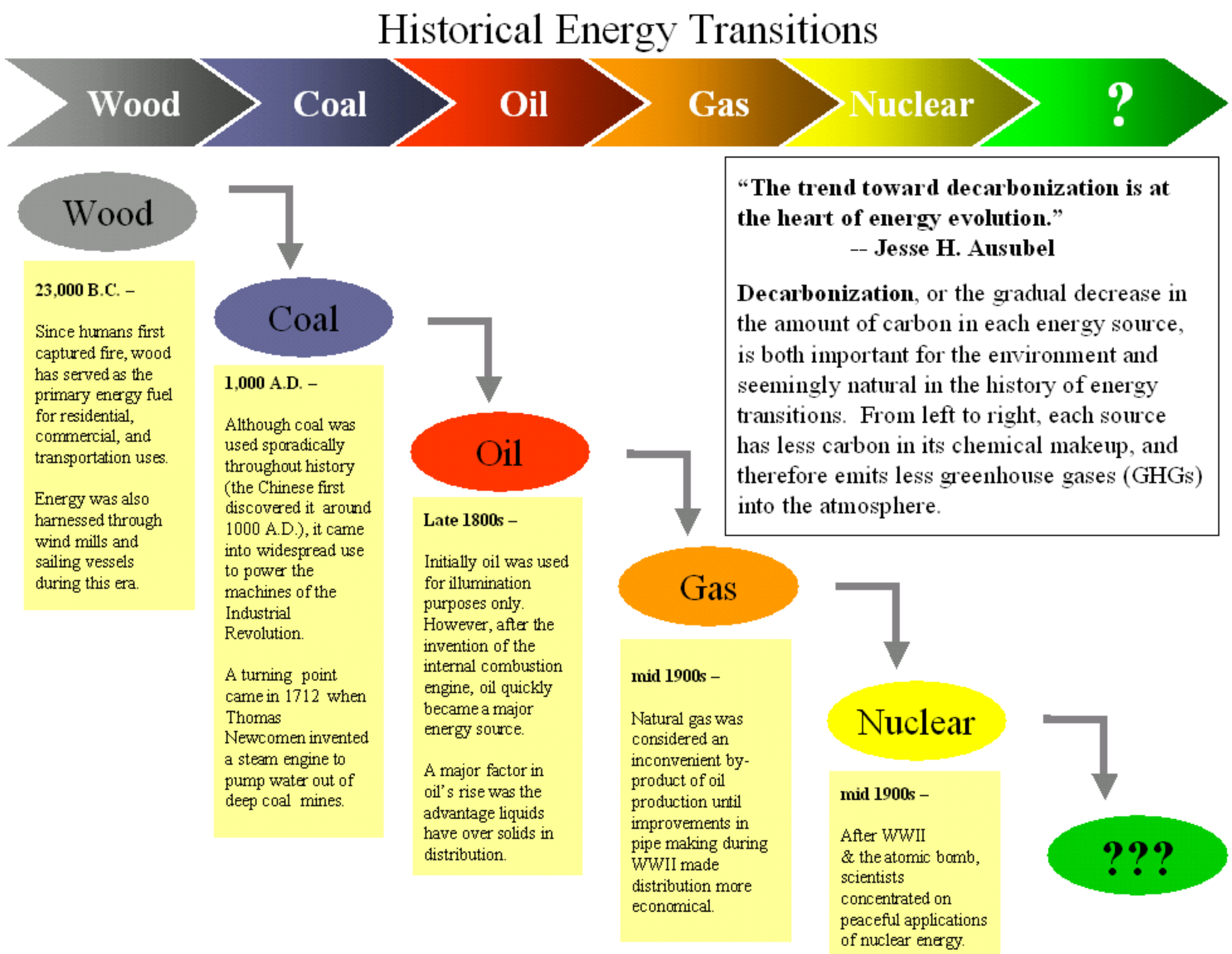
[10] Krammer, Arnold. "An Attempt at Transition: The Bureau of Mines Synthetic Fuel Project at Louisiana, Missouri." Energy Transition: Long-Term Perspectives. Ed. By Lewis J. Perelman, August W. Giebelhaus, and Michael D. Yokel. Boulder: Westview, 1981. page 65.

First, energy consumption has been rising at exponential rates in the past couple hundred years, and therefore the new energy meets the new demand. An example of this is during the emergence of oil. From 1900-1920, US energy consumption doubled in part because new technologies like the internal combustion engine demanded new energy. Oil filled the demand that was created.

Secondly, each new source of energy created a demand itself. The infrastructural aspects to refining and transporting the new energy created a market in which the new energy source could thrive. Both in coal and oil, the tankers, cars, and trains needed to ship the fuel to populated areas were produced to run on the source of energy extracted.

- Even in the case of wood, 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.



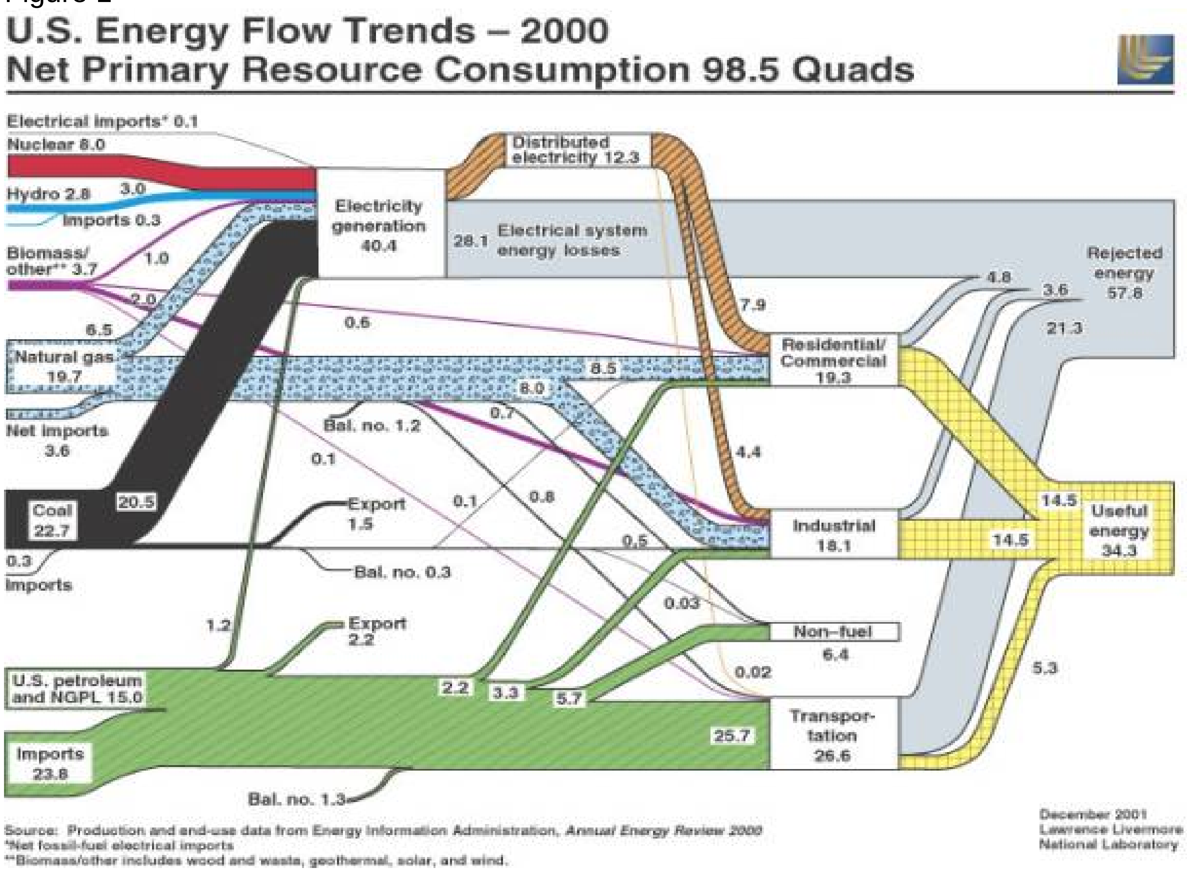
IV. The Present US Energy System

An Introduction

The US energy system is comprised of six basic energy sources – nuclear, hydropower, biomass/other, natural gas, coal, and oil – and three basic end use sectors – residential/commercial, industrial, and transportation. While most of the natural gas and oil are used directly through combustion, the remaining sources mainly are used to generate electricity toward residential/commercial and industrial purposes. From a large perspective, this system is complex and dynamic, yet inefficient in ways as well.

Within this complex system, there are essentially three major end use sectors for energy in the United States. In the flow trend graph provided (Figure 1), they are labeled resident/commercial, industrial, and transportation. Below we have provided some general observations about this system, and then we have given more detailed description of the supply and demand sides of each end use sector.

Figure 1



General Observations of the US Energy System

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

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

- Oil, 60% of which is imported, provides nearly all the energy used for transportation. To solve the problem of dependency on imported oil, changes are needed in the transportation sector.

- Mostly based on the internal combustion engine, the transportation sector averages 20% efficiency.

- Electricity averages 30% 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.

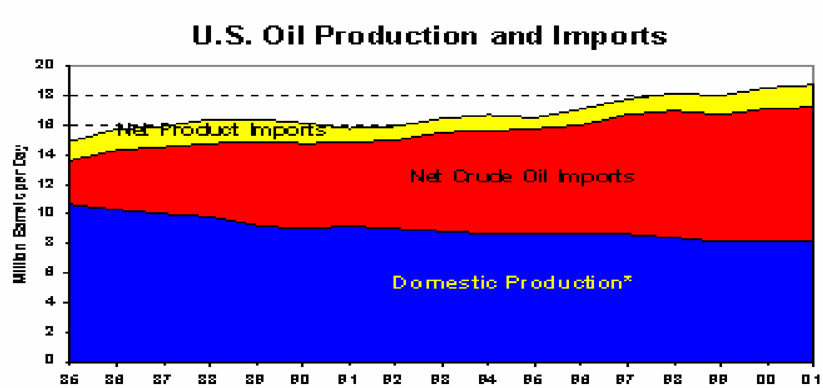
Supply and Demand Brief on Each End Use Sector

Transportation

Supply

For all intents and purposes, the transportation sector is supplied almost 100% by oil. Currently 40% of the oil consumed in the U.S. is produced domestically. This is a major problem as oil has become scarce and expensive, and thus cheaper and more plentiful imports have increased steadily over the past decades (see Figure 2). Even as recent as 10 years ago, oil imports were only 45% of total oil consumed. Unless a concerted effort is made to move this system in another direction, there is no end in sight to this trend.

Figure 2



Consumption is increasing, domestic production is decreasing, and imports are increasing.

A survey of the origins of US imports reveals some interesting facts. The Middle East provides 25.6% of U.S. total crude oil and products imports, of which Saudi Arabia accounts for 14% and Iraq 6.7%. Overall 52% of our imports come from the Western Hemisphere, of which 15.4% originates in Canada, 13.1% from Venezuela, and 12.1% from Mexico (see Figure 3).

Figure 3

Noteworthy Countries	Crude Oil-000s Barrels	Crude Oil % of imports	Total Crude Oil & Products - 000s barrels	Total Crude Oil & 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 Petro Supply Annual 2001)

Demand

Approximately 70% 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% in cars and 26% in light trucks such as vans, pickups, and SUVs), 5% to mid-size trucks, and

14% to heavy trucks. Outside of highway vehicles, about 1% is used to drive buses and all public transit, 9% toward aircraft, 6% to ships and boats, and 2% to railcars[11].

The remaining 30% of oil that is not used for transportation is divided into three places: 6% is used in building (of which 2/3 is residential), 8% is for industrial fuel, and 17% is used as industrial feed stocks such as asphalt and petrochemicals[12].

Industrial

Supply

The industrial sector is provided with four major types of energy supplies: Oil, natural gas, biomass, and electricity. Electricity accounts for 24% of the energy used toward industrial purposes while natural gas provides 44%. Oil comprises 18% and biomass 11%.

Demand

The prominent end use demands within the industrial sector – which includes the agriculture, mining, and construction industries in addition to traditional manufacturing – are for heat and power. Electricity and natural gas are the major sources for this heat and power, to be used for lighting, process controls, communication, machine drive, and some production processes.

Residential/Commercial

Supply

The residential/commercial sector also has the same four main types of energy supplies as the industrial sector: oil, natural gas, biomass, and electricity. Natural gas and electricity supply the residential/commercial sector with the most energy at 44% and 41% respectively, while oil accounts for 11% and biomass a mere 3%.

Demand

The prominent end uses for the residential/commercial sectors are for heat, lighting, and cooking. In the commercial aspect of this sector, lighting remains to be one of the most important demand issues[13] despite the fact that computer usage is increasing the need for electrical power other than lighting. On the residential side, heating, cooling, and

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[11] Lovins, Amory. "Energy Security Facts" Rocky Mountain Institute 2 June 2003 http://www.rmi.org/images/other/S-USESFbooklet.pdf
[12] Lovins, Amory. "Energy Security Facts" Rocky Mountain Institute 2 June 2003 http://www.rmi.org/images/other/S-USESFbooklet.pdf
[13] www.eia.doe.gov/oiaf/aeo/demand.html

lighting are important, especially as new houses are 18% larger than the average current stock[14].

[14] www.eia.doe.gov/oiaf/aeo/demand.html

V. Current Energy Trends

The demand for oil is continuously increasing as a consequence of growth in demand for transport. After a century of automobile development, the dominant mode of transport for individuals in the United States is cars that run on gasoline. A strategic decision was made many decades ago to invest heavily capital in the highway infrastructure rather than in rail. There is a natural path dependence that has arisen from this earlier investment direction: we have urban sprawl (25-60% of urban landscape is for automobile use[15]), cities are not designed to facilitate public transport (more than 75% of all passenger miles in the country are from private automobile usage – US Department of Transportation), and the average household owns 1.77 cars (36% own 1 car, 35% own 2 cars, 20% own 3 or more cars[16]).

Commuting, road trips, business and leisure travel all contribute towards the growth of the transport industry. The demand for automobiles is steadily increasing, and marketing efforts by large automobile manufacturers has shifted public demand towards large vehicles with low mileage potentials. SUVs now represent about 10% of all vehicles on the roads (~22 million vehicles[17]) and still show double-digit annual growth in sales[18].

Where are we going? This question has been asked innumerable times by concerned citizens, politicians, scientists and industry alike. Are we heading in a direction that we have planned for and desire, or is there a historical path dependence that will limit our destination?

Some of the specific questions that arise often relate to the availability of supply, projected reserves and demand & consumption patterns.

Availability Horizon – Oil

Currently, there is a debate among energy experts as to the peak of world oil production. This debate began back in 1956, when M. King Hubbert predicted that oil production in the United States would peak in the early 1970s. When production peaked in 1970, his name and theories gained worldwide recognition. However, not all energy experts accept his theories.

Today's debate can be simplified into two groups: the pessimists and the optimists.

Both the optimists and the pessimists mostly agree on the fact that there will be an oil peak – the question is simply of when it will happen. There are some optimists however who feel that there will not be any oil peak. Nevertheless, current demand and consumption patterns, if unchecked, will cause the peak to occur sooner rather than

[15] Neighborhood Electric Car Company
[16] Ibid.
[17] CNN, http://www.cnn.com/
[18] Associated Press, http://www.ap.com/

later. Predictions for the timing of the peak range from 2004 to 2100, with a median of occurrence in about 2037.

Pessimists

"Welcome to the post-Hubbert peak world."
-Kenneth Deffeyes

The alarmists come from the Hubbert tradition, and in fact, many of the alarmists studied under Hubbert himself. By taking his basic bell curve and applying it to world oil reserves, they posit dates in the very near future. Their estimates range from 2004 to 2010.

Optimists

The optimists are more in number, more mainstream, and more institutionalized. Their membership includes the United States Geological Survey (USGS), the Energy Information Administration (EIA), the American Petroleum Institute (API), and all the major oil companies. Many argue that Hubbert's bell curve was a result of fortune and luck rather than scientific accuracy. Their own estimates for world oil peak production range from 2021 to 2112, with mean estimate of 2037.

In many ways, the debate boils down to estimated crude oil reserves. In 2000, the USGS published a World Petroleum Assessment that claimed world oil reserves to be at 3 trillion barrels. The alarmists disagree with this estimate, saying the number is much closer to 2 trillion barrels.

Pessimists Vs Optimists

"Demand for oil is likely to decline before the physical supply runs out"
Robert Ebel, CSIS

The alarmists take exception to USGS assessment on two fronts – methodology and motive. The methodology is called into question because the USGS took estimates from different provinces and added them up, and some alarmists contend that there is possibility for an overlap of estimates, or counting parts of oil fields twice.

The alarmists also question USGS motives. They accuse the USGS of over-inflating estimates so that countries other than the United States do not hold back their oil production. On the other hand, the optimists state that their estimates for reserves are conservative, especially as the assessment exempted a fair number of provinces from their study.

Notable Parties and selected estimated peaks

Alarmists	**Optimists**
Kenneth Deffeyes – 2005	USGS (Thomas Ahlbrandt)
Colin Campbell – 2010	EIA (Guy Caruso) – 2037
Jean Laherrere	American Petroleum Institute – 2097
	Major Oil Companies

Alarmist arguments:	**Optimists arguments:**
- USGS methodology is faulty - assessment could include overlap of estimate reserves	- USGS estimates are conservative (the estimates do not include a fair number of provinces in the world)
- USGS has hidden motives – the US is trying to convince others to keep oil flowing	- Alarmists (like Campbell) have been "calling wolf" since 1990s, and there is no proof yet
- Even if other predictions (e.g. Campbell's 1999 prediction) have not been accurate to the exact year, predicting the peak within a decade still spells imminent problems	- There is no real debate, only a few dissidents (the alarmists) to widely held fact
- The world is almost out of conventional oil; drilling and processing unconventional reserves will have an impact on the world economy	- Alarmists only look at conventional crude oil, ignore unconventional and other types of petroleum - Unconventional oil is available and profitable; consumers don't care where the oil comes from

Current Energy Demand Trend

Short and Medium Term

Development and industrialization has historically resulted in sharp increases in energy consumption rather than slow regulated growth, and this trend is about to be seen in the emerging markets of today.

> *"…the pace of change is accelerating…So that means the twentieth century was like twenty years of change at today's rate of change; in the next twenty years we're going to make five times the progress you saw in the twentieth century…"*
>
> -Ray Kurzweil, The Technology of Universal Intelligence, What is Enlightenment

The issues that have to be addressed include changing demand and consumption patterns to avoid a large-scale disruption of the world energy markets.

Just as we are projecting the growth in the transportation sector for the US, there is a projected growth in the world transportation sector as well. The growth in countries like

China and India will be extraordinary. China has set a long-term goal of each household owning a car[19]. In the short to medium term, China is projected to have 44 to 50 million registered automobiles by the year 2010[20]. As such countries start to become increasingly huge oil importers, it will result in competition over who will have access to a limited world resource. In the short term the oil supplying countries will not be able to keep up with the continuously increasing demand for oil, and this will cut into the US oil imports.

Long Term

There is no historical precedent to indicate that a reduction in demand and consumption patterns is possible without intervention or crises. People do not change their habits unless there is a pressing need to do so, and businesses do not innovate in environmentally friendly modes without economic incentives. Without significant changes in the political, economic and social environment, the demand patterns will continue to grow quickly and there will be few changes in the efficiency and consumption profiles of consumers and their automobiles.

Current Energy Supply Trends

Short and Medium Term

In January 2003, in the State of Union Address, President Bush announced his FreedomCAR and Fuel Initiative and proposed $1.2B to fund it.

> *"The Initiative will invest $720 million in new funding over the next five years to develop the technologies and infrastructure needed to produce, store, and distribute hydrogen for use in fuel cell vehicles and electricity generation. Building on the FreedomCAR (**C**ooperative **A**utomotive **R**esearch) Initiative, which was launched in January 2002, President Bush is proposing a total of $1.7 billion over the next five years to develop hydrogen-powered fuel cells, hydrogen infrastructure and advanced automotive technologies."*
>
> \- US Department of Energy

Both these initiatives signal a growing awareness and need for a renewable source of energy for the transport sector. This source would push the nation towards energy independence and self-sufficiency in a manner that has not been seen in recent times.

Research thus far has indicates that there are three replacements that would be viable: flex-fuel vehicles[21] (E85: which run on a wide combination of ethanol and gasoline up to 85% ethanol) and hybrid cars[22] (which use both internal combustion engines and electric motors) for the short and medium term, and fuel cell cars (FCV)[23] (which use hydrogen

[19] World Resources Institute, China and Transportation, http://www.wri.org/wri/china/transpor.htm
[20] Ibid.
[21] See Appendix N – Flex Fuel Vehicle Comparison
[22] See Appendix K – Hybrid Vehicle References
[23] See Appendix J – Fuel Cell Vehicle References

sources to produce electricity) in the long term. As we move forward in time, the days of the internal combustion engine powered by gasoline seem numbered.

A J D Powers survey[24] indicates that "sales of hybrid-powered vehicles are expected to exceed 500,000 units annually by 2008 and 872,000 units by 2013." These optimistic forecasts are made on the premise that hybrid SUVs will be available in the mass market starting with the 2004 model year. The current hybrids are all compact cars and do not enjoy the same market growth as SUVs and minivans although that is planned to change in 2004 with an expansion of the number of hybrid-powered models.

Corn growers and ethanol producers are lobbying hard to increase the market share of Flex-fuel vehicles in the medium term. There are various initiatives taken by automobile manufacturers to encourage the market for cars that run on ethanol (General Motors recently signed a two year partnership agreement with the National Ethanol Vehicle Coalition[25]). These cars too would help alleviate the need for gasoline in the medium term, without increasing the production cost of the cars, and without increasing the sticker price for the consumers.

Long Term

Fuel cell cars are a reality of today. The first generation of these cars ran on methanol (e.g. NeCAR5 from Daimler Chrysler- it ran across the nation in 2002[26]). The current generation of cars is running on pure hydrogen, filled up in pressurized gas tanks.

The DOE projects that fuel cell cars will be mass-produced and commercially viable by 2010, however the completion of the transition is projected to take several decades. The DOE Hydrogen Roadmap[27] and Vision[28] reports suggest 2030-2040 as the goal of this transition. These cars could possibly run on any number of fuels, each one requiring a different technology (methanol, ethanol, gasoline, hydrogen). Theoretically, all are options; however the actual technology that will win out will do so based on a variety of factors:

- Economics and infrastructure issues – How much will it cost to revamp the system with this new fuel? Both in R&D money and all of the infrastructural changes needed, what are the economic implications of such a transition?
- Technical feasibility – Where is the technology right now with this new fuel? What are the technical difficulties that still need to be worked out?
- Polluting emissions – What is the systems wide impact of using this fuel on our environment, and specifically our air quality?
- Political environment – How well is this fuel supported by large constituencies in and out of government? Who will benefit from the large-scale use of this fuel?

The fuel choice would determine both automobile efficiency and also impact the extent to which the current fuel distribution infrastructure of the US would be changed.

[24] http://www.evworld.com/databases/shownews.cfm?pageid=news060302-02
[25] http://www.e85fuel.com/news/022503_gmrelease/022503_gmrelease.htm
[26] http://www.daimlerchrysler.com/index_e.htm?/news/top/2002/t20605_e.htm
[27] http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/national_h2_roadmap.pdf
[28] http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/vision_doc.pdf

Fuel of the Future

The current industry research environment suggests that pure hydrogen is likely to be the fuel of choice in 2010 for FCVs, and a large number of new fueling stations would be built to accommodate the needs of the population. Production, distribution and storage issues are of paramount importance in making this scenario a reality and there are any number of breakthroughs or problems that could change this evolutionary path.

Present developments are focused on using both gaseous and liquid hydrogen. A major factor in this switch was the reluctance to have reformers onboard the car that could take methanol, ethanol, gasoline or natural gas as the fuel, make hydrogen from it, and use it to run the FCV. Pure hydrogen does not need a reformation process, and can be used directly in vehicle fuel cells.

> *"However, on-board fuel processing presents serious technical and economic challenges of its own that may not be overcome in the required "transition" time frame. Consequently, DOE is deciding whether to continue onboard fuel processing R&D beyond the end of FY 2004."*[29]
>
> \- US Department of Energy

There are obvious economic advantages for transportation and distribution of liquid fuels in terms of the infrastructure. There are also technical and environmental advantages to using pure hydrogen in either a liquid or a gaseous form.

Methanol has been directly used as a fuel in direct micro-fuel cells, however there is no work being done to scale the technology up for vehicles. Ethanol has also been used with catalysts in PEM type fuel cells however there is no indication that this would be the direct fuel that automobile manufacturers would choose as a standard.

The delay in choosing a fuel for FCVs – whether it be gaseous or liquid hydrogen, ethanol, methanol or anything else – will have implications on when the infrastructure can be put in place, and therefore when the transition would actually be started. Automobile manufacturers do not want to heavily invest in fuels that will not become the global standards, and will not supply hydrogen cars until they are sure that there will be an adequate fuel supply for their consumers. On the other side, the infrastructure stakeholders are not willing to make a huge capital investment into a fuel that they cannot be sure will the final choice in the long run.

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[29] US Department of Energy, Energy Efficiency and Renewable Energy
http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/transportation.html

VI. THE CHANGING CONTEXT

Scenarios

When considering the context for a strategy it must be kept in mind that any of a number of potential futures are possible, each of which would present a substantively different environment relative to the execution of the strategy. Recently the Pew Center for Global Climate Change commissioned the development of a set of energy scenarios that present a well-thought-out spectrum of possible energy worlds that represent the latest contextual thinking that could be factored into a strategy.

In their report, *U.S. Energy Scenarios for the 21st Century*[30], authors Irving Mintzer, J. Amber Leonard, and Peter Schwartz from the Global Business Network, lay out three big energy possibilities.

1. **Awash in Oil and Gas** This is "a market-driven scenario in which abundant supplies of oil and natural gas are available to U.S. consumers and cheap energy remains a staple of the U.S. economy." It is characterized by:

    a. Short-term oil and gas price fluctuations but long-term decline in cost
    b. Consumers use as much energy as they want
    c. Cars become plush, personalized havens – commuters drive farther
    d. Construction of new infrastructure keeps pace with individual demands
    e. Highways and airports continue to be publicly subsidized – parking is cheap
    f. Minimum federal intervention in energy markets – encourages supply
    g. Close control of inflation through federal fiscal policy
    h. Increasing economic activity, rising demands for electricity
    i. Increased use of fossil fuels
    j. Annual carbon emissions grow over 50 percent

Conventional cars and trucks rule the roads in this scenario. Congestion increases and trucks capture a growing share of ground freight shipments. U.S. Corporate Average Fuel Economy (CAFÉ) standards remain unchanged from 2010 to 2035.

2. **Technology Triumphs** This is "a scenario driven by market forces, technological innovations, and policy decisions." It is characterized by:

    a. State policies and regulatory standards that "raise the bar" on engineering and environmental performance
    b. Public and private research on new energy technologies which leads to significant engineering advances
    c. Private investment supports the commercialization of these emerging technologies

[30] http://www.pewclimate.org/global-warming-in-depth/all_reports/energy_scenarios/index.cfm

d. Purchasing decisions by individual consumers and industrial customers are shaped by preferences for technologies that incorporate a package of specific attributes.
e. Rapid and sustained economic growth
f. Primary energy use grows by less than 25 percent while economy-wide carbon emissions increase by 15 percent.

In this world, fuel cell and hybrid vehicles capture a substantial and growing share of the city car, family car, and light truck market. Demand for hybrid cars takes off. Fuel cell cars using pure hydrogen achieve early market penetration – exceeding 5 percent of the light-duty market by 2020. Bio-fuels expand their penetration.

3. **Turbulent World** This is "an event-driven scenario, characterized by severe stresses and broad challenges." It is confusing and chaotic with "constant dislocations, ubiquitous conflicts, and historically low levels of global cooperation." *Turbulent World* is characterized by:

    a. Unstable U.S. economy and disrupted energy sector
    b. Terrorist incidents, accidents, and domestic weather-related disasters
    c. Unsettled confidence of U.S. investors and consumers
    d. High prices for fuels and electricity
    e. Slow economic growth
    f. U.S. carbon emission rise to 15 percent above 2000 level by 2010
    g. Policymakers cannot control external events, loose confidence of people
    h. Energy security is principal driving force for policy
    i. No coherent energy technology policy – shift from "solution" to "solution"
    j. Crash government program to reduce dependence on imported oil
    k. Fuel cells are pushed burning hydrogen derived from coal

A "moonshot" program to generate energy security funds, university and private efforts to produce one million fuel cell powered cars annually by 2025 in this scenario . . . and that target is substantially exceeded. A decade-long program to develop and commercialize hydrogen fuel succeeds. Many new tax incentives and other policies are put in place. Dependence on foreign oil imports is reduced.

Three U.S. Energy Scenarios for the 21st Century: A Comparison

Scenario	*Energy Supply*	*Energy Consumption*	*Government Action*	*Environmenl Issues*	*Transport Technology*	*Economy*
"Awash in Oil and Gas"	Cheap oil and gas available	Consumers use as much energy as they want	Minimum federal intervention in energy markets	Annual carbon emissions grow over 50%	Conventional cars and trucks, no efficiency improvements	Increased economic activity
"Tech-nology Triumphs"	Alternative energy supplies penetrate market (e.g. hydrogen, bio-fuels, etc)	Primary energy use grows by less than 25% by 2020	Pubic funded research into new technologies, Government regulations increase engineering and environmental performance	Econ-wide carbon emissions increase by 15%	Fuel cell and hybrid vehicles capture a substantial and growing share of transportation car market	Rapid and sustained economic growth
"Turbulent World"	High prices for fuel and electricity	The combination of high demand and erratic energy supplies yields steady energy consumption increases	Policy makers cannot control external events; no coherent energy technology policy	Carbon emissions rise to 15% above 2000 level by 2010	"Moonshot" program to produce one million fuel cell cars by 2025	Unstable economy and slow growth

These scenarios paint a very reasonable spectrum of energy possibilities for our nation in the coming decades, but it is clear that a new national energy strategy would only be required for the Technology Triumphs and Turbulent World alternatives and only then if energy security issues become a high priority for the U.S. government. In Awash in Gas and Oil no significant change in direction is contemplated or desired. Technology Triumphs, on the other hand, would lend itself to an evolutionary strategy and Turbulent World would respond to a revolutionary one.

Our strategy is therefore an integrated plan that combines a fundamental evolutionary initiative with key elements that would allow it to respond to revolutionary changes if a Turbulent World or some other change in context should transpire.

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 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.) (See Appendix B for more examples)

- ***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.

Our strategy should allow for a rapid increase in interest in changing energy tracks and provide ways to accelerate progress toward our all-electric world.

This strategy is therefore a single approach that is based upon evolutionary change but allows the system to up-shift should some externality force open the door for revolutionary change. The basic framework moves reasonably toward a hydrogen-fueled transportation system largely utilizing the existing gasoline-based infrastructure, but there are any number of places where participants can leapfrog to other, higher levels if the opportunity presents itself.

VII. The Future: An All-electric World

The Importance of a Vision

Perhaps the most important aspect of an effective strategy is having a clear understanding of what the ultimate vision of the strategy is. If one doesn't have a good image or vision of what the end product of a process is supposed to be contribution to, any number of paths may look appealing but ultimately be disastrous. Alternatively, a clear image of the wrong vision may result in spending a great deal of time and effort to reach that goal only to find that it was wrongly selected in the first place. A clear vision – a desired future – provides a common goal at which all participants can aim; everyone on a team has an unambiguous target – a mental image of where they are headed.

Coherent mental images are powerful devices for shaping behavior. The problem with building pictures of the future, though, is the natural inclination of story tellers and writers to embellish their images with a good deal of detail – so as to make it more compelling and realistic. This works for screenplays, but it's a problem when attempting to explain potential futures.

Thinking about the future is intrinsically uncertain – no story that one comes up with is going to manifest itself with any great preconceived fidelity; life is far to complex and nonlinear for that. Moreover, the role of a scenario is to "outline a new landscape of possibilities", not to predict the future. So a good scenario is long on basic structure and short on details. The role of the scenarist is to define an end point – general area of plausibility – enough so that the reader can visualize any of a number of specific paths to reaching the future.

So let's set the stage for the desired energy world of the future.

Trends

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. 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.[31]

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.

Potential Surprises

A number of other new technologies seem possible in the next decade that would further contribute to this trend of electrification.

A good deal of effort is being made on a number of fronts to dramatically increase the efficiency of photovoltaic cells either by reducing manufacturing costs and or increasing the electrical output that is derived from the sun's radiations. Even a doubling of efficiency would make solar cells economical for a host of new applications that are now being serviced by fossil fuels and other non-renewable sources.

One of the big problems associated with electricity is storage – batteries are heavy, expensive, and polluting. New breakthroughs in using magnesium for batteries have the potential for significantly decreasing the weight and cost of batteries, potentially making them practical for all-electric cars and other very broad-based uses.

Another enduring issue is the distribution of electricity. Copper and aluminum are the major materials that are used for wires and other electrical major electrical components.

[31] 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

These materials drive the size and weight of motors and other devices and also predict the amount of energy that they will consume. A breakthrough in superconductivity – the elimination of resistance in electrical conductors – would produce a revolution in the need for electricity and the options available for much smaller, lighter motors, etc. Such a breakthrough would accelerate the movement toward electric cars, for example. One small company, for example, claims to be only a year or so away from being able to extrude wires from a plastic-based material that exhibits no resistance to electricity at temperatures up to 360 degrees Fahrenheit.

Many argue that nuclear power plants are a long-term solution since they produce electricity at reasonable costs and produce no air pollution like fossil fuel plants. They discount, of course, the potential impact of the disposal of radioactive waste, which is a major issue for that industry and this country. A solution would be a new breakthrough technology that was successful in changing the atomic structure of the waste, converting it into safe, if not usable byproduct materials. One small start-up believes that they understand how to do that and have filed a patent for such a new approach. If they or someone else was successful in this regard, it could seriously change the outlook for nuclear as a power source.

The field of nanotechnology is moving ahead much faster than anyone anticipated only a decade ago, with nano products already in the marketplace. Annual U.S. government investments in this area that are already approaching $1 billion could very well produce new capabilities within the next two decades that change the energy landscape of the future. Early indicators (special bucky tubes that are superconductive at ambient temperatures) again suggest that some of the breakthroughs will likely be in the electricity area.

Advances in information technology will enable scientific discoveries at accelerating rates during the next twenty years. Of particular note is quantum computing, which promises computing power that is billions of times greater than the best current levels. Such capability will power analysis and future development that is very hard to imagine in today's world. It is certain that some of this extraordinary power, if it becomes available, will be directed at solving energy problems.

There is always the possibility, of course, that a revolutionary new scientific discovery would produce a new way of generating inexpensive, pollution-free electricity. Zero point energy[32] and cold fusion[33] (both of which also produce electricity as an output) are two such candidates that researchers continue to pursue that certainly have not yet been proven (nor disproved). If something like this became reality, all bets would be off as to the structure of the future world of energy.

There seems to be a pattern here. Many indicators suggest that there is a place in our future where the convergence of a number of trends that are already in place could be pushed along by new technologies (some of which most certainly will happen in the next two decades) all coming together to produce a world where most of the heating, cooling, and transportation in our world was derived from electricity.

[32] See appendix B
[33] Ibid.

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 familiar 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 much of history as the steam engine is today.

VIII. Strategy Considerations

There are a number of fundamental considerations that underpin our strategic approach to accelerating the reduction of the U.S. dependency upon oil. Each must be substantively addressed in order to successfully reach our objective.

National Security Implications

The present global and U.S. energy situation is intrinsically insecure. There are many aspects to that insecurity that our strategy addresses. Perhaps the most comprehensive assessment of the security implications of energy policy has been done by Amory B. Lovins of the Rocky Mountain Institute.[34] His top ten list of energy insecurity issues includes:

1. Oil imports from unstable countries/regions (Persian Gulf; currently Venezuela, Nigeria)
2. Concentration of cheap oil resources, causing instability in and tension between nations
3. Being whipsawed by volatile world oil prices that also set or influence U.S. energy prices
4. Energy choices and market structures that expose customers to extreme price swings
5. Similar or greater import dependence for U.S. trading partners, allies, and other countries
6. Other countries using U.S. oil payments to buy destabilizing weapons or fund terrorism
7. Relying on U.S. and foreign energy infrastructure that's easy to disrupt and hard to mend
8. Indirect but major security threats such as climate change and the spread of nuclear weapons, created or exacerbated by the use or promotion of particular energy sources
9. Energy usage patterns and policies that perpetuate energy inefficiency, scarcity, inequity, poverty, and unpayable debts in developing countries, thus breeding envy and hatred
10. Constraining and distorting international relations, compromising U.S. moral authority and making it look as though whatever we do in the world is motivated by oil

[34] Lovins, Amory B., *Energy Security FACTS,* Rocky Mountain Institute, Snowmass, CO 81654 http://www.rmi.org/images/other/S-USESFbooklet.pdf

Basic 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.

Guiding Principles

In order to build resiliency into the strategy, these principles shaped our considerations:

Evolve the Technology: Start with existing technology (E85 engines) that can quickly be implemented, expand present leading edge technology (hybrid power) to a broader market, aiming ultimately at fielding radically new technology (fuel-cells).

Utilize New Technology, Fuels, and Efficiency in an Integrated Approach: All of the opportunities should be wrung out of every major area for the largest gain. New fuels can move to energy sources in stable areas of the world. Efficiency can rapidly decrease the use, and therefore requirement for oil. Technology can dramatically decrease the environmental impact of transportation.

Develop Flexibility in the Strategy That Allows it to Adapt to Changing Contexts: The future is not predictable. Any number of scenarios or breakthroughs could materialize that will offer new opportunities or change the general interests of Americans and their leadership. This strategy is designed to allow for new diversions or additions if they seem appropriate.

Leverage the Interests of As Many Major Players as Possible: This should be a win-win initiative if it is going to be successful. As many people as possible should see it in their interest to move in the new direction.

Address the Need for Compensating Measures for Oil Exporting Countries: It is not possible to dramatically decrease the income generated from oil in places like the Middle East and not encourage political and economic instability. Therefore, any comprehensive strategy must address compensatory measures that can be put in place new economic alternatives that offer hope when the flow of petrodollars dries up.

Move Toward the Normative (Desired) Future: This strategy is designed with the end point in mind – moving toward an all-electric world. Each initiative suggested represents a substantial step toward a future where the basic electric automobile can be powered by any of a number of sources of electricity that might be available, economic, and clean at the time.

Timing

This strategy is developed around a nominal 15-20 year horizon, but it is obvious, as with all plans, the execution may either be helped or hindered by a large number of factors and actors who play important roles in carrying it out. The execution could be accelerated by an unanticipated event (technological, geo-political, environmental) that suddenly changes the receptivity for this kind of energy shift. Similarly, there are many major forces that will attempt to hinder global change because of benefits that are being reaped from the status quo.

Components

There are a variety of components – pieces – that can be played in many different ways in this energy game. Although the categories sometimes overlap, in general, they segment themselves into types of *vehicles, fuels, conversion technologies, and efficiency measures.*

- ***Vehicles:*** There are three general types of vehicles:
    - ***Conventional Fuel Vehicles*** have internal combustion engines (present technology) that can run on either gasoline, natural gas, diesel or a gasoline/ethanol mixture. These vehicles by far predominate in the world but the percentage of dual-fuel, gasoline/ethanol versions (called E85 vehicles because they can burn up to 85% ethanol) could very rapidly be increased at no additional cost in manufacturing.
    - ***Hybrid Electric Vehicles (HEV)*** presently are electric vehicles (electric motors power the wheels) powered by electricity that is generated by an internal combustion engine driving a generator and stored in a battery. Regenerative braking also charges the battery. Any of a number of sources of electricity (including fuel-cells) could be utilized in this basic configuration. Presently HEVs using internal combustion engines are competitively available from Honda and Toyota and get over 60 mpg. [35]
    - ***Fuel Cell Vehicles (FCV)*** are technically hybrid electric vehicles (it is likely that by the time that they are fielded in 8-10 years, battery technology will have advanced to where all will have batteries for storage) but for this strategy we will deal with them as a separate category because they exclusively use a power plant fueled by hydrogen. [36]

- ***Fuels:*** There are non-renewable and renewable fuels:
    - ***Non-renewable*** fuels include gasoline, kerosene, and diesel (all generally derived from petroleum) and, natural gas, and methanol, (which is derived from natural gas).
    - ***Renewable*** fuels include ethanol (alcohol distilled from corn and other plants) and bio-diesel (produced from fat or vegetable oil)

- ***Conversion Technologies:*** convert raw materials into usable fuels. Some of these are already in place while others are concepts that have promise breakthroughs of one kind or another.
    - ***Ocean Farming*** involves the potential of large-scale harvesting of kelp in the equatorial areas of the Pacific Ocean that is in turn converted to methanol and other usable products. [37]

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[35] See Appendix M - Hybrid Vehicle Comparison

[36] See Appendix G - Hydrogen References and Appendix J - Fuel Cell Vehicle References

[37] Peter Schauffler, Senior Associate at The Center for Urban Environmental Research, George Washington University

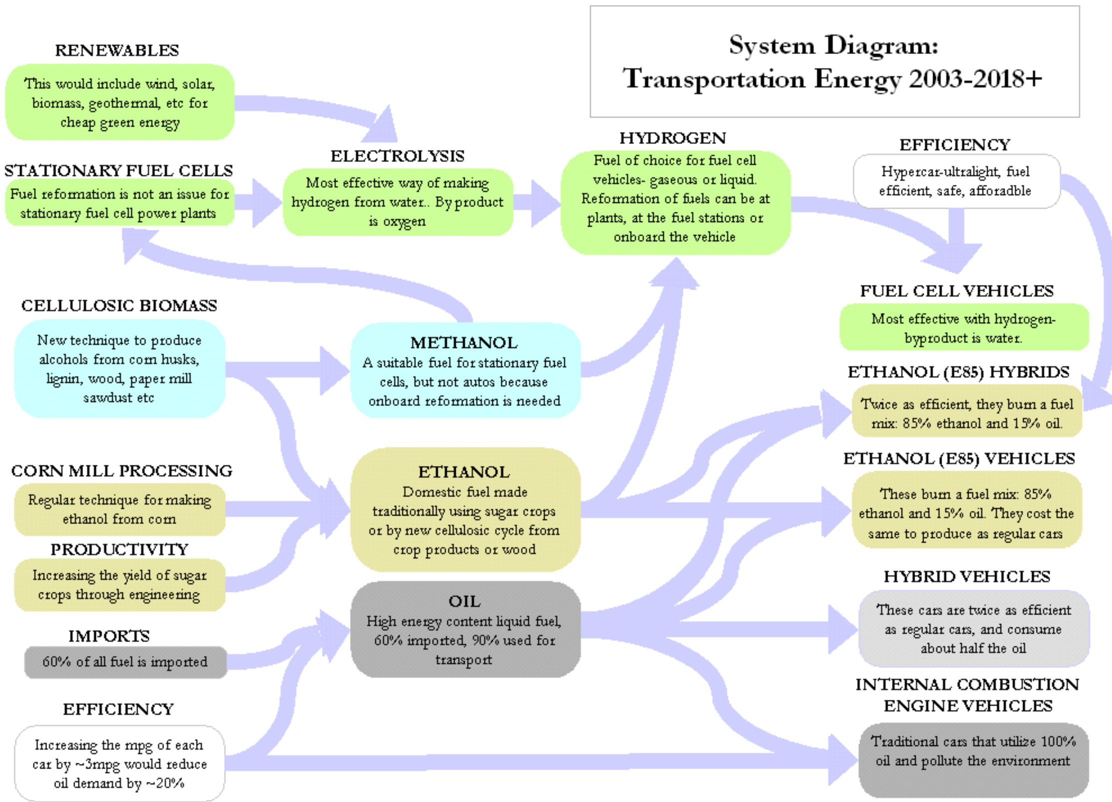
- ***Starch-based distillation*** is the present approach to converting corn, potatoes, sugar beets and a small number of other crops to ethanol. It involves a significant capital investment in plant facilities and significant energy costs to fuel the distillation process. Economically valuable byproducts are also produced in this process.[38]
- ***Cellulosic Biomass*** conversion involves a biotechnologically-based ability to directly convert cellulosic biomass (weeds, industrial waste like wood chips, corrugated cardboard cartons, etc.) directly into ethanol without the energy and capital costs of present distillation methods. This would make many more renewable biomass stocks economically competitive and available for efficient, clean conversion to fuels for the existing vehicle fleet.[39]
- ***Ethanol to Hydrogen Conversion*** on board a fuel cell vehicle would open up a significant opportunity for using domestically produced ethanol (derived from renewable sources) as a fuel for fuel cell vehicles.
- ***Solar Electrolysis*** uses the radiant energy of the sun to directly convert water into hydrogen and oxygen.

- ***Efficiency Measures:*** A great deal can be done to use fuel more efficiently in light vehicles. Essentially this is a systems problem, where all parts of the vehicle are taken into consideration at the same time. If the weight and drag are decreased, less motive power is required – which decreases the size and weight of the power plant. Hybrid electric vehicles increase efficiency by combining the efficiencies of internal combustion engines running at certain speeds with battery power that works in ranges when the engine is not efficient, producing fuel consumption rates in the 50-60 mpg area. If these power plant efficiencies were combined with a full-system design process, the efficiency could theoretically be almost doubled. The best example of this is the Hypercar®[40] design.

[38] See Appendix F - Ethanol References
[39] Ibid.
[40] http://www.hypercar.com/

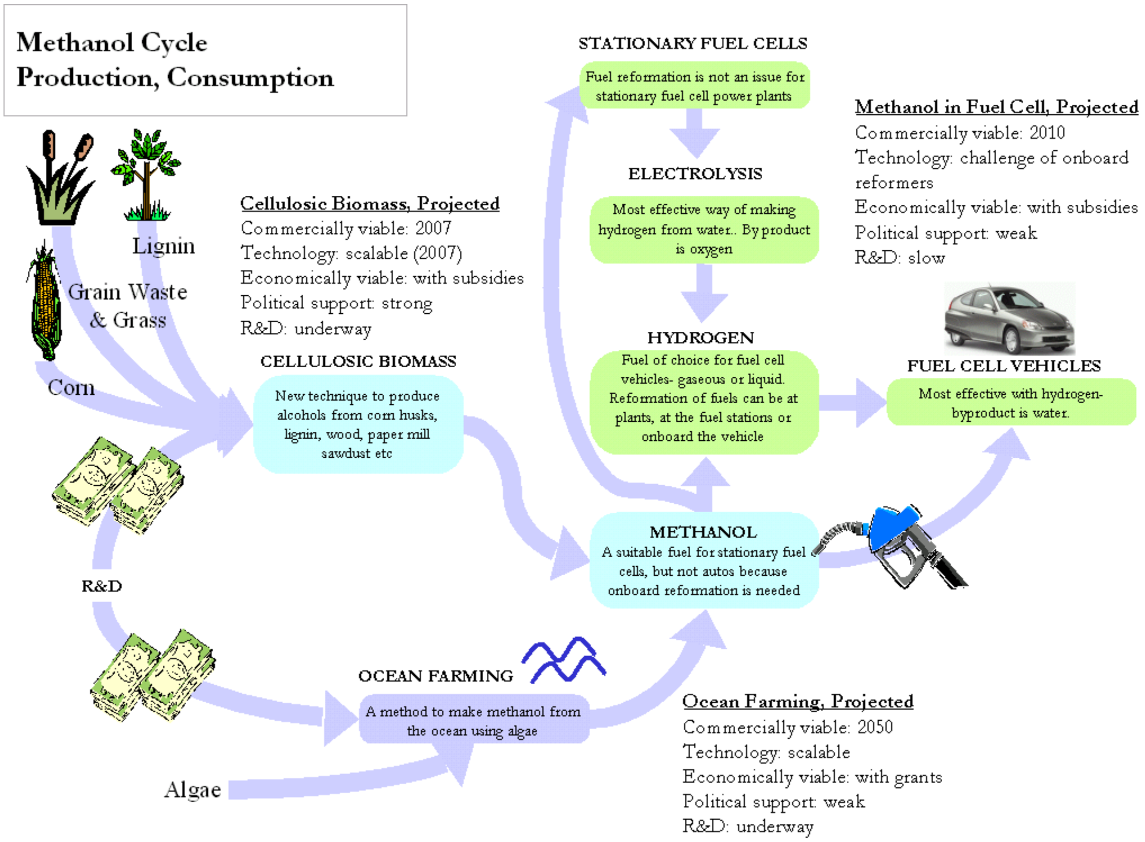
The Transportation Energy System

All of these components work together in the system that is shown below. As can be seen, there are a number of alternative paths linking different sources and processes with different fuels that can then supply alternative vehicles.



Methanol

Each of the fuels has its advocates that tout the unique benefits of each one. Methanol (wood alcohol), for example, can be made from natural gas and as a liquid can be easily transported. It will not burn in existing internal combustion engines but is a potential source of hydrogen for fuel cells. It is being used in small fuel cells to power laptop computers and in large stationary fuel cell installations. There are health issues associated with methanol and it produces free carbon when the hydrogen is extracted for fuel cells. The major problem with methanol for FCV is the requirement for on-board reforming and the fact that a good deal of natural gas comes from outside of the country.

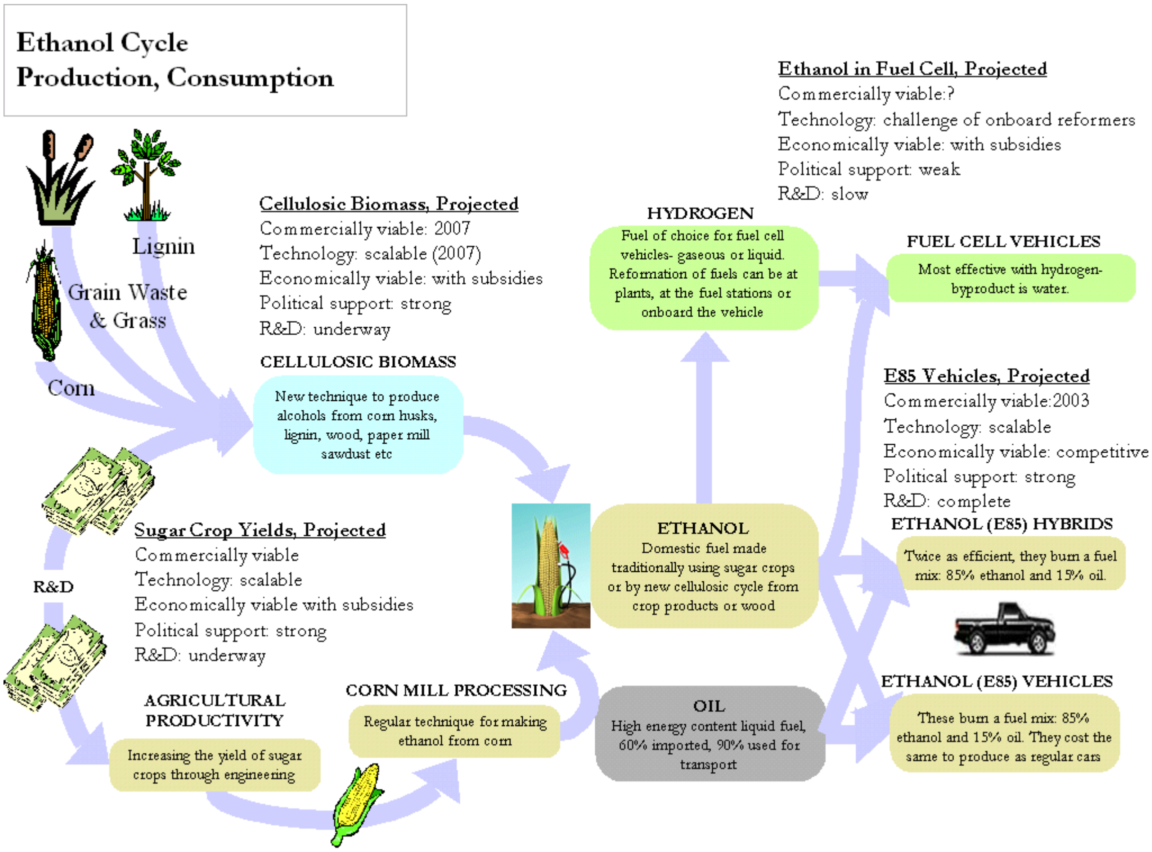


Ethanol

Ethanol is alcohol that is presently distilled from starchy crops like corn, sugar cane, sugar beets and potatoes. Its advantage is that it can be used in current internal combustion automobiles, the feed stocks can be grown in this country and it is liquid and can be transported and dispensed through the existing gasoline infrastructure system. Potential near-term breakthroughs could allow ethanol to be made using biotechnology that would significantly decrease the manufacturing cost and open up huge alternative sources of cellulosic biomass as feedstock. If another technology breakthrough made it possible to convert ethanol to hydrogen onboard a light vehicle, then it would be the ideal fuel – nontoxic, domestically produced, easily distributed and carried in a vehicle, clean, and easily converted into hydrogen.

There is a large farm-belt political support system for ethanol and if use of the fuel was to rapidly expand, the benefits for rural parts of the country would not be insignificant.

Ethanol certainly presents significant incentives for at least a near-term alternative to gasoline.



Option Evaluation

We used the Think Tools™[41] Option Evaluation tool to evaluate the alternative paths through this system. Different criteria were selected to evaluate the options that were available. In each case we looked at every alternative path through the system, testing each one for their contribution in each of the following six dimensions:

1. **Resilience of facilities**
   a. Decentralized system
   b. Protect national infrastructure
2. **Resilience of energy flows**
   a. Increased personal mobility and access
   b. Technological alternatives
   c. Reduce dependence on imported oil
3. **Increased efficiency in energy use**
   a. Reduce oil usage
4. **Decreased environmental effect**
   a. Energy sources non-polluting

[41] http://www.thinktools.com/

   b. Reduce fossil energy emissions
5. **Contribution to stable political environment**
   a. Global stability (compensatory)
6. **Encouraging domestic economy**

Each of these characteristics was assigned a relative importance for 2006, 2010, and 2013 and all alternative paths through the system were evaluated. Then, using the Think Tools™ Options Evaluation tool, each of the alternative configurations of fuel and vehicle was evaluated against a comprehensive set of metrics that were determined to be important to this assessment. The metrics were:

1. Economics: Low government investment
2. Economics: Low industry investment
3. Transition: Distribution infrastructure
4. Transition: Rate of transition
5. Transition: Transition time to complete
6. Geopolitics: Domestic support
7. Geopolitics: International politics
8. Geopolitics: Energy independence
9. Social: Environmental impact
10. Social: Market acceptance
11. Technology: Maturity
12. Technology: Modularity/flexibility

Each of these metrics was assessed relative to each vehicle/fuel combination over 1-5 years, 5-10 years, and 10-15 years. The assessment is included in the appendix.[42]

[42] See Appendix A – Think Tools Evaluations

IX. Strategy

It is clear that a hydrogen and fuel cell economy is most likely the optimal future for the United States and the world if present trends continue. However, it is also obvious that there are still many technological and infrastructural challenges that need to be resolved before this transition can take place, such as the production and storage of hydrogen, the current high cost of fuel cells, and the arduous infrastructural changes that will need to be made. In addition, there are other, more readily available alternatives to oil today. So the question is: how can the US achieve two imperative objectives?

- One, the U.S. must take advantage of existing technological alternatives to wean itself from oil before fuel cells and hydrogen come on board.
- Two, the U.S. must find a way to facilitate the transition to hydrogen and fuel cells in the longer term.

How can the U.S. make strides today that extract the US away from oil in the short term and also act as a stepping-stone to the fuel cell and hydrogen future?

To achieve these needs, 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. off 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.[43]

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-

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

1986, the U.S. decreased energy intensity, increased mpg, and lowered imported oil from 46% to 28% of total consumption.[44] This success was largely due to the fact that new U.S. built cars became 7 mpg more efficient from 1979-1985.[45]

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 [46], 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.[47]

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.

Currently, there are three hybrid vehicles on the market in the United States: The Prius from Toyota claims to save 50% of fuel and 90% of emissions when compared to a non-hybrid vehicle,[48] and the Civic Hybrid and Insight from Honda offer similar benefits. Ford will launch a hybrid version of its Escape sports utility in 2004, and DaimlerChrysler is also aiming to sell a hybrid vehicle within the next year. General Motors Corp plans offer a hybrid pick-up truck in 2004.

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% of cars were 48-mpg hybrid electric, or 15% were ultralight hybrid SUVs.[49]

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.

Below are the objectives to be attained during this initial phase, and the specific policy steps on how to achieve the objectives.

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[44] "Fuel Savings" Rocky Mountain Institute. www.rmi.org/sitepages/pid320.php
[45] Lovins, Amory B., and L. Hunter Lovins. "Mobilizing Energy Solutions" The American Prospect 28 January 2002: 18-21.
[46] www.ita.doc.gov/td/auto/cafe.html
[47] Lovins, Amory B., and L. Hunter Lovins. "Energy Forever." The American Prospect 11 February 2002: 30-34. www.rmi.org/images/other/E-EnergyForever.pdf
[48] www.rmi.org/sitepages/pid414.php
[49] Lovins, Amory B. "Energy Security Facts" Rocky Mountain Institute 2 June 2003 http://www.rmi.org/images/other/S-USESFbooklet.pdf

Objectives

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)

How to get there

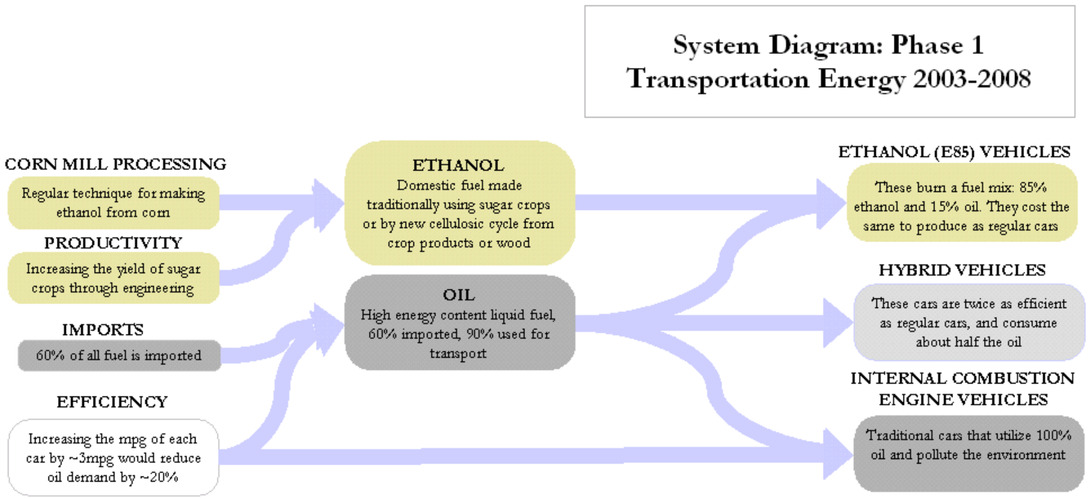
The objective of all replacement vehicles to be hybrids or E85s by 2008 is ambitious, yet attainable, through the five steps stated below:

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

First, heavy tax incentives for consumers who buy hybrids are needed because right now the hybrids cost a few thousand dollars more on average than a non-hybrid counterpart. Currently federal and some state tax exemptions come close to covering the extra price, but it is necessary that the costs are at least equal for the consumer. Second, tax penalties must be put forth as added pressure for transition. These penalties will take into account the negative social and economic impacts that oil consumption incurs, namely pollution, global warming, and military presence in oil rich areas. Third, hybrids must be marketed to the consumer, so that the consumer understands the all the negative social and economic impacts of oil consumption, and the money that will be saved over the life of the vehicle in fuel alone. Fourth, an increase in taxes on fuel will add more incentives for consumers to buy more fuel-efficient vehicles. Fifth, the government should begin ordering large purchases of hybrid vehicles from automakers. This will increase mass production, lowering the costs and pushing the transition forward.

Already, Ford has stated that their average sedan will be a hybrid vehicle by 2010, and Toyota had at one point stated they wanted all their new cars to be hybrids by 2012.[50] These trends could be accelerated quickly with the incentives and actions listed above.

[50] http://www.evworld.com/databases/shownews.cfm?pageid=news081102-01



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% 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,[51] this process has the capability to 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.[52]

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

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

Objectives

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[53].

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

How to get there

Phase II broad objectives are attainable through the following steps:

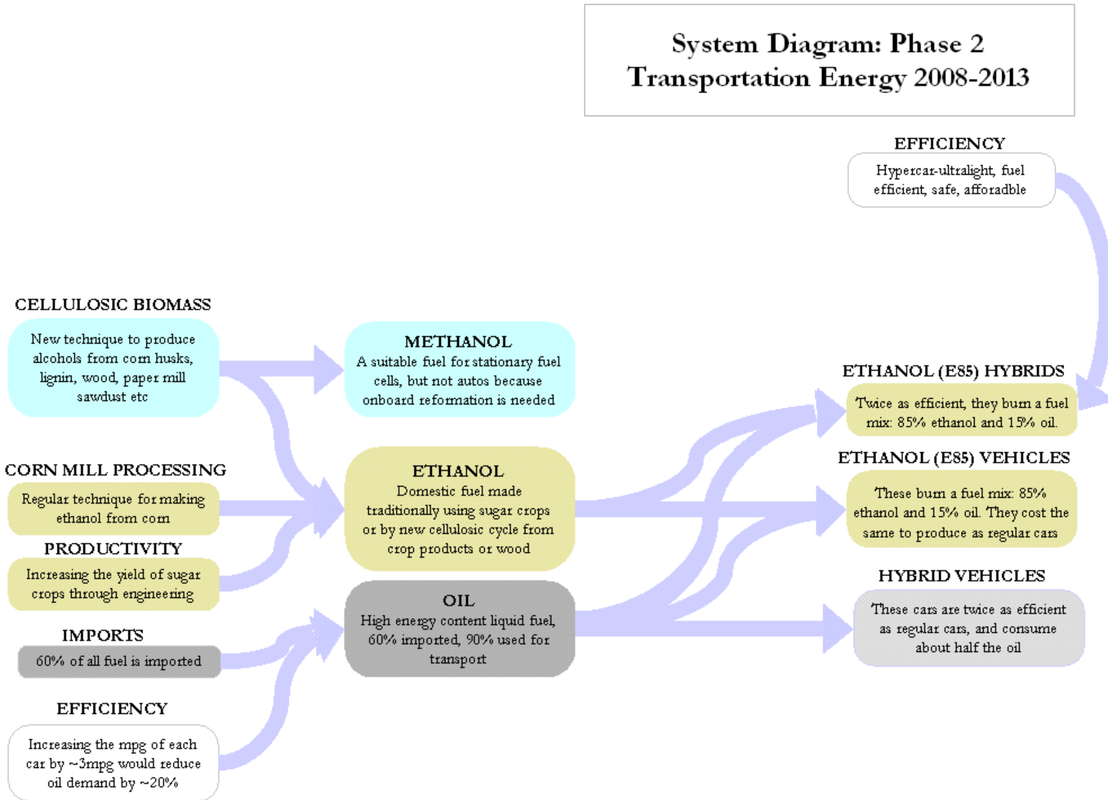
1. R&D Money to cellulosic biomass technology (into ethanol)
2. Incentives to promote storage, distribution, production infrastructural changes
    a. Storage – water tight storage containers
    b. Distribution – change seals on current infrastructure
    c. Production – increase ethanol production
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® Designs

To introduce ethanol at a significant level in the current system, ethanol production must increase, mostly by means of cellulosic biomass. Infrastructural changes must also be made, but these are very minor, which is a major advantage of ethanol. Making the storage and distribution infrastructure watertight is incidental in cost and time. By 2010, all replacement vehicles should be hybrid or E-85, vehicles already on the market that run on 85% ethanol and 15% gasoline. Of course, subsidies and marketing may be necessary in the first few years of ethanol production from cellulosic biomass.

It should be noted that a technology of potential significance in this strategy is an E-85 hybrid engine. Not only would this vehicle lessen the amount of oil needed to produce or import, 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, perhaps up to 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.

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



Phase III (10-15 years)

At all 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; they combine hydrogen and oxygen in a chemical reaction to produce an electrical current in a manner that allows for up to 70% efficiency.

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 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 into 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 in 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.

Objectives

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 – Hybrids Fuel Cell Vehicles; Hypercar® Design

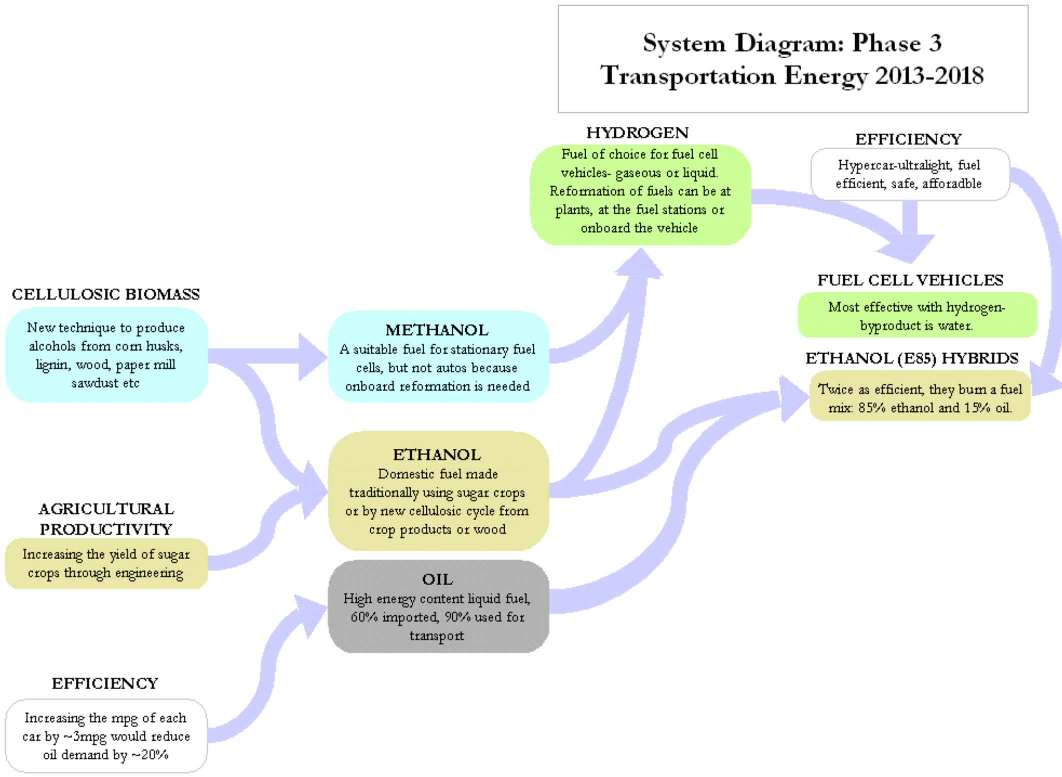
How to get there

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
5. Incentives and Tax Breaks for Fuel Cells
6. R&D into onsite reformation stations

As the steps above indicate, extensive R&D is needed in the realm of fuel cells and biofuels. Also, some incentives from the government are needed to promote the infrastructural changes that will be needed in the storage, distribution, and production of these fuels. Incentives are also needed for Fuel Cell production and purchase in general, as well as R&D into onsite reformation stations and fuel cell hybrid vehicles, which could increase the efficiency of fuel cells even further. Carmakers are beginning to explore this option.[54]

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



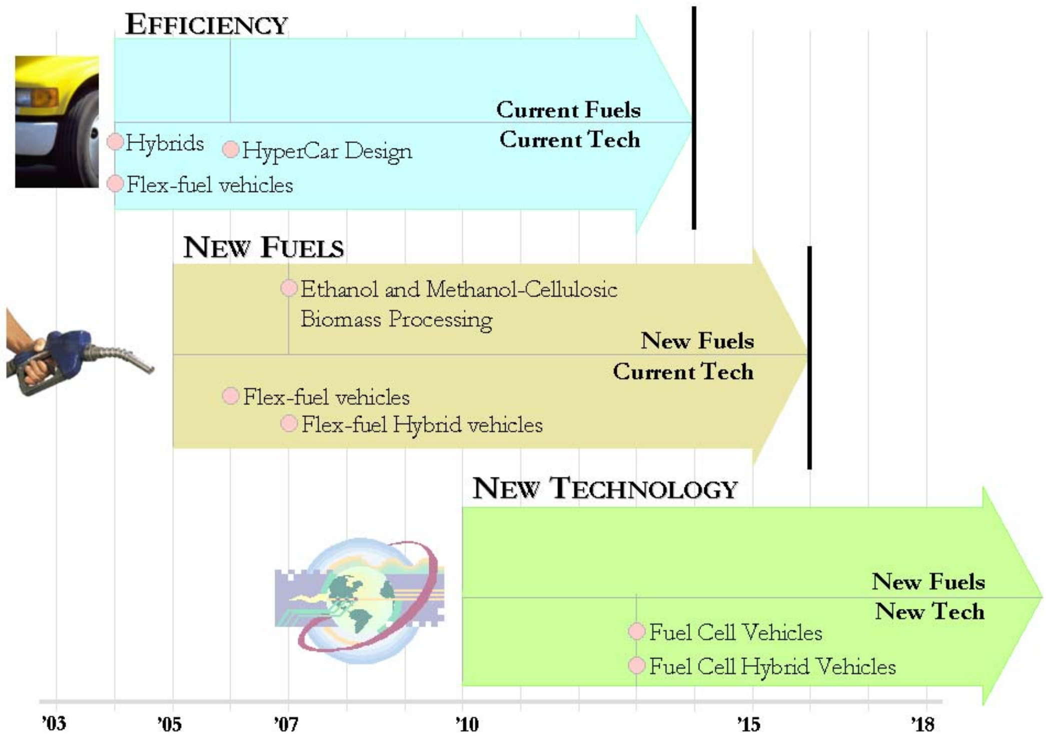
In summary, our analysis suggests that E85 ethanol vehicles and hybrids have the potential to make the most significant impact in the near term with essentially no design or manufacturing changes by car manufacturers. In the mid-term, hybrid electric vehicles using E85 engine/generators with battery 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 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[55].

[55] An Energy Strategy for the Future, Foreign Affairs, July/August 2003 by Timothy Wirth, C. Boyden Gray, and John Podesta

Approximate Timeline

A Strategy: Moving America Away From Oil



Economics

Of course, the economics is crucial to any effective strategy. What are the estimated impacts of implementing this strategy on the composition and growth of the general economy? What is the scale of federal investment or tax reduction that would be needed to shift the market for transportation services in the direction of this strategy? How much public and private investment would be required to make this strategy a success?

It is not within the scope of this project to look at the economic implications of this strategy with much detail. However, generally speaking, this strategy would benefit the U.S. economy in two ways. First, it would provide much needed relief to the U.S. trade deficit. The U.S. currently spends $70 billion annually on imported oil, which is 40% of the current trade deficit. Beginning to create our own, homegrown fuels, the U.S. could make a considerable dent in this large trade deficit, and reinvest these funds into our own economy. Second, and more specifically, this strategy would be investing that money into the agricultural and rural areas of America -- many bio-fuel proponents claim that the United States is already "the Saudi Arabia of agriculture." In order to process cellulosic biomass at a scale enough to displace oil consumption, investments in

America's rural areas would necessarily be re-invigorated with public and private investments.

As far as how much investment is needed to make this strategy a success, others have taken a stab at these numbers. In "How Hydrogen Can Save America" Peter Schwartz balks at President Bush's $1.2 billion for hydrogen, and rightly posits that $100 billion could make significant progress within a decade[56]. Our strategy would more than likely take the latter kind of numbers, but potentially not quite $100 billion because existing infrastructure could be utilized for a significant amount of time. In addition, this initial investment would pay large dividends down the line for our economy.

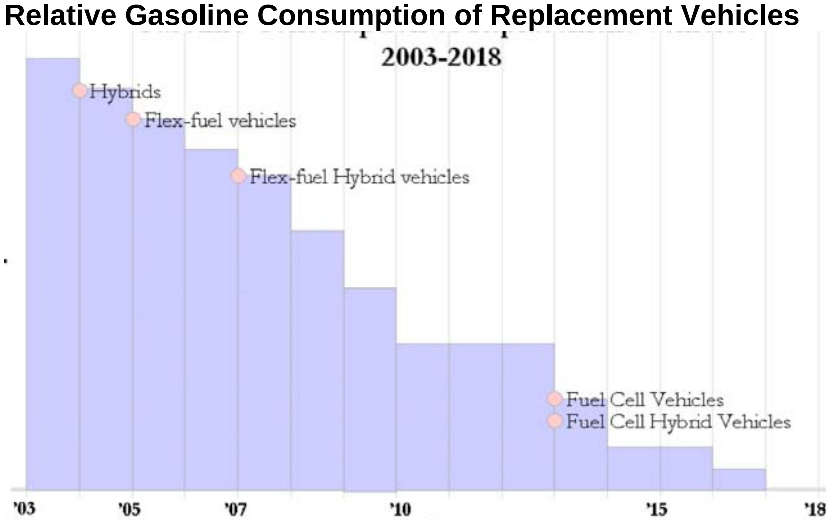
[56] http://www.wired.com/wired/archive/11.04/hydrogen.html

General Benefits to this Strategy

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. (The U.S. currently spends $70 billion for imported oil, which is 40% of the current 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.

Relative Gasoline Consumption of Replacement Vehicles



Strategic Benefits to the Military

Increased Efficiency, Increased Surprise and Reconnaissance Capabilities, Decreased Cost

The strategy of technology, fuels, and efficiency that makes oil obsolete could have profound positive impact on the U.S. military forces. Major benefits include increased range, increased capabilities for surprise and reconnaissance purposes, increased agility of forces, and decreased costs. 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 significant benefits.

Increased Range and Mobility

As an initial phase, the integration of gasoline-electric hybrid engines would significantly improve the efficiency of U.S. forces. Just as in civilian vehicles, gasoline-electric hybrid engines are able to go up to twice the distance on the same tank of fuel, without sacrificing performance. In the longer term, both HyperCar™ technologies and fuel cells will have the same effect – make the vehicles more efficient in fuel consumption. 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[57], 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

In addition, this increased efficiency saves costs. When taking into consideration the transporting of fuel and the vehicles that must refuel, large amounts of money can be saved through a decrease in fuel needs to perform the same tasks and missions. 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[58]. These funds can then be reallocated toward other endeavors.

Increased Surprise and Reconnaissance Capabilities

Gasoline-electric hybrid engines also have the potential to dramatically improve the surprise and reconnaissance capabilities. This is because the electric motor is 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.
This capability would only increase when fuel cells become available, as fuel cells are even quieter than gasoline-electric hybrid engines. Investment in these technologies would add many advantages to war-fighting situations.

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[57] Lovins, Amory B. "Battling Fuel Waste in the Military." Autumn 2001. Rocky Mountain Institute. http://www.rmi.org/sitepages/art7049.php

[58] Ibid.

The benefits in range and mobility, decreased costs, and surprise and reconnaissance capabilities would only improved as the strategy accelerates and new technologies are brought on board. Increased efficiency would save time, money, and energy and increase capabilities for most aspects of the military.

X. Compensation for the Oil Producing Countries

It is of significant importance for the United States to rapidly move toward energy independence in the very 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. Also, our lack of energy independence often forces us to support and do business with countries that, in President Bush's words, "are not our friends." Thus, via unfriendly regimes, the money we spend on foreign oil too often goes to fund the same terrorists with whom we find ourselves in conflict. As such, 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, it is apparent more now than ever how interdependent each person, community, and country is, in economic, political, and other terms as well. Through advances in communication, technology, and transportation, the world has become too small and interconnected for any country to think they can take care of themselves with ambivalence toward the rest of the world. Thus, 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 issues in a number of other countries that are exclusively dependent upon oil exports to prop up their governments.

There are some who suggest that, if the transition were at a slow enough pace, 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 masses. 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 instable 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 too clear. But the questions are very important, and serious scenario development in this area would be a requisite of any complete strategy. These questions should be addressed in the very near future, as this reality of a world without oil appears to be not too far around the corner.

XI. Conclusions

This is not a final strategy. Some additional economic work needs to be done and it would be helpful to see if the light of publication generates additions and changes that would strengthen it. We also think some significant value could come from developing nonlinear systems dynamics models of the system to test alternative approaches. But the basic concept seems to work and it could well be the basis for guiding large-scale change.

Weaning ourselves away from oil in the short term is both necessary and possible. The benefits would be profound, and there are existing technologies that can start the process immediately with broad-reaching options on the near horizon to complete it – if only our government decides that such a fundamental change is in the national interest.

Although a comprehensive shift like this is certainly possible, it will not be easy. This is very complicated, with many differing economic and political interests that would need to be balanced, to say nothing of the compensating effort that would be required to maintain global stability when the oil spigot is turned down.

Perhaps our military, the largest buyer of light-oil-products in the world, could start the national – and then global – transition by becoming the prototypical tester of the strategy. A major change in direction by the military could produce huge direct benefits in reducing the cost and time of deployment (70 percent of the gross tonnage moved when the Army deploys is fuel), and dramatically increase vehicle operational capabilities freed up by the need to carry less fuel.

In the same way that the military organically controls the purchase, storage and distribution of petroleum-based fuels, it could do the same thing for ethanol or methanol – initiating the inexorable global move toward hydrogen. If it began to specify E85 engines tomorrow it would gain more flexibility at no additional cost. And if the world's biggest customer changed its mind, certainly the marketplace would listen.

It would be nice to believe that this could happen just because it was a good idea – that there wouldn't have to be another major, painful event that finally dislodges the status quo. Perhaps there is an enlightened, perspicacious leader who will see the benefits and start the process. Absent that, we will probably have to allow the slow wheels of change to grind through the present system . . . and hope that we adapt while there is still time to reap the benefits.

XII. Appendix A - Think Tools Evaluations

As explained in section *VII. Strategy Considerations*, we used Think Tools™ (TT) to assess the numerous alternative vehicle and fuel combination options for reducing US economic dependence on oil. In attempting to be as comprehensive as possible, we cast a wide net in our assessment, considering fuel cell vehicles, internal combustion vehicles, electric vehicles, and hybrid vehicles running on a wide variety of fuels produced by a number of different processes. The different vehicle and fuel combinations are listed on the Y-Axis and the metrics for which we evaluated each combination are on the X-axis (see TT Options Evaluations on page 69).

First we weighted each metric category on the basis of its importance to our overall goal to move America away from oil on a -10 to +10 scale for 5, 10, and 15 years into the future. For example, "Geopolitics: Energy Independence" was given a weight of 10 in each of the next 5, 10, and 15 year increments because it was central to the premise of this project.

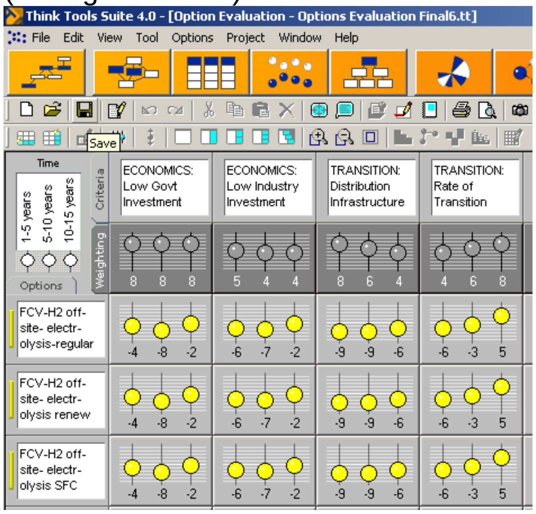
Second, we systematically considered each fuel and vehicle combination and gave it a value that corresponded to each metrics category – based upon how feasible that combination would be in each of the three time frames. For example, concerning "Economics: Low Government Investment," internal combustion gasoline engine cars would require a very low amount of government investment; therefore the values given were very high in the 5, 10, and 15 year time frames.

Third, based on our importance valuations and feasibility analysis, Think Tools™ calculated the optimal fuel and vehicle combinations in each of the three time periods. These findings are visualized on the TT Option Evaluation Bar Graphs (page 70-71).

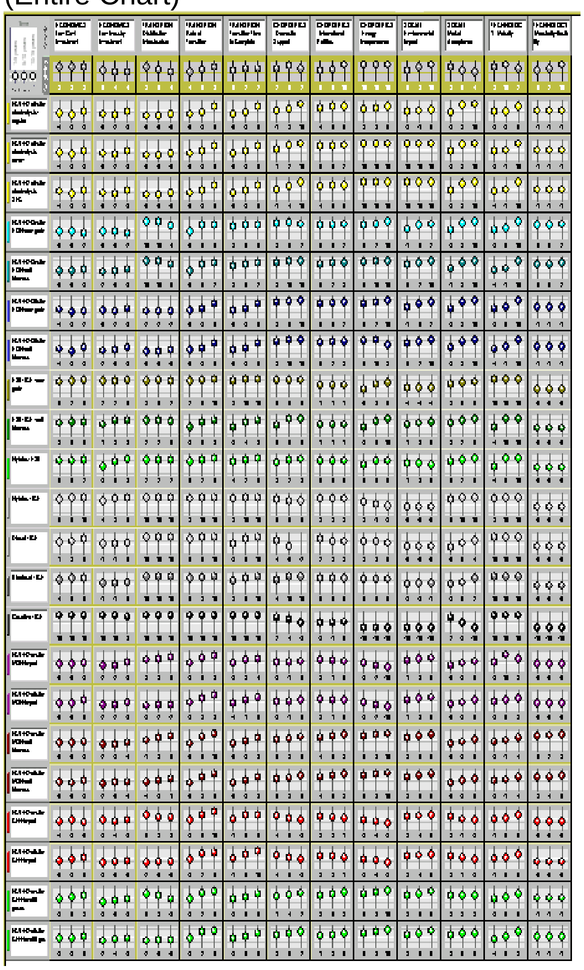
As the TT Options Evaluation Bar Graphs indicate, our systematic assessment revealed that in the short term (Phase I), hybrids using oil and E85s would effect the most change. In the medium term (Phase II), hybrids on oil and hybrids on ethanol offered the most competitive edge. In the long term (Phase III), fuel cell vehicles on ethanol and methanol, mainly produced from cellulosic biomass, afforded the optimal way to decrease US dependence on oil.

TT Options Evaluations

(Enlarged Portion)



(Entire Chart)



Vehicle and Fuel Combinations assessed in Think Tools™

Y-AXIS

1. FCV-H2 off-site- electrolysis-regular
2. FCV-H2 off-site- electrolysis renew
3. FCV-H2 off-site- electrolysis SFC
4. FCV-H2-Onsite-EOH-corn grain
5. FCV-H2-Onsite-EOH-cell biomass
6. FCV-H2-Offsite-EOH-corn grain
7. FCV-H2-Offsite-EOH-cell biomass
8. E85 - ICE -corn grain
9. E85 - ICE -cell biomass
10. Hybrids- E85
11. Hybrids – ICE
12. Diesel – ICE
13. Biodiesel – ICE
14. Gasoline – ICE
15. FCV-H2-onsite-MOH-import
16. FCV-H2-offsite-MOH-import
17. FCV-H2-onsite-MOH-cell biomass
18. FCV-H2-offsite-MOH-cell biomass
19. FCV-H2-onsite-CH4-import
20. FCV-H2-offsite-CH4-import
21. FCV-H2-onsite-CH4-landfill gases
22. FCV-H2-offsite-CH4-landfill gas

Decision Metrics

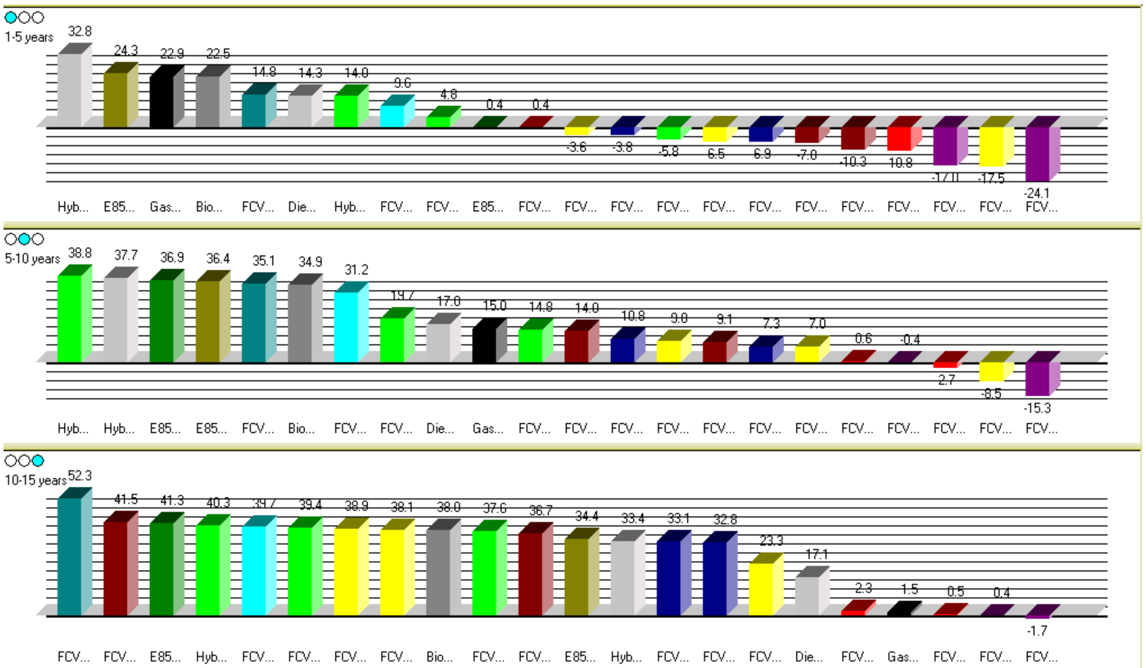
X-AXIS

1. Economics: Low government investment
2. Economics: Low industry investment
3. Transition: Distribution infrastructure
4. Transition: Rate of transition
5. Transition: Transition time to complete
6. Geopolitics: Domestic support
7. Geopolitics: International politics
8. Geopolitics: Energy independence
9. Social: Environmental impact
10. Social: Market acceptance
11. Technology: Maturity
12. Technology: Modularity/flexibility

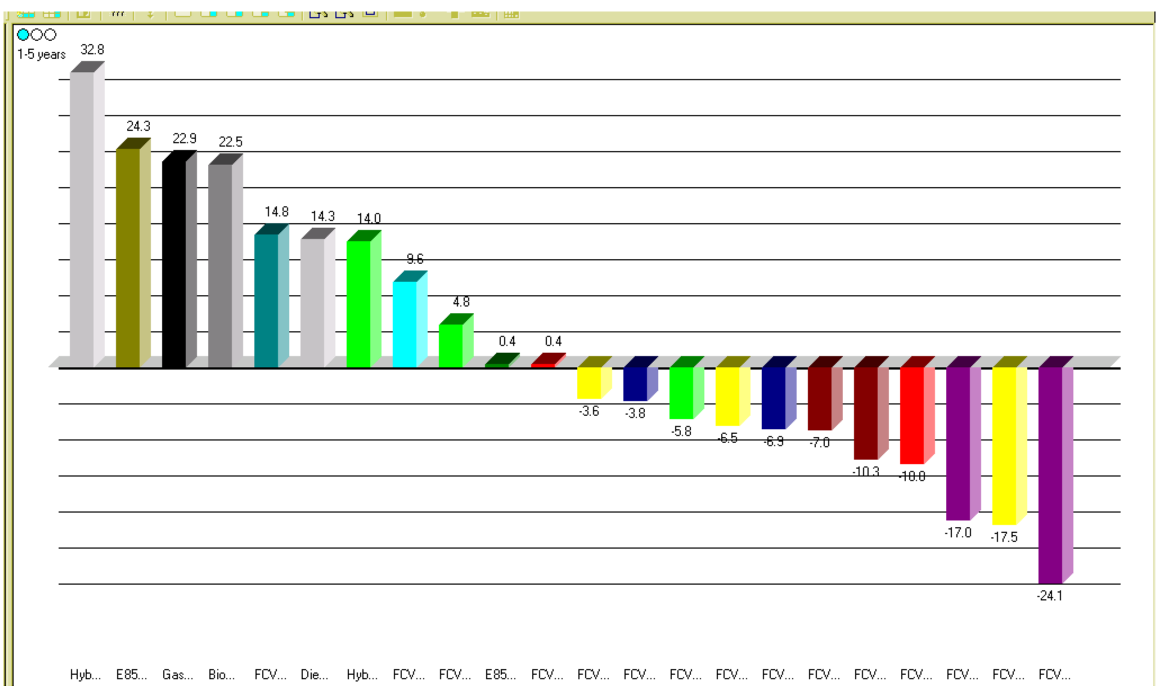
KEY

FCV - Fuel cell vehicle
H2 - Hydrogen fuel
EOH - Ethanol
SFC – Solar Fuel Cell
E85 – Vehicle that runs on 85% Ethanol
ICE - Internal Combustion Engine
MOH - Methanol
CH4 - Natural gas
Onsite - Production of H2 at the pump site
Offsite – Production of H2 at remote location

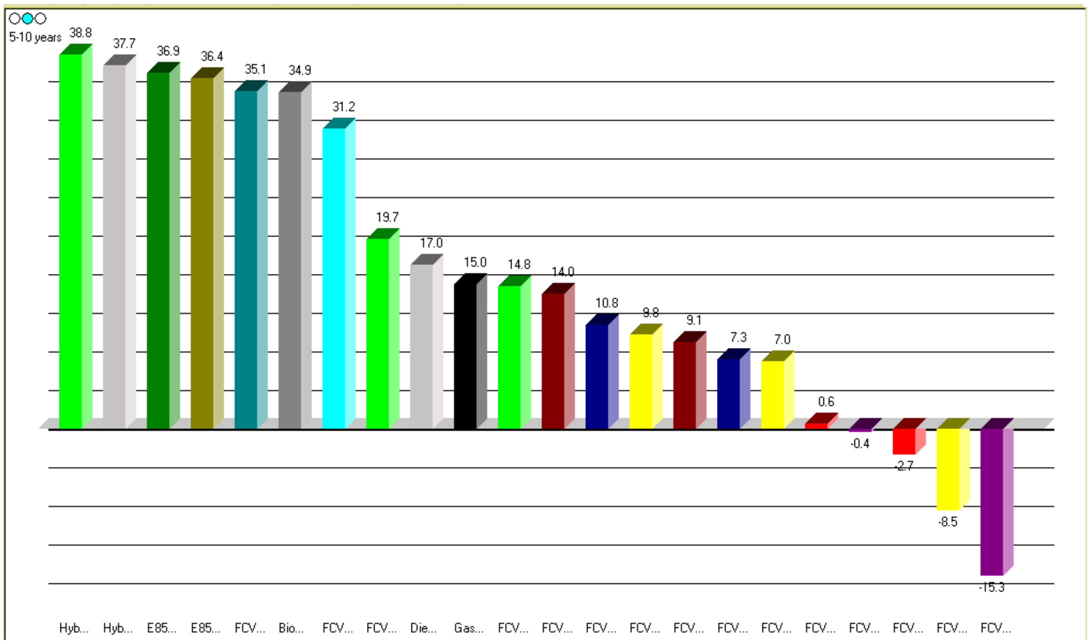
TT Options Evaluations Bar Graphs



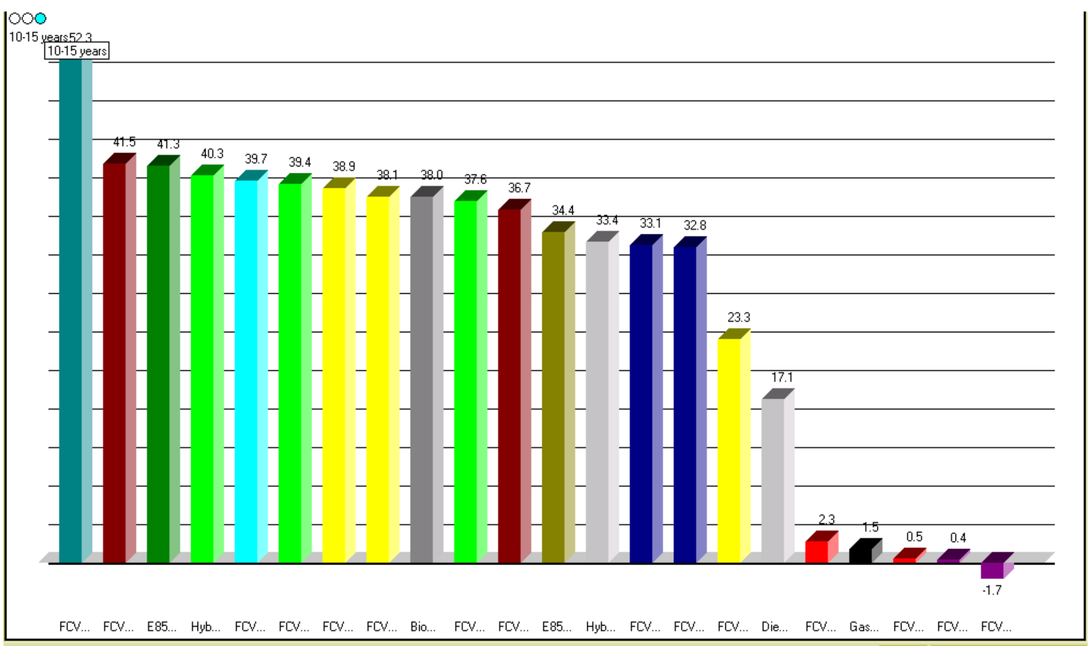
Phase 1



Phase 2



Phase 3



XIII. Appendix B– Alternative Energy Options for the Future

"The 'overunity energy community' is largely in the condition of having mostly only successful small experimental buildups, not robust and proven systems ready for production and full-bore on line power utility operation. It's an area where additional research and development --- and funding for that --- are very much still required for a substantial period, at least for the developments I personally know anything about."
- Tom Bearden (11 Oct 2002)

Radiant Energy

In theory, Radiant Energy is a natural energy form that differs from electricity. It's proponents claim that tapping radiant energy is substantially cheaper than current methods of energy production.

Nu Energy Technologies Inc. - Nu Energy Technologies is developing a version of Moray's radiant energy generator. http://www.nuenergy.org

Clear Tech, Inc. - Edwin V. Gray found the discharge of a high voltage capacitor could be shocked into releasing an electrostatic burst which is captured in a device called the conversion element switching tube (this could be used to power motors and recharge batteries). www.free-energy.cc

Testatika Machine – invented by Paul Baumann of spiritual community Methernitha in Switzerland - www.methernitha.com/Mether_2/Free_energie/free_energie.html

Magnets

Producing energy with various types of magnets still needs further research and development. All of these machines have yet to go to market and there is doubt as to the validity of some claims.

Jasker - developed a self-running home power plant. http://www.jasker.com/

Lutec – is developing a 1,000 watt self-running home power plant using permanent magnets, out of Australia. http://www.lutec.com.au/

Perendev Power Systems - development of a 9kw power plant driven by a permanent magnet motor. http://www.perendev.co.za/

Magnetic Energy Ltd. – Tom Bearden and his group have had a series of successful experiments that appear to validate the over-unity concept of the Motionless Electromagnetic Generator - (Jean-Louis Naudin (France) duplicated the MEG) http://jnaudin.free.fr/html/meg.htm

Permanent Magnet Motor - Howard Johnson – 5,000 watt generator powered by a magnetic motor. www.altenergy.org/3/new_energy/magnetics_and_gravitics/johnson/johnson.html

Aethmogen Technologies – Robert Adams – electric motors, generators, and heaters that run on permanent magnets. http://www.aethmogen.com/about/intro.shtml

Energy Science Ltd. - Harold Aspden - development of the Adams-Aspden motor with Robert Adams. http://www.energyscience.co.uk/

Electrolysis

There are many ways in which people are trying to economically make hydrogen from water.

Hydro Environmental Resources Inc (HERI)- main product: Electro Chemical Hydrogen Fuel Reactor (ECHFR); claims to produce hydrogen gas from tap, ocean, or polluted water because multiple safe compounds are added to any water-based liquid, producing a reaction. http://www.hydrogenerate.com/

Millenium Cell - process by which hydrogen can be liberated from a solution of water mixed with sodium borohydride in the presence of a certain catalyst. http://www.milleniumcell.com/

Powerball Technologies - a process whereby hydrogen gas is liberated from a solution of water and sodium hydride (NaH) - the NaH powder is sealed into small "powerballs." http://www.powerball.net/

Brown’s Gas - Yull Brown – Brown's Gas is a method of extracting hydrogen from water and utilizing it as a car fuel (and as a fuel for welders). www.Eagle-Research.com

Pacheco Bi-Polar Autoelectric Hydrogen Generator - Francisco Pacheco has built successful prototypes that separate hydrogen from seawater. He claims to have fueled a car, motorcycle, lawn-mower, flashlight, boat, and an entire home with this technology. http://www.delphion.com/details?pn10=US05089107 -

Chemaloy Smelting Process - Samuel Freedman - metal alloy was patented in 1957 that spontaneously breaks water into hydrogen and oxygen. www.keelynet.com/energy/chem.htm

Low-Energy Nuclear Reactions (Cold Fusion)

Since 1989, when Pons and Fleischmann's claims of cold fusion rattled the energy world, hope and investment in nuclear fusion at room temperature has dwindled. Yet, currently there are a few hundred scientists worldwide who continue to chase this dream of infinite energy.

Institute for New Energy Commercial Sources Page - a list of companies interested in commercializing cold fusion or other enhanced energy devices:

www.padrak.com/ine/CSOURCES.html

Black Light Power - claims electrolytic cells have produced 30-1000% excess power or greater for extended periods of time, some for more than a year. http://www.blacklightpower.com/

Clean Energy Technologies, Inc. (CETI) – developers of the Patterson Power Cell; unsuccessful attempt to replicate CETI experiment of cold fusion by B. Merriman and P. Burchard
http://www.math.ucla.edu/~barry/CF/reportcover.html

Others investigating cold fusion:

Naval Research Lab megabattery program (Report #1862)
www.spawar.navy.mil/sti/publications/pubs/tr/1862/tr1862-vol1.pdf
www.spawar.navy.mil/sti/publications/pubs/tr/1862/tr1862-vol2.pdf

Michael McKubre (SRI)
http://www.wired.com/wired/archive/6.11/wired25.html?pg=25
www.nytimes.com/library/national/science/032399sci-cold-fusion.html

Edmond Storms - http://home.netcom.com/~storms2/index.html

Electric (Battery)

Currently, NiHH batteries are among the best on the market. However, there is some unconventional R & D taking place that could have a large impact on the energy sector.

Energy Conversion Devices, Inc. - Nickel-Metal Hydride (NiMH) batteries are developed by its subsidiary, Ovonic Battery Company, Inc. These batteries have superior energy density and high power. They are currently used in the Honda Insight. www.ovonic.com

Tilley Foundation – claims that an electric car built with experimental technology can run coast to coast without ever relying on the battery being charged from an outside source www.tilleyfoundation.com

Betavoltaic Industries Incorporated - a nuclear battery that converts energy from beta particles (electrons) released by a beta emitting radioactive source, such as tritium, into electrical power. http://www.betavoltaic.com

Bedini Technology - John Bedini and his group have created motor designs that recharge their own batteries. http://www.icehouse.net/john1

Fuel

There are various ways in which people are trying to increase the efficiency of fuels for environmental and economic reasons. A good deal of the research has revolved around combining water and diesel fuel.

Quantum Energy Technologies Corporation - Keith Johnson (retired MIT professor) - diesel fuel/water mixture that works in existing engines and is stable for years. http://arxiv.org/html/physics/9807058

AquaFuel Research Ltd. - Paul Day combines water and diesel fuel with castor bean oil. http://www.powerpulse.net/cgi-bin/displaystory_new.pl?id=6968

Aquazole - emissions-reducing emulsified diesel fuel (water/fuel mixture) developed by TotalFinaElf (TFE), one of the world's leading oil companies. http://www.aquazole.com/en/index.htm

Turbodyne Systems, Inc. - a water injection system. http://www.autospeed.com/A_0456/page1.html?src=suggestions

The AquaFuel Generator – uses a combustible gas composed of Hydrogen, Oxygen, and Carbon. www.angelfire.com/ak/egel/aquagen.html

GEET Fuel Processor – a fuel delivery system and a pollution elimination unit. www.geet.com

Xogen Power - a hydrogen-oxygen gas mixture at rates sufficient to run an internal combustion engine straight from water. www.xogen.com

Misc. R&D

High Density Charge-Clusters

- Electrical energy converter by Ken Shoulders http://www.earthtech.org/ev/shoulders.html
- Aether Power from Pulsed Plasmas in Vacuo - Paulo und Alexandra Correa, Labofex, Canada, www.Aetherometry.com http://www.globalserve.net/~lambdac/CorreaPublicRefs.html

Hydrocatalytic hydrogen energy

- Peter Graneau - water arc over-unity experiments - http://www.padrak.com/ine/NEWELBOOK.html
- Wallman's Carbon Arc Biomass Gasifier - http://www.wired.com/news/technology/0,1282,19446,00.html

Thermoelectric

Thermoelectric modules are solid-state devices (no moving parts) that convert electrical energy into a temperature gradient, known as the "Peltier effect" or convert thermal energy from a temperature gradient into electrical energy, the "Seebeck effect - http://www.remote-site.com/thermo.html

- EVAPORATIVE SYSTEMS INC. - http://www.remote-site.com/thermo.html
- ENECO - www.ENECO-USA.com

Solar

- Alvin Marks - LUMELOID/LEPCON/QUENSOR, http://web.archive.org/web/20010926110233/http://www.ardev.com/
- Joseph Newman - The Newman Energy Machine - "drastically reduces the number of solar panels needed, www.josephnewman.com

Ultrasonic

- -Hydro Dynamics, ShockWave Power generator (Patent 5,188,090)
- http://www.hydrodynamics.com/technology_review.htm
- ULTRASONIC ENERGY SYSTEMS - http://www.ultrasonic-energy.com/index.shtml
- Sonoluminescence research - Taleyarkhan at ORNL (Science, V. 295, p.1868, March 8, 2002). http://www.sciencemag.org/feature/data/hottopics/bubble/index.shtml
- http://www.ornl.gov/Press_Releases/archive/mr20020305-00.html

Investing and Investigating Organizations

EarthTech International - *http://www.earthtech.org/*

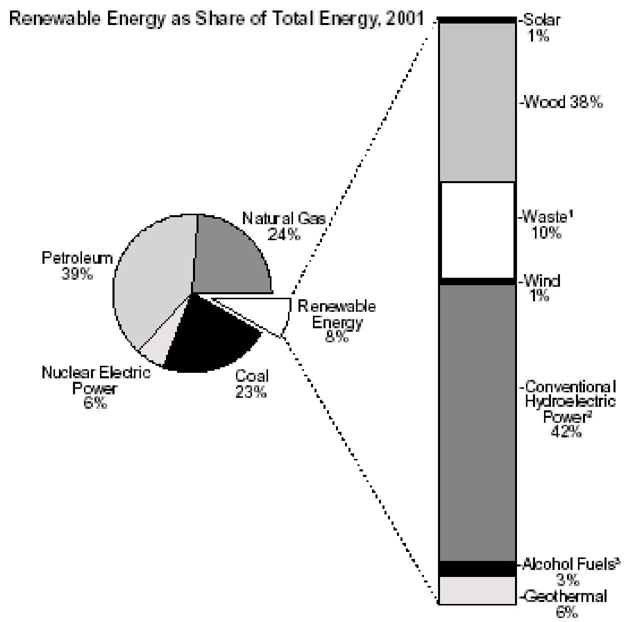
Space Energy Assessment Systems, Inc. – announce $1 million energy prize for an energy invention that would dramatically decrease the need for fossil fuels http://www.SeasPower.com/zprizeannounced.htm

New Energy Partners, Limited Partnership - a venture capital fund that invests in revolutionary new energy technologies. http://www.new-energy.com

Zenergy Corporation (Zpower) - founded in 1996 to facilitate the introduction of commercially viable energy alternatives. www.zpower.net

XIV. Appendix C- Resources from Energy Workshop

Biomass Overview



- Bioenergy was 51% of the total renewable energy consumption in 2001.
- Most was from wood products that are renewable although not sustainable.
- It is projected to be 1%, of all electricity production by 2020.
- Ethanol production is highly subsidized and not competitive

Biomass Resources

- Landfill gas: used for both biofuels (ethanol) and biopower
- Bio-energy crops: herbaceous, woody energy, industrial, agricultural, aquatic
- Clean urban wood waste, agricultural waste
- Animal waste
- Mill residues and forest materials
- Municipal waste: tires, old growth forests, and recyclable papers

Biopower: electricity generation

- *Direct combustion*- burns the biomass with air to produce gas and steam to run turbines
- *Co-firing*- uses biomass as a supplementary energy source to coal fired boilers
- *Gasification*- heats biomass without air to create “biogas” for burning in plant
- *Pyrolysis*-allows high temperatures decomposition without air into solids, liquids, gases
- *Anaerobic digestion*-exposes biomass to bacteria without air to produce methane and other products

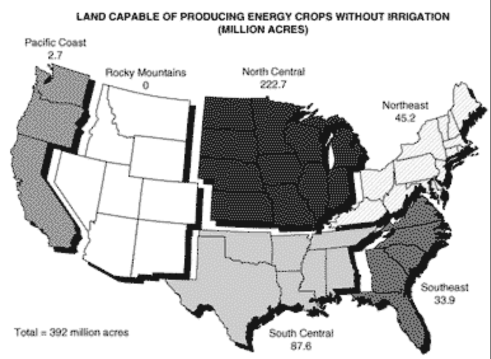
Biofuels

- Ethanol - the most widely used biofuel (current capacity 1.8 billion gal/year)
- Bio-diesel
- Bio-Fuels from Synthetic Gas

BioProducts

- Antifreeze, plastics, glues, artificial sweeteners, and gel for toothpaste
- Biosynthesis gas: plastics and acids, for photographic films, textiles, and synthetic fabrics
- Phenol*:* for wood adhesives, molded plastic, and foam insulation

Availability

- Each person in the US generates about 4.5 pounds of waste per day and about 1 ton a year that can produce landfill gases - 392 million acres are suitable for growing biomass energy crops - Annually, 229 million tons of dry woody biomass would produce ~15 billion gal of ethanol (10% of U.S. gasoline consumption) or 296 million MWh of electricity (11% of U.S. electric power consumption).	

Hydropower Overview

Technology Maturity

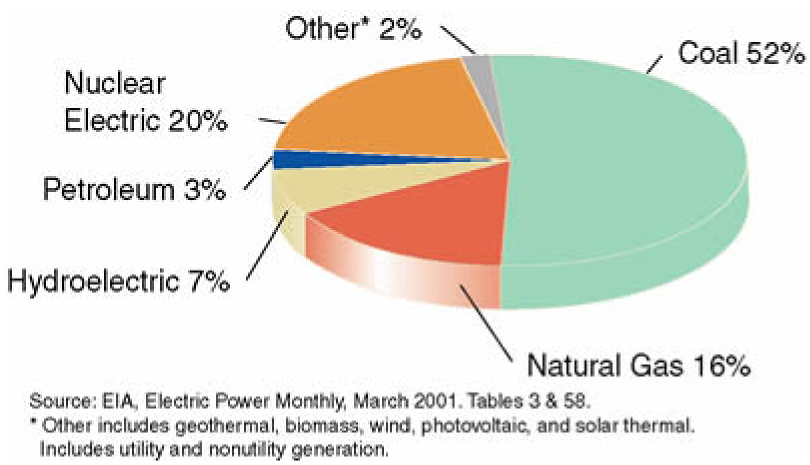
Types of Hydropower	Turbine Technologies
• Impoundment – a dam • Diversion – channel river toward a canal or penstock • Pumped Storage – water is stored at a higher altitude, when needed it is released to produce electricity	• Pelton Turbine – traditional, buckets with a circular disk runner • Propeller Turbine – like a ship's propeller • Francis Turbine – traditional but some advancements have been made to increase dissolved oxygen in water discharge • Kaplan Turbine (variable pitch) – turbine safer for fish & more sophisticated, able to adjust under part flow conditions

Consumption and Production

2001 Consumption	2376 Trillion Btu	3.34%
2001 Electrical Generation	217.5 Billion kWh	5.85%

Electric Utility Net Generation of Electricity

(Based on year 2000 total kilowatt hours generation)



Note: Between 2000-20001, a 21 percent drop in electricity production from conventional hydropower—most likely due to the summer's drought—appears to be the main cause of the fall-off in renewable energy use.

Availability Horizon

The U.S. Hydropower Resource Assessment suggests that there are potentially 30,000 megawatts of power available through 5,677 undeveloped hydropower sites.

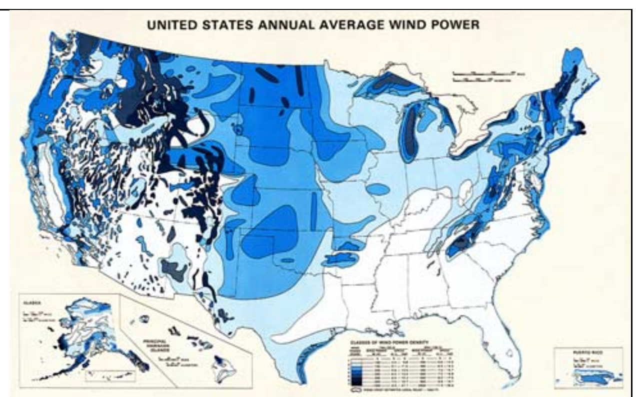
However, many people, including the EIA's Annual Energy Outlook 2002 project that U.S. conventional hydroelectric generation will decline in the coming years as environmental and other concerns further hamper the industry.

Wind Energy Overview

Technology Maturity

- Wind energy is a form of solar energy, created by circulation patterns in the Earth's atmosphere that are driven by heat from the sun.
- This energy is harnessed through the use of turbines for electrical use.
- Turbines range in size from 50 to 750 kilowatts.
- Taller turbines, and thus a larger area swept by the blades, are more powerful and productive than smaller turbines

There are two main types of turbines:
- vertical-axis turbines-the axis



(source: http://rredc.nrel.gov)

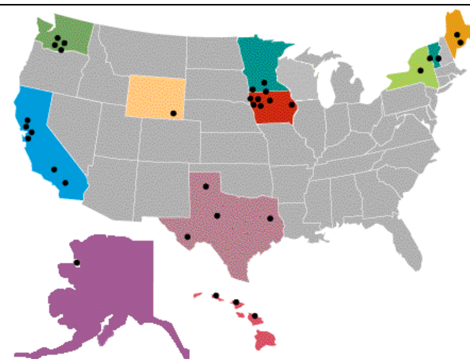
of rotation is vertical with respect to the ground • horizontal-axis turbines- the axis of rotation is horizontal with respect to the ground. Currently, horizontal-axis machines are much more common.	

In the near future, however, purpose designed airfoils and low-solidity, flexible blades, taller towers, and advances in generators should optimize energy capture (eren.doe.gov).

Current Consumption, Production in the United States

In 1999, EIA calculated that installed wind energy generating capacity now totaled 4,265 MW, and generated about 11.2 billion kWh of electricity.

Total wind power accounted for less than 1% of the total renewable consumption in the United States, at 0.046 Btu.



Wind Energy Deployment in US (source: NWTC.com)

Availability Horizon

The American Wind Energy Association estimates the total amount of electricity that could potentially be generated from wind in the U.S. is 10,777 billion KWh annually – three times the electricity generated by the U.S. today. This figure is extremely optimistic.

Solar Power Overview

Types of Solar Power

- Photovoltaics
- Thermal Heat

Technology Maturity – Photovoltaics

Types and Efficiency of various kinds of solar cells and panels (early 2001)

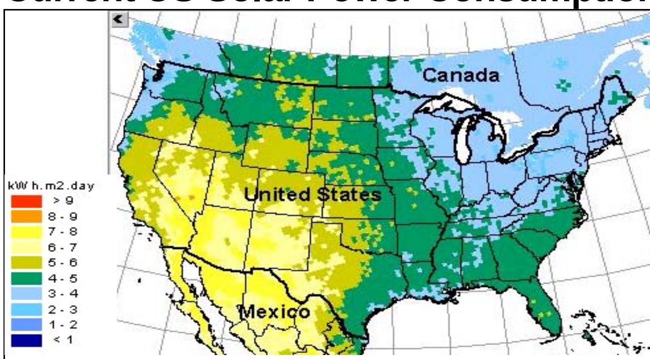
Type	Material	Max	Typical	Cost

		efficiency in laboratory	efficiency commercial	
Cells	Mono-crystalline silicon	25%	13-16%	
Cells	Poly-crystalline silicon	20%	12-14%	Less expensive
Thin film	Amorphous silicon	14%	6-8%	• Requires less expensive semiconductor material • Can be mass-produced.
Thin film	Copper Indium Diselenide	19%	9-11%	
Thin film	Cadmium telluride	16%	7-9%	

(source: solar.phillips.com)

New technology usage: Power View laminate, an integrated thin film photovoltaic that combines solar power with building materials, replaces other building materials such as glass, spandrel panels, and roofing while providing PV electricity.

Current US Solar Power Consumption and Production



2001 Consumption	64 Btu
% of total consumption	0.09 %
2001 Electrical Generation	0.5 billion kwh
% of total electrical generation	0.013 %
Average Cost of Generation	
Generation	c/kWh
Conventional-2002	6-7
Solar-2002	20-30
Solar-1990	90

Availability Horizon

In some ways, the potential for solar power is limitless; every minute, the sun pounds the surface of the earth with more energy than the entire world consumes in a year.

- The cost of solar energy remains three or four times higher than its competitors.
- Even if the market for solar continues to double every three years, as is currently the case, the industry will only reach 10% of peak power generation by 2030 (Fairley TR).

One solution may come in the form of organic solar cells. While thinner and cheaper to produce than even thin film, organic solar cells so far are quite fragile and only reach an efficiency of around 4%. Still, these show the growth potential to balance cheap production with legitimate efficiency.
http://www.nrel.gov/ncpv/documents/thinfilm.html

Fission Overview

Technology Maturity

Two main reactor types in the United States:

- *Pressurized Water Reactors* (PWR)- about 70% of reactors in U.S.
- *Boiling Water Reactors* (BWR)

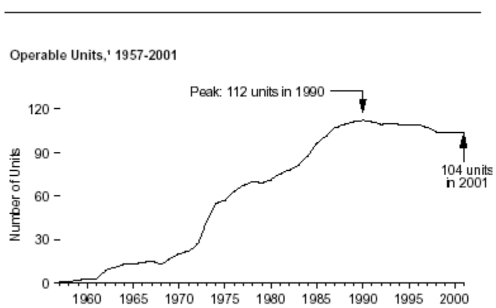
Other types of reactors:

- *Pressurized Heavy Water Reactors* (PHWR) –used in Canada
- *Fast Breeder Reactor* (FBR) – designed to produce more fissile material than they consume
  - MAGNOX
  - RBMK (Chernobyl)
- *Advanced pressurized water reactor* (AP600)
- *Advanced liquid metal reactor* (ALMR)
- *Advanced boiling water reactor* (ABWR)
- *Integral fast reactor* (IFR)
- *Modular high temperature gas cooled reactor* (MHTGR)

Simplified boiling water reactor (SBWR

Also:

- *High temperature gas cooled reactors* (HTGR)
- *Advanced gas cooled reactors* (AGR)



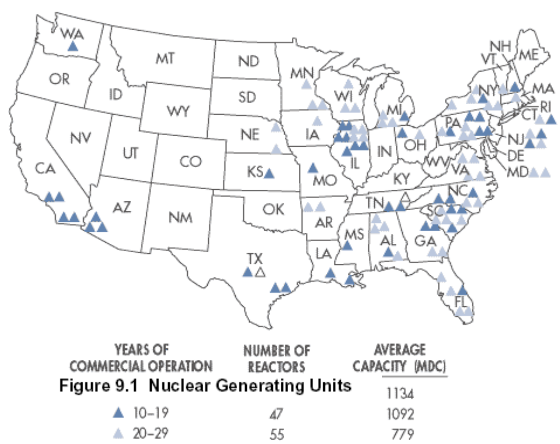
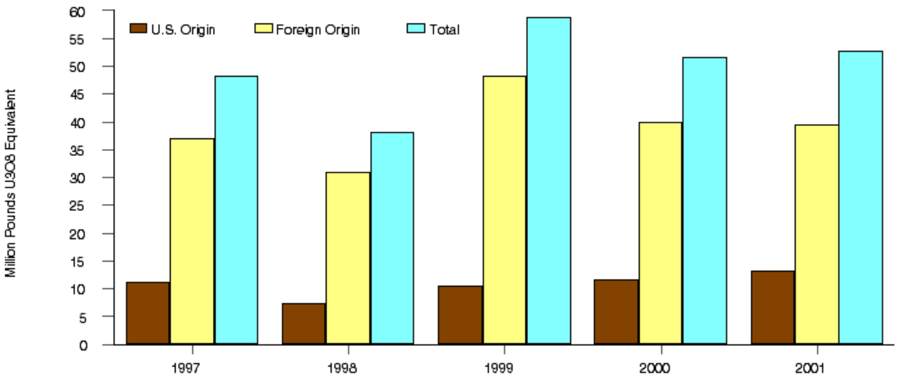


Figure 9.1 Nuclear Generating Units

Note: There are no commercial reactors in Alaska or Hawaii. Calculated data as of 12/00.

Figure 18. Uranium in Fuel Assemblies Loaded into U.S. Civilian Nuclear Power Reactors by Year, 1997-2001



US Consumption, Production, and Imports

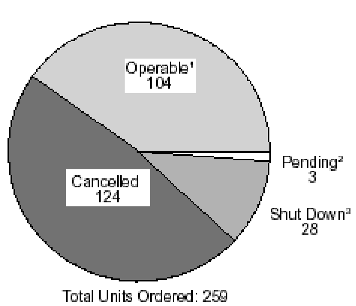
Electrical	2001
Consumption	8,028 Trillion Btu
% Consumption	20.82%
Generation	768.8 Billion kWh
% Generation	20.67%

(source: EIA – Uranium Industry Annual 2001)

Availability Horizon

Estimated Recoverable Resources* of Uranium - (source: uic.com.au)

Country	tonnes U_3O_8	%	Country	Tonnes U_3O_8	%
Australia	889,000	27%	Brazil	232,000	7%
Kazakhstan	558,000	17%	Russian Fed.	157,000	5%
Canada	511,000	15%	USA	125,000	4%
South Africa	334,000	11%	Uzbekistan	125,000	4%
Namibia	256,000	8%	World Total	3,340,000	100%

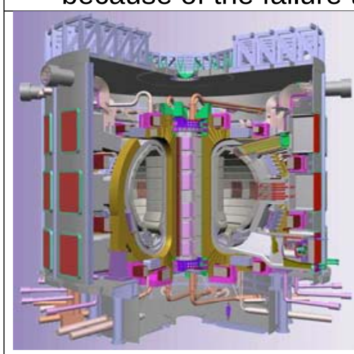


Status of All Ordered Units, 1953-2001

Fusion Overview

Technological Maturity

- Normal fusion requires very high energy in order for the protons to overcome their natural electrostatic repulsion, Temperatures of at least 5 million degrees are necessary.
- The main problem is finding a containment mechanism to contain this hot plasma.
- Work to date involves sophisticated magnetic bubbles and trapsa tokamaks.
- Scientist shave discovered ways to minimize heat loss from turbulence through smaller eddies that don't carry away as much heat
- To date tokamaks require more energy to sustain their integrity than the fusion experiment releases.
- Many countries are phasing out fusion research because of the failure to reach a breakthrough.

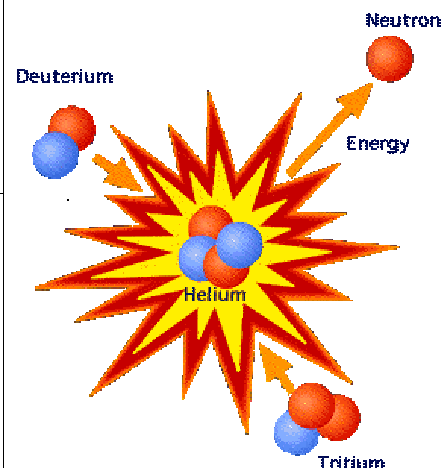


Tokamak – a toroidal (doughnut-shaped) magnetic configuration in which to create and maintain the conditions for controlled fusion reactions

Scientists have not yet been able to contain a fusion reaction long enough for there to be a net energy gain.

Two fuels needed (both isotopes of hydrogen):

- Deuterium – abundant because it occurs naturally in sea-water
- Tritium – can be bred in a fusion system when lithium absorbs neutrons produced in fusion reaction; world



lithium resources are plentiful

Potential U.S. Consumption and Production

There are three major research fusion experiments currently in the United States:

- MIT's Alcator C-Mod
- DIII-D by General Atomics in San Diego
- National Spherical Torus Experiment at Princeton.

ITER, a collaboration of Russia, Europe, Japan, and Canada, continues to strive toward building the largest tokamak. It could potentially produce many times more power from fusion than it consumes because of scaling to a larger size. The U.S. Government pulled out of the ITER project in mid-1999.

Future Horizon

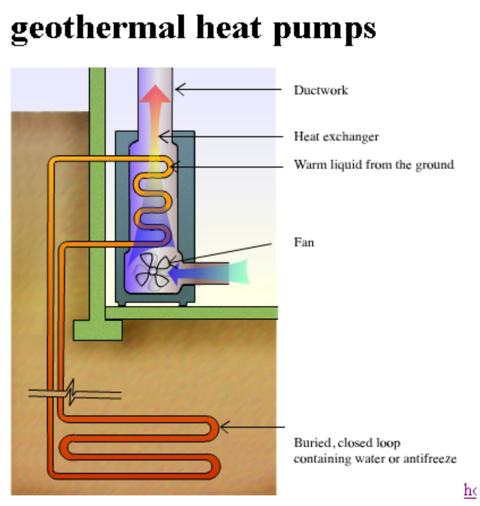
- The building of ITER would take 10 years, and 20 years are foreseen for operation.
- DEMO could be designed by 2020 and operated by 2035.
- The first commercial fusion power station could come on line at the earliest in 2050.

Two things are needed to make fusion a reality:

- Money- Money and commitment has significantly dropped off; interest may rekindle as it becomes more and more clear that fossil fuels will soon be depleted.
- Time- has allowed technological advancements, but they can only be tested and pushed forward with essential funding.

Geothermal Overview

(source: consumerenergycenter.org)



Technology Maturity

Geothermal energy utilizes heat from the earth. There are three basic ways to utilize this abundant source:

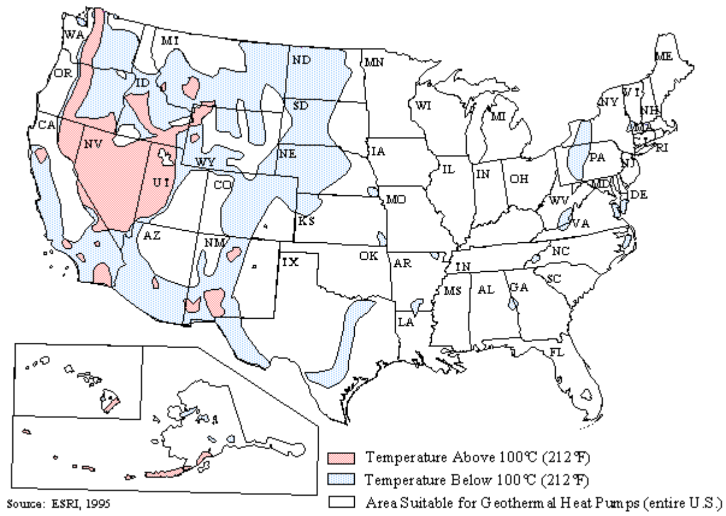
- *Electricity* – geothermal power plants gather steam, heat, or water from deep in the earth, which spins turbine generators to produce electricity. Used water can be returned to sustain reservoirs.
- *Direct Use* – Geothermal waters of all temperatures are used directly to heat greenhouses, sidewalks, individual buildings, and even entire districts. The geothermal water is pumped through heat exchangers until the hot water is transferred into the heating system of buildings.
- *Heat Pumps* – Almost everywhere, the upper 10 feet of the earth's surface maintains a nearly constant temperature between 50-60 degrees. Heat pumps utilize the difference in temperatures between above ground and below ground through heat exchangers. In winter, heat from relatively warmer ground is brought into house; during summer, heat is pulled from the house. (horizontal ground closed loops, vertical ground closed loops, pond closed loops)
- Other possible technologies that are currently pursued outside of the United States include hot dry rock, geopressured brines, and magma energy.

Current US consumption and production

2001 US	
Consumption	315 trillion Btu
% Consumption	0.44%
Net Electrical Generation	13.8 Billion kWhr
% Net Electrical Generation	0.37 %

Availability Horizon

Geoheat.oit.edu identified 271 cities and communities with a population of 7.4 million in the 10 western states that could potentially utilize geothermal energy for district heating and other applications. A collocated community is defined as being within 8 km of a geothermal resource with a temperature of at least 50°C. Over 1900 thermal wells were identified by State Teams as having temperatures greater than or equal to 50°C and 1469 are collocated with communities.

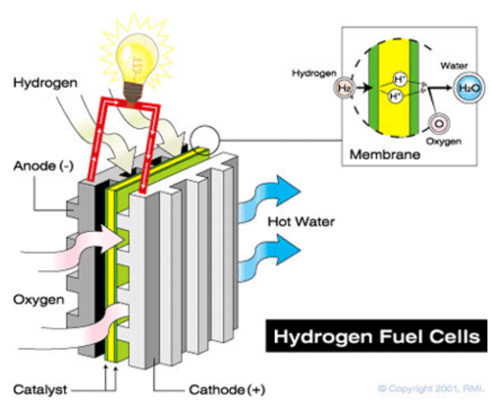


(source: geoheat.oit.edu)

Hydrogen Overview

Technology Maturity

- Fuel-cells have been used by NASA for Space Shuttle engines since the 1960s.
- Fuel Cells combine hydrogen and oxygen in a chemical reaction to produce an electrical current in a manner that allows for up to 70% efficiency
- Hydrogen is the least complex and most abundant element in the universe



source: *www.rmi.org/sitepages/pid537.php*

Hydrogen Production

Hydrogen has proven difficult to extract from nature.

- *Steam reforming*-taking hydrogen from fossil fuels, is the only economically feasible option.
- *Electrochemical process*- hydrogen is taken from water with a surge of electricity. Costs are too high to be competitive because of the amount of electricity needed in one location (Rifkin).

- *Photoelectrochemical*-splitting water by illuminating a water-immersed semiconductor with sunlight
- *Photobiological*- using the natural photosynthetic activity of bacteria and green algae to produce hydrogen.

Some see a biomass-conversion or hydrogen-producing bacteria as the intermediate next step until water splitting becomes efficient (Gorman).

Hydrogen Storage and Transportation

The storage and transport of hydrogen is also a challenge.

- *Compressed-gas* tanks are the best option for storage.
- Hydrogen can also be stored in a *cryogenic liquid* form
- The most promising, safest, and efficient solution is in a *solid state*.
- *Solid-state* research and metal-hydride in particular, are in its early stages yet appear to offer the most advantages in the long term (sciam.com).

Hydrogen Production Worldwide

<table>
<tr><th>Origin</th><th>Amount Billions Nm^3/yr</th><th>Percent %</th><td rowspan="6">Most of the hydrogen produced today is consumed on site, e.g. oil refinery, and is not sold on the market (cost- $0.32/lb).
When sold on the market, the cost of liquefication and transportation is added to the production cost (cost- 1.00-1.40$/lb for delivered liquid hydrogen).
Some users requiring small amounts of very pure hydrogen (such as the electronics industry) use electrolyzers at their facilities (cost -$1.00–$2.00/lb).</td></tr>
<tr><td>Natural gas</td><td>240</td><td>48</td></tr>
<tr><td>Oil</td><td>150</td><td>30</td></tr>
<tr><td>Coal</td><td>90</td><td>18</td></tr>
<tr><td>Electrolysis</td><td>20</td><td>4</td></tr>
<tr><td>Total</td><td>500</td><td>100</td></tr>
</table>

Availability Horizon

Many people predict hydrogen as the leading candidate fuel for the next energy transition because it is the fuel of choice for energy efficient fuel cells.

- The cost of a kilogram of hydrogen can be four to six times higher than the cost of a gallon of gasoline fuel.
- However, because fuel cells are at least twice as efficient, the cost of hydrogen need only be twice as expensive to be competitive.
- Recent studies indicate that the cost is nearer and nearer to the required price range.

XV. Appendix D- Biodiesel References

Biodiesel a viable alternative?

SOURCE: http://www.globalhemp.com/News/2002/November/biodiesel_a_viable.shtml
Saturday, November 16, 2002

The concept of using the Canterbury plains as New Zealand's "fuel basket" by growing a biological version of diesel fuel might have other benefits besides clean running cars and trucks, writes Dave Moore.
Dave Moore, The Press

The idea of New Zealand growing its own fuel is a compelling one. After all, if you can circumvent the tens of millions of years normally occurring between growing forests and turning them into fossil fuels, there are obvious advantages. Not to mention of course being able to forget about the costs and time taken to actually find conventional fossil fuels.

Already many vehicles in Holland, Belgium, Germany, and the United States are using biodiesel and blends of the fuel in existing diesel engines. VW in particular has modified versions of its Polo and Golf models to take advantage of the concept, and special green diesel fuel bowsers are becoming increasingly common in parts of Europe.

European governments, as well as Australia, are doing something about the future use of biodiesel, so it seems it deserves to be taken seriously as a potentially viable vehicle fuel alternative.

What is biodiesel?
Biodiesel fuel is generally the term given oxygenated fuels made from rape, hemp, and other vegetable oils or animal fats. The concept of using vegetable oil as an engine fuel isn't new. In 1895 Dr Rudolf Diesel's demonstration engine at the Paris World Exhibition in 1900 used peanut oil as fuel.

Modern diesels require a clean- burning, stable fuel that performs well under a variety of loads and operating conditions. Biodiesel is the only alternative fuel that can be used directly in any existing, unmodified diesel engine, as it has very similar properties to petroleum-based diesel fuel, and can be blended in any ratio with it.

It has been said that the low emissions of biodiesel make it ideal for use in marine areas, reserves, and forests, as well as the city.

Biodiesel has many advantages as a transport fuel. For example, it can be produced from oilseed plants such as rape which will grow in most countries. Producing biodiesel from rape, hemp, and other domestic crops can also reduce dependence on imported petroleum, not to mention the effects of crude price fluctuations, and simultaneously increase a country's agricultural revenue, with the potential to create jobs if the take-up numbers are large enough.

The Benefits
Biodiesel can be used in most conventional, unmodified diesel engines. It can be stored anywhere that petroleum diesel fuel is stored. It can be used alone or mixed with petroleum diesel fuel, and a common blend is a mix of 20 per cent biodiesel with 80 per cent petroleum diesel.

The lifecycle, production, and use of biodiesel produces approximately 80 per cent less carbon dioxide, and almost 100 per cent less sulphur dioxide than conventional diesel. Combustion of biodiesel alone reduces unburned hydrocarbons by 90 per cent, while resulting in a 75 to 90 per cent reduction in aromatic hydrocarbons.

Biodiesel provides significant reductions in particulates and carbon monoxide compared with petroleum diesel fuel, and provides a slight increase or decrease in nitrogen oxides depending on engine type and testing procedures.

Biodiesel is 11 per cent oxygen by weight and contains no sulphur, and it may even extend the life of engines that use it.

According to some experts, it is more lubricating than petroleum diesel fuel, while fuel consumption, auto ignition, power output, and engine torque are very similar.

Being biodegradeable, biodiesel would appear to be safe to handle and transport, while it has a higher flashpoint of about 150deg compared with petroleum diesel fuel, which has a flash point of 52deg.

Over 50 million successful US road kilometres have been completed using biodiesel, and it has more than two decades of use in Europe.

When burned in a diesel engine, biodiesel replaces the exhaust odour of petroleum diesel with what most regard as the more pleasant smell of hemp, popcorn, or even french fries.

Economic benefits include value added to the biodiesel feedstock (oilseeds or animal fats), an increased number of manufacturing jobs, an increased tax base from plant operations and income taxes, investments in plant and equipment, improvement of the trade balance, and reductions in health care costs due to improved air quality.

An agriculturally savvy nation like New Zealand could not only start to grow a fair percentage of its future fuel, it would give a huge opportunity for the farming sector to diversify.

Europe plans to grow 5 per cent of its diesel needs by 2005. There's no reason why New Zealand shouldn't do better than that.

VW Golf using eco fuel

competitors, VW should have got a prize for merely turning up for the Energywise Rally this week. Not necessarily be for low fuel consumption — although that's a given benefit from the Golf model's "Pump Duse" diesel engine. No, it should have won out for being the only car that could compete the rally without consuming ANY fossil fuels at all.
That's because one of the two Volkswagen entries in the rally ran on biodiesel made from rapeseed oil. The 1.9-litre Golf TDI entered in partnership with the Massey University Centre for Energy Research and was driven by Professor Ralph Sims, director of the centre.
Although it wasn't eligible for class or overall awards available in New Zealand, the Golf produces a remarkably low figure for CO^2 emissions, which enhances the car's rating under the environmental formula used for the event.
Volkswagen has been a big supporter of the use of biodiesel, which is now widely available throughout Europe. Since 1996 Volkswagen has approved the use of biodiesel in all their diesel models, including the high-performance TDI models, and was one of the first manufacturers to maintain engine warranties with biodiesel fuel.
Biodiesel can be produced from various animal and/or vegetable oils by simple chemical processes, and can be used either by itself or in blends with normal pump diesel.
The non-mineral fuel has been proved to reduce tailpipe emissions from diesel vehicles and is virtually free of sulphur.
"This event is a great opportunity for us to demonstrate Volkswagen's worldwide commitment to the environment," said Dean Sheed, Volkswagen division manager for European Motor Distributors. "We are delighted to have the chance to work with Prof Sims and his team, and we are confident that the Golf will be one of the most talked-about cars on the Rally."
Volkswagen's other entry was a 2.5-litre V6 Passat TDI, which used conventional diesel fuel.

What is Biodiesel?

SOURCE: http://www.biodiesel.org/resources/faqs/

Biodiesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics.

Is Biodiesel the same thing as raw vegetable oil?

No! Biodiesel is produced from any fat or oil such as soybean oil, through a refinery process called transesterification. This process is a reaction of the oil with an alcohol to remove the glycerin, which is a by-product of biodiesel production. Fuel-grade biodiesel must be produced to strict industry specifications (ASTM D6751) in order to insure proper performance. Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act Amendments. Biodiesel that meets ASTM D6751 and is legally registered with the Environmental Protection Agency is a legal motor fuel for sale and distribution. Raw vegetable oil cannot meet biodiesel fuel specifications, it is not registered with the EPA, and it is not a legal motor fuel.

For entities seeking to adopt a definition of biodiesel for purposes such as federal or state statute, state or national divisions of weights and measures, or for any other purpose, the official definition consistent with other federal and state laws and Original Equipment Manufacturer (OEM) guidelines is as follows:

Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to ASTM D6751 specifications for use in diesel engines. Biodiesel refers to the pure fuel before blending with diesel fuel. Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (ie: B20 is 20% biodiesel, 80% petroleum diesel).

Is biodiesel used as a pure fuel or is it blended with petroleum diesel?

Biodiesel can be used as a pure fuel or blended with petroleum in any percentage. B20 (a blend of 20 percent by volume biodiesel with 80 percent by volume petroleum diesel) has demonstrated significant environmental benefits with a minimum increase in cost for fleet operations and other consumers.

Is it approved for use in the US?

Biodiesel is registered as a fuel and fuel additive with the Environmental Protection Agency (EPA) and meets clean diesel standards established by the California Air Resources Board (CARB). Neat (100 percent) biodiesel has been designated as an alternative fuel by the Department of Energy (DOE) and the US Department of Transportation (DOT).

How do biodiesel emissions compare to petroleum diesel?

Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the Clean Air Act. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter compared to emissions from diesel fuel. In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to diesel.

Of the major exhaust pollutants, both unburned hydrocarbons and nitrogen oxides are ozone or smog forming precursors. The use of biodiesel results in a substantial reduction of unburned hydrocarbons. Emissions of nitrogen oxides are either slightly reduced or slightly increased depending on the duty cycle of the engine and testing methods used. Based on engine testing, using the most stringent emissions testing protocols required by EPA for certification of fuels or fuel additives in the US, the overall ozone forming potential of the speciated hydrocarbon emissions from biodiesel was nearly 50 percent less than that measured for diesel fuel.

Can biodiesel help mitigate "global warming"?

A 1998 biodiesel lifecycle study, jointly sponsored by the US Department of Energy and the US Department of Agriculture, concluded biodiesel reduces net CO^2 emissions by 78 percent compared to petroleum diesel. This is due to biodiesel's closed carbon cycle. The CO^2 released into the atmosphere when biodiesel is burned is recycled by growing plants, which are later processed into fuel..Is biodiesel safer than petroleum diesel? Scientific research confirms that biodiesel exhaust has a less harmful impact on human health than petroleum diesel fuel. Biodiesel emissions have decreased levels of polycyclic aromatic hydrocarbons (PAH) and nitrited PAH compounds that have been identified as potential cancer causing compounds. Test results indicate PAH compounds were reduced by 75 to 85 percent, with the exception of benzo(a)anthracene, which was reduced by roughly 50 percent. Targeted nPAH compounds were also reduced dramatically with biodiesel fuel, with 2-nitrofluorene and 1-nitropyrene reduced by 90 percent, and the rest of the nPAH compounds reduced to only trace levels.

Does biodiesel cost more than other alternative fuels?

When reviewing the high costs associated with other alternative fuel systems, many fleet managers have determined biodiesel is their least-cost-strategy to comply with state and federal regulations. Use of biodiesel does not require major engine modifications. That means operators keep their fleets, their spare parts inventories, their refueling stations and their skilled mechanics. The only thing that changes is air quality.

Do I need special storage facilities?

In general, the standard storage and handling procedures used for petroleum diesel can be used for biodiesel. The fuel should be stored in a clean, dry, dark environment. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene and teflon. Copper, brass, lead, tin, and zinc should be avoided.

Can I use biodiesel in my existing diesel engine?

Biodiesel can be operated in any diesel engine with little or no modification to the engine or the fuel system. Biodiesel has a solvent effect that may release deposits accumulated on tank walls and pipes from previous diesel fuel storage. The release of deposits may clog filters initially and precautions should be taken. Ensure that only fuel meeting the biodiesel specification is used.

Where can I purchase biodiesel?

Biodiesel can be made available anywhere in the US. The National Biodiesel Board (NBB) maintains a list of registered fuel marketers. A current list is available on the biodiesel web site at www.biodiesel.org or by calling the NBB at (800) 841-5849.

Who can answer my questions about biodiesel?

The NBB maintains the largest library of biodiesel information in the US. Information can be requested by visiting the biodiesel web site at www.biodiesel.org, by emailing the NBB at info@nbb.org, or by calling NBB's toll free number (800) 841-5849.

Biofuels

SOURCE: http://earthsci.org/energy/biofuels/biofuels.html - What%20is%20Biodiesel

What is biodiesel?

Technically, biodiesel is Vegetable Oil Methyl Ester. It is formed by removing the triglyceride molecule from vegetable oil in the form of glycerin (soap). Once the glycerin is removed from the oil, the remaining molecules are, to a diesel engine, similar to petroleum diesel fuel. There are some notable differences. The biodiesel molecules are very simple hydrocarbon chains, containing no sulfur, ring molecules or aromatics associated with fossil fuels. Biodiesel is made up of almost 10% oxygen, making it a naturally "oxygenated" fuel.

Biodiesel is the name for a variety of ester-based oxygenated fuels made from soybean oil or other vegetable oils or animal fats. The concept of using vegetable oil as a fuel dates back to 1895 when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil. Diesel demonstrated his engine at the World Exhibition in Paris in 1900 using peanut oil as fuel.

Key Advantages of Biodiesel:

1. Biodiesel is the only alternative fuel that runs in any conventional, unmodified diesel engine. It can be stored anywhere that petroleum diesel fuel is stored.
2. Biodiesel can be used alone or mixed in any ratio with petroleum diesel fuel. The most common blend is a mix of 20% biodiesel with 80% petroleum diesel, or "B20."
3. The lifecycle production and use of biodiesel produces approximately 80% less carbon dioxide emissions, and almost 100% less sulfur dioxide. Combustion of biodiesel alone provides over a 90% reduction in total unburned hydrocarbons, and a 75-90% reduction in aromatic hydrocarbons. Biodiesel further provides significant reductions in particulates and carbon monoxide than petroleum diesel fuel. Biodiesel provides a slight increase or decrease in nitrogen oxides depending on engine family and testing procedures. Based on Ames Mutagenicity tests, biodiesel provides a 90% reduction in cancer risks.
4. Biodiesel is 11% oxygen by weight and contains no sulfur. The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel, while fuel consumption, auto ignition, power output, and engine torque are relatively unaffected by biodiesel.
5. Biodiesel is safe to handle and transport because it is as biodegradable as sugar, 10 times less toxic than table salt, and has a high flashpoint of about 300 F compared to petroleum diesel fuel, which has a flash point of 125 F.
6. Biodiesel can be made from domestically produced, renewable oilseed crops such as soybeans.

7. Biodiesel is a proven fuel with over 30 million successful US road miles, and over 20 years of use in Europe.
8. When burned in a diesel engine, biodiesel replaces the exhaust odor of petroleum diesel with the pleasant smell of popcorn or french fries.

Power
One of the major advantages is the fact that it can be used in existing engines and fuel injection equipment (no modification required) without negative impacts to operating performance.

Fuel availability/economy
Virtually the same MPG rating as petrodiesel and the only alternative fuel for heavyweight vehicles requiring no special dispensing and storage equipment.

Storage
Readily blends and stays blended with petrodiesel so it can be stored and dispensed wherever diesel is stored or sold.

Combustibility/Safety
Biodiesel has a very high flash point (300°F) making it one of the safest of all alternative fuels.
Production/Refining
The only alternative fuel that can boast of a zero total emissions production facility

Lubricity
The only alternative fuel that can actually extend engine life because of its superior lubricating properties.

Environmental Impact
The only renewable alternative diesel fuel that actually reduces a major greenhouse gas components in the atmosphere . The use of biodiesel will also reduce the following emissions:

carbon monoxide
ozone-forming-hydrocarbons
hazardous diesel particulate
acid rain-causing sulfur dioxide
lifecycle carbon dioxide .

Oil Producing Plants
Corn, Cashew, Oat, Palm , Lupine, Rubber seed, Kenaf, Calendula, Cotton
Hemp, Soybean, Rapeseed, Olive tree, Castor bean, Jojoba, Pecan
Oil Palm, Coffee, Linseed, Hazelnut, Euphorbia, Pumpkin seed, Sesame
Safflower, Rice, Sunflower, Peanut, Tung oil tree, Jatropha, Macadamia nut
Brazil nut, Avocado, Coconut, Macuba palm

Diesel Automobiles Will Soon Invade The U.S. Highways

SOURCE: /http://www.ewire.com/index.cfm?temp=detail&id=3C95C6B4-3E42-4380-8C987533DB49442A
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E-WIRE PRESS RELEASE

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FOR IMMEDIATE RELEASE

Diesel Automobiles Will Soon Invade The U.S. Highways Under Growing Pressure To Make Vehicles More Fuel Efficient
SAN DIEGO, CA, Nov. 22 -/E-Wire/-- Green Star Products Inc. (OTCBB:GSPI) announced that through its subsidiary, American Bio-Fuels (ABF), is preparing to prove that the "extra cost" associated with the use of biodiesel can be offset by the use of other GSPI peripheral products that will provide sufficient "fuel savings" for the consumer to have positive net savings!

In a Wall Street Journal article dated Oct. 24, 2002, the chairman of the powerful California Air Resources Board (CARB) is taking a new look at diesel vehicles. The article states that this represents a striking change of heart for Dr. Alan Lloyd who has regarded diesel as a dirty word for over three decades. Dr. Lloyd has concluded that a new generation of high tech diesel vehicles developed in Europe could be on American roads within years. The article further stated, "Detroit's Big Three and their European and Japanese rivals face growing pressure to make their vehicles more fuel efficient, reduce dependence on mid-East oil and help global warming."

As light trucks, SUVs and minivans have soared in popularity in the U.S., they have dragged down the average fuel economy to the lowest level in two decades. The article concludes that the only way to address these concerns is to introduce the diesel automobile to the American market and these vehicles will most likely appear on the American highway.

It is the opinion of many automobile industry experts that even these high tech diesels will have a rough time meeting the tougher 2007 emissions standards set by the EPA without an alteration in thepetroleum diesel fuel these vehicles will burn. Presently, in California over 60% of the total vehicle emissions are by diesel trucks, which represent less than 10% of the vehicle population.

The use of a blend of biodiesel with regular diesel will certainly aid the existing and new diesel engines in meeting the new standards along with some peripheral automobile devices.

The advantages for using biodiesel are extensive; in a news release by the National Biodiesel Board dated Sept. 5, 2002 entitled "Biodiesel

Emissions Reduce Cancer Risk Compared to Diesel," it stated, "In wake of EPA conclusions that diesel can cause lung cancer, biodiesel can reduce cancer causing compounds by 90%."

The press release further stated, "The findings are the results of two years of independent studies on biodiesel as the fuel completed the health testing requirements of the Clean Air Act. To date, biodiesel is the only fuel to have completed the test, and the industry submitted the results to the EPA."

In the United States today biodiesel is used by a broad scope of vehicles, fleets and the U.S. military and is blended with regular diesel from 2% biodiesel (B-2) to 5% (B-5), 10%(B-10), 20%(B-20) and 100% (B-100) for different applications. These blends require no infrastructure changes or changes to engine operation.

Europe is far ahead of the U.S. in the use of biodiesel and the use of diesel automobiles to reduce green house gases, increase fuel efficiency and reduce many other emissions and toxins. It may come as a shock to American drivers that many of the most popular luxury cars (BMW, Mercedes-Benz, etc.) sell very well in Europe with diesel engines, which are no longer "noisy and dirty."

Biodiesel is the only fuel that contains no sulfur, carries its own oxygen (11% by weight), is biodegradable, reduces many other emissions and reduces CO_2 (green house gas) by 78% (see GSPI press release dated July 23, 2002 on CO_2 reductions on Bloomberg.com or baat.com).

GSPI is not only in the biodiesel production business (see GSPI press release dated July 23, 2002), but also has attracted key personnel who have been working for many years on biodiesel additives, diesel engine technology and peripheral devices to further reduce diesel emissions and increase diesel fuel efficiency. GSPI along with its subsidiary and affiliate companies, including American Bio-Fuels, has its own research and laboratory facilities that will be moved to its new location at the Hondo Chemical site in Bakersfield, Calif. These include engine dynamometers, state-of-the-art emission testing equipment, biofuel and additive laboratories, and engine building facilities. All research work is done in-house.

GSPI has been installing and testing diesel engines in American automobiles since 1998. GSPI management has long believed that diesel engines will find their way to the American market and also to the hybrid vehicle market, which is already happening. Detroit is presently building hybrid diesel vehicles.

GSPI recently tested its diesel engines installed in a General Motors Geo Metro at the California Speedway in Fontana, Calif. The test vehicle was operated with a blend of 20% biodiesel and 80% diesel and achieved 99 MPG at 45 MPH (see GSPI press release dated Aug. 20, 2002). The GSPI test vehicle also ran with a biofuel additive, which reduces NOx and increases fuel mileage.

The GSPI test facility never certifies its own data; all performance data is certified by independent certified facilities.

Presently, GSPI and ABF are testing their biofuel and biofuel additives in combination with GSPI's other developed products. These tests are taking place in several places simultaneously that include CARB testing facilities, stationary fuel testing and testing in Europe on European diesel autos. Preliminary testing is very encouraging with significant reductions in all emissions including NOx, particulates and also fuel efficiency gains.

GSPI is aiming to prove that the extra cost associated with the use of biodiesel and other GSPI peripheral products can be completely offset by the fuel savings potential of these products therefore the net cost to the consumer is zero or even a plus net savings. If cleaner air costs nothing then we all benefit!

Green Star Products Inc. is organized as a holding company with major ownership positions in a set of subsidiary companies now commercializing advanced automotive and energy technology products. For more information, see GSPI's Web site at http://www.baat.com or call Investor Relations, 619/409-8977, 619/409-9598 fax, or email info@baat.com. Information about trading prices and volume can be obtained at several Internet sites including http://www.bloomberg.com under the ticker symbol "GSPI."

Forward-looking statements in the release are made pursuant to the "safe harbor" provisions of the Private Securities Litigation Reform Act of 1995. Investors are cautioned that such forward-looking statements involve risks and uncertainties, including without limitation, continued acceptance of the company's products, increased levels of competition for the company, new products and technological changes, the company's dependence on third-party suppliers, and other risks detailed from time to time in the company's periodic filings with the Securities and Exchange Commission.

SOURCE: Green Star Products Inc
-0-11/22/2002
/CONTACT: Green Star Products Inc. Joseph LaStella, 619/409-8977, Fax 619/409-9598 info@baat.com/
/Web Site: http://www.baat.com//

Power in a load of old rot

SOURCE: renewable energy yahoogroup

15.05.2003 By ELIZABETH BINNING

Hamilton ratepayers will benefit from a new electricity scheme which transforms methane gas from rotting landfill rubbish into cheap power.

The scheme, which is expected to be running by the end of the year, will provide the council with cheaper electricity than is available through the national grid.

The Hamilton City Council spends about $3.3 million of ratepayers' money each year on electricity.

However, that bill could be reduced by up to 25 per cent when a generator, capable of transforming methane gas into electricity, is installed at the Horotiu Landfill.

Sally Davis, city council works and services general manager, said the electricity scheme was a joint venture between the council, WEL Networks and Green Energy.

WEL Networks and Green Energy will collect the natural gases then sell the electricity back to the council at a cheaper rate.

"This project will mean considerable saving to the council for up to 20 years and will reduce our draw on the national electricity supply."

Ms Davis said the venture not only transformed gas - which would normally be burned off into the atmosphere - into a useful resource but provided valuable savings to the ratepayer.

The council's energy manager, Martin Lynch, said it was a coincidence - but fortunate timing - that the sustainable energy project came as New Zealand was being asked to cut power use by 10 per cent.

Mr Lynch said the new generation plant would be able to supply enough power for the equivalent of 1000 homes each year, once it was running at full capacity.

It would not be used for homes, but would supply council buildings and services.

WEL Networks chief executive Mike Underhill said the methane project was the company's first renewable generation project and was made possible by changes to the Electricity Act.

He said the project would also benefit the rest of the country by reducing greenhouse gas emissions and reliance on fossil fuels.

The Horotiu landfill closes in 2006 but is expected to produce enough gas to keep the scheme running for 20 years.

* Dairy giant Fonterra is already making money out of the power crisis.

It has seven generation plants, with a total generation capacity of 163MW, powered by gas, diesel and coal. For the next three months the company will export more into the national grid than it uses.

Vegetable oil carries kids across country

SOURCE: http://www.cnn.com/

Wednesday, May 21, 2003 Posted: 10:14 AM EDT (1414 GMT)
MIDDLEBURY, Vermont (AP) -- A group of college students has set out on a post-finals cross-country road trip that is going to smell a lot like french fries.

But at least there won't be any squabbles over gas money: Their converted school bus is fueled by used vegetable oil from cafeterias and fast-food restaurants.
The 13 Middlebury College students said they wanted to combine their rite-of-passage road trip with an environmental message.

Vegetable oil creates less pollution than diesel fuel, said Thomas Hand, 19, who took a crash course at Middlebury in converting diesel tractor engines to run on vegetable oil.

"It's an energy source that comes from the United States. It's being self-sufficient," Hand said. "Also, it's free. It's using some resource that was going to be thrown away and reusing it."

The students are not the first to power their wheels with vegetable oil. Activist Joshua Tickell drove about 25,000 miles on his "Veggie Van USA" tours in the late 1990s.

start quote[The oil] smells a little bit like whatever it was used to fry -- sometimes you get onion rings, french fries, chicken patties.end quote -- Thomas Hand, Middlebury College student

The Middlebury students left campus Monday night and plan to arrive in Conway, Washington, by June 11, with plenty of stops in between to drop off classmates and do some rock climbing.

Along the way, they will be keeping an eye out for restaurants to get them there. Based on a few trial runs in Vermont, the students -- several of whom are environmental studies majors -- are optimistic they will find the fuel they need.

The students filter the vegetable oil and store it in two vats on the bus. To get the bus rolling, the students first start it briefly with diesel fuel to heat and lower the viscosity of the vegetable oil.

They are sure to draw attention: They will be cruising no faster than 55 mph, with "Powered by Veggie Oil" painted on the back of the bus. And the oil "smells a little bit like whatever it was used to fry -- sometimes you get onion rings, french fries, chicken patties," Hand said.

The students plan to keep people posted through journal entries and photographs on the Internet.

"It's part of an adventure we'll remember for the rest of our lives hopefully," said Logan Duran.

XVI. Appendix E– Diesel References

Quick Facts About Clean Diesel Technology

SOURCE: http://www.dieselforum.org/didyouknow/cleandiesel.html

DID YOU KNOW...
Emissions Reduction:

- Particulate matter (PM) emissions of new on-highway diesel engines have been reduced 83% since 1988.
- Nitrogen Oxides (NOx) emissions of new on-highway diesel engines have been reduced by 63% since 1988.
- Emissions standards for 2004 will cut NOx emissions in half for on-highway diesel engines, effecting an 83% total reduction since 1988.
- Among all on-road mobile sources, heavy-duty vehicles account for only 3% of total Carbon Monoxide (CO) emissions.
- Among on-road mobile sources, heavy-duty diesel vehicles account for only 6% of total Hydrocarbon (HC) emissions.

Fuel Efficiency:

- In Europe, where fuel prices put energy conservation at a premium, diesel powers nearly 25% of all new passenger vehicles.
- In France, Belgium, Austria, and Spain, over 40% of new passenger vehicles are diesel.
- Light-duty diesels, such as automobiles, use 30-60% less fuel than similarly sized gasoline engines, depending on the type of vehicle and driving conditions.
- Studies have found on-road heavy-duty diesels to be more than 60% more fuel efficient than similarly sized spark-ignited natural gas engines (both CNG and LNG).
- Diesel's superior fuel efficiency is not only a result of compression ignition, but also a result of diesel fuel's higher energy content. A gallon of diesel fuel contains roughly 11% more energy than a gallon of gasoline, 67% more than a gallon of LNG and 250% more than a gallon of CNG.

Source: "Engineering Clean Air: The Continuous Improvement of Diesel Engine Emission Performance" March, 2001
The Diesel Technology Forum

Frequently Asked Questions

SOURCE: http://www.dieselforum.org/factsheet/faqs.html

Why is diesel power so widely used even though it has critics?
No other form of energy comes close to diesel for its power, versatility, cost-effectiveness and range of applications. As a result, diesel is the predominate form of power for a wide range of industries, including trucking, railroads, shipping, agriculture, public transportation, mining, homeland security and defense. In order to ensure diesel's continued viability, the industry works closely with regulators to address concerns raised about diesel's environmental impact, a process that has proven successful, as today's diesel systems are significantly cleaner than older ones.

What are the specific advantages that diesel has over other energy sources?
Diesel is the most energy-efficient internal combustion engine. Diesel power offers a number of advantages over other forms of energy, including safety due to its lower combustibility, more energy per gallon than gasoline, better fuel economy, greater power density for higher performance, and unmatched durability for longer engine life.

What is it about how diesel engines run that makes them more efficient?
Diesel systems are more efficient due to the nature of the fuel and how it is burned. Diesel fuel's higher energy content makes diesel engines more fuel efficient than equivalent gasoline engines. Unlike gasoline engines, which ignite fuel with spark plugs, diesels ignite fuel with compression, which creates more torque and uses less fuel to produce the same amount of power.

Do clean diesel engines offer any environmental advantages over other types of engines?
Clean diesel engines usually emit lower levels of certain emissions than gasoline engines. Of the five major emissions from internal combustion engines - carbon monoxide, hydrocarbons, carbon dioxide, particulate matter and nitrogen oxides - diesel emits only small amounts of the first three. In addition, the fuel efficiency of diesel engines means they burn considerably less fossil fuel when they operate.

How are diesel systems different from 10 years ago?
The industry has made significant strides in recent years to develop diesel systems that are cleaner and more efficient than ever before, thanks to state-of-the-art engines, cleaner-burning fuels and effective emissions-control systems. Advancements in the fuel injection system that optimize combustion, refinement of turbo-charging, and advanced electronic engine controls have played pivotal roles. Trucks and buses are eight times cleaner than those built a dozen years ago, and data from the US Environmental Protection Agency shows that the level of diesel particulates in the air fell by more than 37 percent from 1990-1998. During the same time period, the per-mile cost of moving a ton of freight fell by four percent even though the number of inter-city ton-miles grew by nearly 25 percent, and America's growing reliance on clean diesel was instrumental in these productivity and efficiency gains.

Are there any alternatives to diesel for industrial applications?
Although diesel is the dominant form of power for many industries and is the only option for some of them, there are situations when it is appropriate to use engines powered by natural gas, solar, wind and batteries, and in the future, hydrogen fuel cells also offer potential. But overall, diesel systems are unrivaled for industrial and manufacturing applications that require power, fuel and cost efficiency, durability and reliability.

Is it normal for diesel engines to emit black smoke?
Absolutely not. When a diesel engine emits excessive smoke, it means that it is out of tune, in need of maintenance or not operating efficiently. Because black smoke is caused by unburned fuel, it also means wasted energy and lost money for diesel system operators, so it is in their interest to take corrective action quickly. New clean diesel engines do not smoke and have been designed to be smoke free since 1994.

What is the industry doing to continue clean diesel's record of continuous improvement?
The industry remains committed to continuous improvement by building cleaner engines and taking steps to lower emissions in the existing fl eet of diesel engines. New emissions control technologies such as particulate traps and catalytic converters can be used to upgrade many older diesel engines and reduce pollutants by up to 90 percent. Refiners are working to virtually eliminate sulfur from diesel fuel to facilitate the performance of these aftertreatment systems and have committed to making ultra-low sulfur fuel available nationwide by 2006. On the regulatory front, new regulations for reducing bus and truck emissions take effect in 2007, calling for a reduction of particulate matter and nitrogen oxides by 98 percent from 1988 levels, a virtual elimination of emissions from on-highway engines.

Where is ultra low sulfur diesel available for sale in the U.S.?
View the current EPA map of ULSD availability.

Diesel Cars, Trucks And SUVs Part Of The Solution

SOURCE: http://www.dieselforum.org/news/jun_06_2003.html

Diesel Cars, Trucks And SUVs Part Of The Solution To Petroleum Reduction, Says California Study

California Assembly Bill 2076, adopted in 2000, required the California Energy Commission and the California Air Resources Board to identify strategies to reduce California's reliance on petroleum, primarily as an effort to moderate fuel price fluctuations. The report, Reducing Petroleum Dependency in California, will be discussed at a public hearing on June 6, 2003 in Sacramento and will be adopted by the two agencies at the end of June 2003. The report will then be sent to the state legislature.

SACRAMENTO, Calif. - California legislators looking for ways to cut petroleum demand over the next 30 years and reduce transportation fuel price swings, will soon learn, probably to their surprise, that environmentally friendly diesel cars, trucks and SUVs are one of the most practical, cost-effective ways to do it.

Reducing Petroleum Dependency, a joint project of the California Energy Commission and the California Air Resources Board, concludes that significantly more fuel efficient vehicles are the most effective way of slowing, even reducing, petroleum demand in California.

Tops for their petroleum-reducing potential in the next 20 years are gasoline-electric hybrids, clean diesel vehicles, and a natural-gas-derived fuel that can run in diesel engines when blended at about 33% with diesel fuel. Diesel passenger vehicles yield a 45% improvement in fuel economy over gasoline models, according to the report.

Longer term, the study puts great hope in fuel cell technologies, which use hydrogen to power engines, providing high fuel efficiency, reduced climate-change impacts, and no tailpipe emissions. Still in R&D stage, cost is a major consideration in the future of this technology.

The advantages of diesel passenger vehicles are numerous. First, they're market ready, not just on the engineering drawing board. Second, diesel cars, trucks, and SUVs available in Europe today provide significant fuel economy over similar gasoline-fueled models, and put out roughly 15% less carbon dioxide emissions. Third, their energy efficiency is cost effective for the consumer and won't require heavy government subsidies. Fourth, the engines are durable and reliable. And fifth, drivers who want power and space can get it, without sacrificing fuel economy.

"If we want these fuel efficient vehicles to reduce petroleum use, as the report hopes, they've got to be available, affordable, and appealing enough to get them on the road in large numbers," said Allen Schaeffer, Executive Director of the Diesel Technology Forum. "When Americans learn to appreciate the combination of fuel efficiency and power, these diesel vehicles are really going to find their market," said Schaeffer.

"By 2030, if 32% of the passenger vehicles in California were based on fuel-efficient diesel engine powertrains, as is the current case in Europe, petroleum consumption would be reduced by 840 million gallons of gasoline a year," according to the DTF's Schaeffer. "That's 20 million barrels of petroleum a year." The projection is based on a study conducted by M Cubed, a Davis, California-based economics consulting firm, for the Forum. (The complete study is available at: http://dieselforum.org/whitepaper/downloads/McCann.pdf)

Unfortunately, the California report discounts the full potential benefit of diesel vehicles by assuming that U.S. consumers won't be eager buyers of the improved technology, in contrast to the rising market demand for the fuel efficient, powerful vehicles in Europe. There, 40% of new cars and light trucks, and 70% of new luxury cars, are powered by diesel engines sporting new, fuel efficient engine components and featuring advanced emissions control technologies. The California report assumes a market penetration of only 10% by 2020. (DTF report on the popularity of diesel passenger vehicles in Europe is available at: http://dieselforum.org/whitepaper/downloads/europeanexperience.pdf)

Surprisingly, the California report recommends that the legislature set a goal to increase the use of alternative fueled vehicles to 10% of the market by 2020, even thought the report's data indicates that compressed natural gas, electric batteries, liquid petroleum gas and other "boutique" fuels just don't pass the cost-effectiveness test for reducing petroleum use. And they're unlikely to gain much acceptance elsewhere in the country because of high expense relative to fuel savings.

"Regardless of the admirable intention of diversifying the fuel source, what good is a vehicle that runs on a boutique California fuel if you can't fill up the tank once you cross the state line?" asked Schaeffer.

"Even the alternative fuel infrastructure alone would cost California taxpayers hundreds of millions in subsidies for technologies that, at best, provide a 20- to 50-year bridge to vehicles powered by fuel cells," said Schaeffer.

When the California petroleum reduction study was requested by the legislature in 2000, many people assumed petroleum-based diesel vehicles wouldn't even be a consideration. But when the California Energy Commission and the California Air Resources Board calculated the costs and benefits, not only to the consumer, but to the environment, diesel passenger cars emerged on the positive side of the choices.

###

The Diesel Technology Forum represents manufacturers of engines, fuel and emissions control systems. It brings together the diesel industry, the broad diesel user community, civic and public interest leaders, government regulators, academics, scientists, the petroleum industry and public health researches to encourage the exchange of information, ideas, scientific findings and points-of-view to current and future uses of diesel power technology. For more information about the Forum and to view our white paper, visit our web site at www.dieselforum.org.

What is Clean Diesel?

SOURCE: http://www.dieselforum.org/factsheet/cleandiesel.html

Clean diesel is an evolutionary systems-based process that combines advancements in diesel **engines**, cleaner burning **fuels** and **emissions control system**, all working and optimized together.

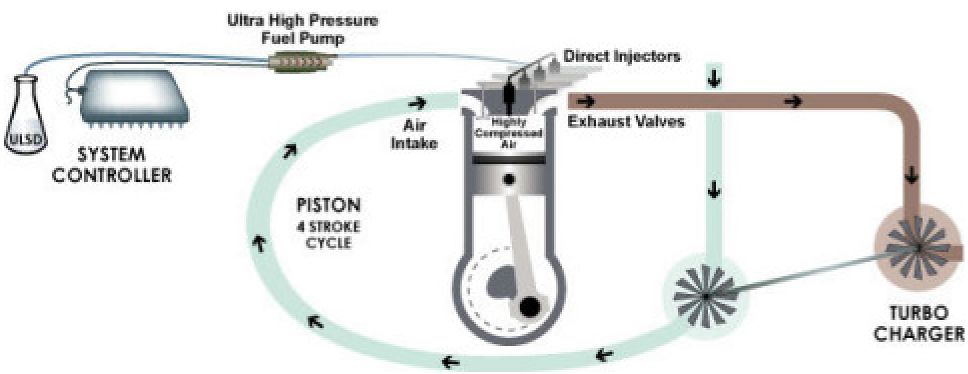
The Engine

Diesel is the world's most efficient internal combustion engine. It provides more power and more fuel efficiency than alternatives such as gasoline, compressed natural gas or liquefied natural gas.

Fuel combustion is the primary difference between gasoline and diesel engines. Gasoline engines ignite fuel with spark plugs, whereas diesels ignite fuel with compression. The piston stroke in a diesel engine results in a compression of the fuel air mixture so intense that it combusts spontaneously. The compression ignition process provides more torque, and is more efficient than the use of spark plugs required by gasoline engines, because a gasoline engine would have to use more fuel to produce the same amount of power. Advanced technologies - such as electronic controls, high-pressure fuel injection, variable injection timing, improved combustion chamber configuration and turbocharging - have made diesel engines cleaner, quieter and more powerful than past vehicles.

It is not widely recognized that diesel has some environmental advantages over other types of engines. Of the five major emissions from internal combustion engines - carbon monoxide, hydrocarbons, carbon dioxide, particulate matter and nitrogen oxides - diesel emits only small amounts of the first three.

Excessive smoke means a problem with the engine, such as being out of tune, needing maintenance or not operating efficiently. Excess smoke is bad for operators because it's unburned fuel or "dollars going right out of the smokestack," so most act quickly to correct the problem. New clean diesel engines do not smoke and have been designed to be smoke-free since 1994.



The Fuel

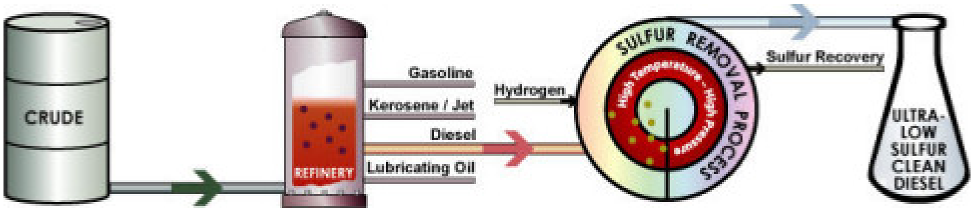
Diesel is a petroleum-based fuel with a higher energy content than gasoline. This greater energy content -coupled with the efficiency of compression ignition - explains why diesel vehicles get better gas mileage

Clean diesel refiners are working to virtually eliminate sulfur from diesel fuel. The primary purpose of lower sulfur diesel is to enable or improve the performance of aftertreatment systems, although lower sulfur fuel can reduce particulate emissions without the addition of any exhaust-control device.

By 2006, clean diesel refiners are committed to making ultra-low sulfur fuel (ULSD) available nationwide. The sulfur content in ULSD (15 parts per million) is equivalent to one ounce of sulfur per tanker truck of diesel.

[View](#) the current EPA map of ULSD availability.

[Find out more](#) about the current availability of ULSD in Texas.



The Emissions Control System

With the introduction of lower sulfur diesel fuel, a number of exhaust treatment systems can further reduce emissions from diesel engines.

Particulate Traps - These filters collect particulate matter as the exhaust gases pass through and can reduce particulate emissions by 80-90% using a catalytic reaction or an auxiliary heating element.

Catalytic Converters - These devices use a chemical reaction to convert emissions into harmless substances. Some catalysts - such as selective catalytic reduction (SCR) devices and NOx absorbers - focus on nitrogen oxides and can reduce these emissions by 25-50%.

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View the current EPA map of ULSD availability.

Find out more about the current availability of ULSD in Texas.

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Why Diesel?

SOURCE: http://www.dieselforum.org/factsheet/dieselemissions.html

Clean diesel's vital role in America's economy, quality of life and national security is due to the wide range of performance, efficiency and safety benefits it offers as an energy source. The attributes that make diesel such an effective source of power include:

- **Safety** - Diesel is a safer fuel than gasoline or other alternatives. It is less flammable and explosive than gasoline.
- **Energy content** - Diesel fuel contains about 30% more energy per gallon as compared to gasoline.
- **Efficiency** - Today's heavy duty clean diesel truck engines get 10 - 30% better fuel economy than those built in the last 10 years
- **Performance** - Diesel technology has a greater power density than other fuels - it packs more power per unit volume than other fuels.
- **Durability** - Diesel engines are renowned for their durability, lasting hundreds of thousands of miles. This helps conserve resources.
- **Continuous improvements** - Significant progress has been made in reducing emissions from diesel engines of all kinds. Thanks to new, clean diesel

technologies, today's trucks and buses are eight times cleaner than those built just a dozen years ago.

Detroit awakens to benefits of Europe's diesels

SOURCE: http://uktop100.reuters.com/latest/Jaguar/top10/20030305-AUTOS-SHOW-DIESEL.ASP

AUTOSHOW-Detroit awakens to benefits of Europe's diesels
2003-03-05 16:14:45 GMT (Reuters)

By Michael Ellis

GENEVA, March 5 (Reuters) - As a child growing up in New Jersey, Mark Fields had a nickname for the diesel-engine truck his neighbor drove to work every morning.

"I used to call it the alarm clock," said Fields, the head of Ford Motor Co.'s luxury vehicle group, which includes Volvo, Land Rover, Aston Martin and Jaguar.

"He used to start up at 7 o'clock in the morning and I used to wake up for school because it was so loud," he told reporters at the Geneva auto show.

Many Americans share similar memories of diesels as noisy, smoke-belching, smelly beasts only truck drivers would want.

A recent study by J.D. Power and Associates of 5,200 car buyers confirmed that most Americans have negative impressions diesels, contrary to the perception in Europe where diesels account for 40 percent of new passenger vehicle sales.

But the same study found that 40 percent of those Americans would consider buying a diesel engine car or truck after learning that today's diesels are not the loud and stinky engines of 20 to 30 years ago.

Diesel engines get about 25 percent to 40 percent better fuel economy than gasoline engines, and have more torque for quicker acceleration and better towing, which is why they are loved by U.S. heavy truck drivers. Diesel could also trim the U.S. dependence on foreign oil.

Though several automakers offer diesel engine trucks in the United States, Germany's Volkswagen AG is the only major automaker currently selling diesel engine cars.

Volkswagen's sales of diesels, available as an option on the New Beetle, Golf and Jetta, jumped 24 percent last year, but they still only totaled 31,220 units -- only about two of every thousand vehicles sold in the United States industry-wide.

CHEAPER RIDE

But with the popularity of diesels in Europe, where government tax incentives and the better fuel economy make diesel engines a much less expensive alternative to gasoline engines, some automakers are trying the technology in the United States.

"I think the American consumer is ready for diesel," said Jim Schroer, head of sales and marketing for the Chrysler Group, the U.S. arm of DaimlerChrysler AG .

DaimlerChrysler will launch two diesel vehicles in the U.S. market next year as an option on the Jeep Liberty sport utility vehicle and on the Mercedes E-Class luxury sedan.

DaimlerChrysler's Mercedes chief Juergen Hubbert said the German brand aims to offer more optional diesels engines in the future.

VW will soon also offer the a diesel engine option on its upscale Passat sedan, and other automakers are watching the market closely.

Ford has a fleet of Focus small cars with diesel engines that it is testing in the United States.

"I think we are seriously looking at diesel potential in the U.S.," said David Thursfield, the head of Ford's overseas operations. "There is a mindset in the U.S. that diesels are all tractor engines that clack away. That myth I think is exploding now. The diesel technology now is totally different than when GM tried to introduce diesel back in the 1980s."

GM, which rushed poorly engineered diesels to market more than 20 years ago in response to gas shortages, is considering more new generation diesels for fuel-thirsty sport utility vehicles, GM officials said. The brawny vehicles are under attack by environmentalists for excessive fuel consumption and greenhouse gas emissions.

NATURE'S CURE

But many environmentalists argue that diesel engines are not nature's cure. America's dirtier diesel fuel has rougly ten times as much acid rain-producing sulfur than European diesel fuel. Diesel engines also produce more nitrogen oxide, which creates ozone and can cause respiratory problems.

New U.S. regulations will make cleaner diesel fuel available in a few years, and "particle traps" under development could catch most of the dirty emissions from diesel engines before they are released into the air.

Economic hurdles also remain. Unlike in most of Europe, diesel and gasoline fuel is sold at nearly the same price in the United States. Americans could save money with diesel because they would use 25 to 40 percent less, but that would be offset by the higher costs of diesel engines, the automakers said.

And with the price of fuel up to three times as cheap in the United States than in parts of Europe, fuel economy is a low priority for many Americans.

J.D. Powers Walter McManus said that, as cleaner diesel engines become available over the next few years, diesel-powered vehicles could account for as much as 12 percent of U.S. new car and truck sales by around 2007, he said.

But once Americans drive or ride in a modern diesel engine car, they'll find out how quiet they are now, McManus said. That should make automakers, and kids growing up in New Jersey, sleep easier.

Quick Facts About Diesel Power & Applications

SOURCE: http://www.dieselforum.org/didyouknow/dieselpower.html

DID YOU KNOW...

- Diesel powers almost two-thirds of all **farm** machinery.
- Over 95% of the nation's full-sized **transit buses** are powered by diesel.
- Approximately 60% of American students travel to **school** on diesel-powered buses.
- Diesel power is the workhorse of the nation's **railroads**.

- Without diesel power, the nation would have to spend $300 billion to electrify merely the most heavily used portions of the **railroad** network.
- More than 14 million children will rely on diesel-powered **buses** to transport them safely and reliably to **school**.
- Diesel-powered **trucks, trains, barges and boats** will on average, move more that 18 million tons of freight every day.
- More than 14 million people will board a diesel-powered **transit bus** to get to their jobs in cities around the country each day.
- Diesel powers **emergency stand-by generators** for hospitals and telecommunications networks, and helps utilities meet peak power demands.

- 50% of light-heavy and 91% of heavy-heavy **trucks** are diesel.
- 85% of **trucks** operated over 75,000 miles per year are diesel.
- 66% of **trucks** having typical trip lengths of 501 miles or more are diesel.
- Railroads operate approximately 20,000 diesel **locomotives**.
- Over 95% of all **emergency vehicles** in use today - fire engines, rescue squads and ambulances - are powered by diesel engines.

- 72% of the energy used in the surface **mining of coal** is diesel
- Without diesel, **rail transportation** costs would increase by 48%, trucking costs by 56%.
- 85% of the energy used in **drilling oil and gas wells** is diesel.
- The increased use of mechanized **farm equipment**, most of which is powered by diesel, is one of the reasons for increased farm productivity.
- Diesel powers all major **aircraft tugs** and major services of the **Air Force**.
- Diesel engines provide vital power to the nation's **defense** system.

Source: "Diesel Technology and the American Economy" October, 2000 Charles River Associates

Diesel Days

SOURCE: http://www.embarq.org/events/diesel.htm

Introduction

On January 16-17, 2003, the World Resources Institute (WRI), and the World Bank, through its Clean Air Initiative, organized "Diesel Days" to discuss emission control options for diesel vehicles in cities.

Diesel engines are used extensively in transportation, especially in public transportation and heavy-duty applications due to their power, durability, and efficiency, can be significant sources of air pollution. However, diesel combustion is a significant source of urban air pollution (e.g., fine particulates) that is harmful to human health --- action is needed to reduce the negative impacts of the existing diesel vehicle fleet.

The first day, at WRI, focused on what can be done with diesel exhaust and emissions in large urban areas, and the potential for cleaner technologies and fuels.

For further information please contact Lee Schipper at schipper@wri.org.

The second day, at the World Bank, aimed to respond to issues and challenges that developing countries face in addressing emissions from in-use diesel vehicles and to provide a broader perspective of the different policy and technical options within which solutions can be found. The agenda, participants list, key proceedings and publications can be found by clicking on Diesel Day 2 "Reducing Emissions from In-Use Diesel

Vehicles in Developing Country Cities: Challenges, Opportunities, and Costs." For further information on Diesel Day 2 please contact Jitu Shah and/or Paul Procee at jshah@worldbank.org and/or pprocee@worldbank.org.

From Wells to Wellness: Why the Concern About Diesel Emissions in Urban Areas? What to Do?

Background: Diesel fuel accounts for around 40% of all road fuels worldwide and roughly 25% of that burned in urban areas. In France, diesel, fueling nearly 1/3 of all motorcars and virtually all trucks, has surpassed gasoline as the dominant energy source transport. While the role of diesel as an efficient fuel has been questioned for automobiles in Europe, it certainly is the case for heavy vehicles that diesel occupies a position challenged only by compressed natural gas in a few markets for urban buses.

Yet there are danger signs about the health effects of diesel exhaust and diesel's contribution to local air pollution, and this concern has been paramount in the US, particularly in California. Recent studies also show that black carbon emitted by diesel engines and other combustion sources may also be contributing to global warming. Fuel producers and vehicle/engine manufacturers are reluctant to put too many resources into developing very advanced diesel propulsion in the face of major unresolved issues.

What can be done about diesel? What should be done? If diesel is indeed clean and acceptable, or can be made so, what can it deliver in terms of energy and emissions savings? Above all, what can be done to control and reduce diesel emissions in large urban areas, particularly those in developing countries where vehicle standards, culture of maintenance, and fuel quality are low? How pressing is the need?

Format, target group, and Objectives: The format of the Roundtable was a conversation – a series of short interventions – designed to motivate discussion. Invited interveners were asked to provide 10 minutes of background, giving their position on each subject. Discussion was guided towards identifying the key uncertainties in each area that affect both policy and technology development.

The target group was decision-makers in government and the private sector in developed and developing countries, World Bank project managers and specialists, and NGOs. Transport and environmental officials and experts from Mexico, Brazil, Peru, Chile, Thailand, Philippines, India, and China attended the WRI Day 1.

Results: There were three key messages from this meeting. First, clean diesel fuel is making its way into use in Europe and the U.S. "Clean" is a relative issue – use of compressed natural gas may release less particulate matter and possibly NOx, but experience says that costs more in investment and operation – fuel and maintenance. Neither diesel nor CNG (or alternatives) is "the answer". Local circumstances and costs dictate what is the best choice, or more likely mix.

Second, steady progress must be made in North American refineries to clean up diesel. This will ultimately raise diesel fuel prices by a few US cents/liter. Some clean diesel may have to be imported until US refineries are reconfigured. Indeed, there were strong suggestions that for fuel and greenhouse gas savings, countries without a large diesel fleet of light duty vehicles – the US for example – might reap greater savings by pushing for gasoline hybrids. In some locations, synthetic diesel fuel might provide a clean alternative until either conventional clean diesel or CNG is available.

In developing countries, advanced technologies and cleaner fuels also have an important role to play in reducing diesel emissions, but they will only be effective if proper maintenance, enforcement, and other related policy measures are addressed first. In other words, the factors that have made diesel vehicles highly polluting today will likely jeopardize the benefits of advanced fuels and vehicle technologies.

Third, clean diesel is not without uncertainties and liabilities, as discussed by regulators from the U.S. and California, public health officials, NGOs, and representatives from the fuel industries themselves. The most serious uncertainty is the production of black carbon particles through diesel combustion; these may also add to the greenhouse gas impacts of diesel combustion.

The most obvious liability of diesel technology is pollution from older vehicles, from untuned engines, poor driving, and poor quality diesel fuel. These issues were the subject of Diesel Day 2.

Europe's Carmakers Sticking With Diesel

SOURCE: http://www.greendieseltechnology.com/pt_news177.html

(Source: Mark Landler, **The New York Times**, March 8, 2003)

GENEVA, March 5 — Chalk it up to the widening gap in the way Europeans and Americans look at the world.

Last week, General Motors brought its prototype of a hydrogen-powered car to the Geneva International Motor Show. The futuristic car, known as the Hy-Wire, had just gotten a nice lift from President Bush, who was photographed admiring it after announcing that the government would put $1.7 billion into researching hydrogen as a replacement for gasoline.

In the salons of Geneva, however, the Hy-Wire sat forlornly next to a prototype of a monstrous Cadillac with a 16-cylinder engine. The crowds all but ignored the car, preferring to swarm around the latest Mini, which is made by the plucky English carmaker owned by BMW of Germany.

What was the attraction? The new Mini has a diesel engine.

To be fair, the Mini is rolling out this summer, while the Hy-Wire is merely a twinkle in the eye of automotive engineers. That difference helps to explain why the European auto executives in Geneva seemed notably less dazzled by the hydrogen future than did their American counterparts.

The Europeans produce millions of diesel passenger cars, which they say deliver many of the economic and environmental benefits that hydrogen or hybrid engines will not deliver for at least a decade.

''Why do we talk about hydrogen so much when the experts all agree we already have a good technology?'' said Jens Neumann, the head of strategy and North American operations for Volkswagen.

About 40 percent of the VW cars sold in Europe use a diesel technology called turbo direct injection, which Mr. Neumann says is cleaner and more fuel efficient than traditional diesel engines.

It also offers better driving performance than comparable gasoline engines, which may come as a revelation to many Americans who think of diesel cars as noisy, smoky machines with the agility of a tractor.

VW sells turbo-diesel versions of its Golf, Beetle and Jetta models in the United States, and plans to introduce a diesel Passat sedan. Mr. Neumann said he believed that the proliferation of $2-a-gallon gasoline would help Volkswagen surmount the distaste of Americans for diesel cars.

''You can drive a Beetle from New York to Chicago with one fill-up, which is an exciting thing,'' he said.

European auto executives do not dispute the long-term potential of hydrogen as a replacement for gasoline. BMW, Mercedes-Benz and others have experimented with fuel cells and hybrid engines.

But they are skeptical of the sudden halo of publicity surrounding what they view as a science project. Some executives suggest that Detroit is seizing on hydrogen to avoid the most obvious way to make its vehicles more fuel efficient and environmentally friendly: build them smaller.

''People think this is just playing with the problem until the politicians in the United States have the courage to tax gasoline, which would shift demand to smaller cars,'' said Garel Rhys, director of the automotive industry research institute at Cardiff University in Wales.

At the moment, diesel fuel costs slightly more than gasoline in the United States. In Europe, it is generally cheaper. This deprives European carmakers of one of their major selling points for diesel in the United States.

Diesel faces other hurdles in the American market, not the least of which are environmental regulations. The United States limits the amount of particulates an exhaust system can emit. In 2007, the Environmental Protection Agency plans to tighten those limits greatly.

Critics of diesel, in Europe and the United States, say it emits more particulates than gasoline. But while the campaign against diesel in Europe has failed to catch on, carmakers here know they must make their engines cleaner to comply with the coming American regulations.

Engineers are working to fit engines with filters to screen out many of these particulates. It is an expensive process, however, that can add $2,000 to the sticker price. Diesel cars already cost more than gas-powered cars -- a disparity that is offset in Europe by the cheaper fuel.

Mercedes plans to introduce a diesel version of its popular E-class sedan in the United States next year. A spokesman acknowledged that pricing the car would be tricky, given the cost of the fuel.

''We know that customer acceptance of diesel in the U.S. is very low,'' said the spokesman, Johannes Reifenrath. ''If we want to help build acceptance, we should want to help the price.''

The situation in Europe could not be more different. More than 40 percent of all cars sold here have diesel engines. In France, the number is above 60 percent, and in Austria, 70 percent. Carmakers without a diesel in their lineup are severely constrained in terms of growth prospects.

Mini, the British maker of pint-size cars, has been a marketing triumph under BMW. But when the parent company's head of marketing, Michael Ganal, rolled out the new Mini One D to a charmed crowd in Geneva, he made it sound essential to Mini's survival in Europe.

Despite the obsession with diesel, BMW is determined to be a pioneer in hydrogen cars as well. Its emphasis, however, is on technologies that can be brought to the market as soon as possible.

The Munich-based company has built a version of its luxury 7-series sedan with an internal combustion engine that runs on liquid hydrogen or gasoline. G.M.'s Hy-Wire, by contrast, uses fuel cells that convert compressed hydrogen into electricity to power an electric engine.

Because the BMW can be filled up at regular gas stations, the company says it may be commercially viable by the end of the decade. Many experts believe that fuel-cell cars will not be widely available until 2020.

''We're not talking about the distant future,'' a BMW spokesman, Daniel Kammerer, said. ''We're talking about producing a hydrogen car within the life cycle of the current 7-series.''

XVII. Appendix F- Ethanol References

Ethanol Information

SOURCE: http://www.ethanol.org/Information/ethanol_information.htm

Ethanol Information
Consumer Benefits

- U. S. consumers use more than 18 billion gallons of high performance, cleaner burning ethanol-blended gasoline each year.
- Ethanol increases oxygenate supplies, reducing the need for MTBE imports and helping to reduce consumer costs.
- Ethanol is a high-octane blending component used by many gasoline marketers -- helping to keep this important class of trade viable and creating competition for the major oil companies.
- Since the petroleum refining industry is running at near capacity, the ethanol industry helps extend our petroleum supply, thereby helping moderate fuels costs to consumers.

Taxpayer Benefits

- The partial excise tax exemption for ethanol and ETBE blends available to gasoline marketers saves money. A General Accounting Office (GAO) study has shown that reduced farm program costs and increased income tax revenues offset the cost of the incentive.
- The economic activity attributable to the ethanol industry will generate $3.5 billion in additional income tax revenue over the next five years -- $1 billion more than the cost of the exemption. The U. S. ethanol industry will create a net gain to the taxpayers of almost $4 billion over the next five years.

Economic Benefits

- More than $3 billion has been invested in 60 ethanol production facilities operating in 20 different states across the country.
- The ethanol industry is responsible for more than 40,000 direct and indirect jobs, creating more than $1.3 billion in increased household income annually, and more than $12.6 billion over the next five years.
- The ethanol industry directly and indirectly adds more than $6 billion to the American economy each year.
- The demand for grain created by ethanol production increases net farm income more than $12 billion annually.
- As the economic activity created by the ethanol industry ripples throughout the economy, it generated $30 billion in final demand between 1996 and 2000.

- Increases in ethanol production offer enormous potential for economic growth in small rural communities. USDA has estimated that a 100 million gallon ethanol plant could create 2,250 local jobs.

Agricultural Benefits

- Industrial corn use, which includes ethanol and sweetener production, is now the second largest consumer of corn in America. Each $1 of up-stream and on-farm economic activity generates $3.20 in downstream economic stimulus attributable to ethanol processing, compared to just $0.31 when corn is exported.
- Ethanol production consumed 535 million bushels of corn in 1994 (5.3% of the record 10 billion bushel corn crop). About 667 million bushels of corn were used for ethanol in 2001.
- The demand for corn created by the ethanol industry increases crop values -- accounting for approximately $0.14 of the value of every bushel of corn sold, or $ 1.4 billion.
- If the market for ethanol did not exist, corn stocks would rise and net income to American corn farmers would be reduced by $6 billion over the next five years, or about 11 %.
- Many farmers now own and operate ethanol plants, allowing them to add value to their own corn.

Energy / Trade Benefits

- Domestic ethanol production reduces demand for imported oil and imported MTBE which drains our economy - oil and MTBE imports now represent almost 80% of the U.S. trade deficit.
- Currently, imported oil accounts for about 56% of oil used, and imported MTBE is at a record 31% of domestic production.
- Today, ethanol reduces the demand for gasoline and MTBE imports by 98,000 barrels per day. A 98,000 barrel/day replacement of imported MTBE would represent a $1.1 billion reduction to our annual trade deficit.
- Ethanol production also generates exports of feed co-products, such as corn gluten, further enhancing our balance of trade.
- Ethanol production is extremely energy efficient, with a positive energy balance of 125%, compared to 85% for gasoline. Ethanol production is by far the most efficient method of producing liquid transportation fuels. According to USDA, each Btu used to produce a Btu of gasoline could be used to produce 8 Btus of ethanol.

Environmental Benefits

- 10-percent ethanol blends reduce carbon monoxide better than any other reformulated gasoline blend -- more than 25%.
- Ethanol is low in reactivity and high in oxygen content, making it an effective tool in reducing ozone pollution.
- Ethanol is a safe replacement for toxic octane enhancers in gasoline such as benzene, toluene and xylene.

- Oil companies are now starting to acknowledge the environmental and energy benefits of ethanol. For example, see the brochure published by Mobil which is available to download below.

Kyoto Commitment Holds Promise for Ethanol

SOURCE: http://www.greenfuels.org/ethindex.html

Kyoto Commitment Holds Promise for Ethanol

The Prime Minister's recent declaration at the Johannesburg Summit on Sustainability that he intends to ratify the Kyoto protocol can only be good news for ethanol. "Support for ethanol as been building in Ottawa and around the country for the past two years and ratification will only boost that support further," said CRFA Chair Robert Sicard.

Department officials from Natural Resources Canada and Environment Canada have been working throughout the summer on an ethanol mandate and dealing with the many complicated issues that would confront the government should the Minister go forward with his plans to have ethanol in all gasoline. It is still unclear what form a mandate may take, but ethanol is clearly on the minds of Ministers and the Prime Minister's Office when discussing Kyoto and green house gas reductions. The Ottawa citizen reported this spring that Minister Dhaliwal was "seriously considering a law that would force oil companies to mix the plant-based fuel ethanol into motor vehicle gasoline as a way to cut green house gases under the Kyoto protocol." Under the recently announced Climate Change discussion paper, Ottawa has proposed a 5% and 10% mandate for ethanol in Canada.

With respect to timing, it is expected that the federal government will provide a "plan" to meet its Kyoto target some time in late October prior to the next round of climate change discussions known as CoP8.

While momentum continues to build for ethanol it is very important that people evidence their support to the government. If you wish to express your support for ethanol and Minister Dhaliwal's proposed mandate please click on the icon below and send a message to the Prime Minister.

CRFA Launches Ad Campaign to Promote Ethanol

The CRFA launched their climate change ad campaign on September 16 with a series of bus shelter ads promoting the benefits of ethanol. The bus shelter ads promote ethanol's climate change and green house gas benefits and will be initially located along Wellington Street facing Parliament Hill. The campaign will also launch a series of newspaper ads beginning with the Hill Times in Ottawa later this month that will focus on the many benefits of developing an ethanol industry in Canada. The bus shelter ad featured above will almost certainly get the attention of a few MPs when the House resume sitting at the end of September!

Ethanol Glance

SOURCE: The Associated Press

By The Associated Press, The Associated Press
Published June 1, 2003

A look at ethanol as a gasoline additive:

An ethyl alcohol made from fermenting and distilling starches from corn and other crops. Used for wide range of purposes from a gasoline additive to making beer and whiskey.

Today, 90 percent of ethanol used in gasoline comes from corn. Researchers hope in the future it can be processed from cellulose biomass (grasses and various plant waste).

2.13 billion gallons were made last year, mainly in five states - Illinois, Iowa, Nebraska, Minnesota and Indiana. One bushel of corn yields 2.5 gallons of ethanol.

Ethanol is more expensive to produce and transport than gasoline, but benefits from a 53-cents a gallon tax credit to make it competitive. Critics contend ethanol supply problems could cause higher gas prices if the fuel is mandated.

Reduces carbon monoxide and toxic chemical emissions from tailpipes. But evaporates more easily, adding to smog problem. May make it harder to deal with gasoline spills in groundwater. Modest reductions in emissions of greenhouse gases.

Some scientists say more energy from fossil fuels is used to make ethanol than it replaces. The ethanol industry cites studies showing for every 23.8 gallons ethanol in gasoline, 1 barrel of oil will not be needed.

Ethanol Facts

SOURCE: http://www.iowacorn.org/ef.htm

Economy

The U.S. ethanol industry has grown to over 2.3 billion gallons of production capacity, with plants located in 19 states.

Ethanol reduces the consumer cost of gasoline by extending supplies, providing an alternative to costly imported oil and leverage for independent gasoline marketers to compete against the larger, more powerful integrated oil companies.

Increased production and use of renewable fuels would create an additional $71.1 billion in household income over the next 15 years.

Increased use of renewable fuels, such as ethanol, could provide an additional $6.6 billion of net cash income annually for America's farmers over the next 15 years.

Consumers could save approximately $7.8 billion between 2002 and 2016 in the form of reduced government farm payments by expanding their purchases of renewable fuels.

Over the next 15 years, 300,000 new jobs could be created through expanded production and use of renewable ethanol blends.

Ethanol production provides more than 200,000 U.S. jobs, spurring growth in many rural areas.

More than 13,250 Iowa jobs are affected by ethanol, including 2,550 directly related to ethanol production.

The ethanol tax incentive is crucial to farmers' bottom lines. Ethanol production helps boost U.S. farm income by $4.5 billion.

A healthy demand for ethanol could add up to 30 cents to the value of every bushel of corn grown.

The benefits of the ethanol tax credit extend far beyond ethanol producers and blenders. Clean air, new jobs, increased farm income, rural economic development, lower fuel costs and reduced U.S. dependence upon foreign oil are good for ALL Americans.

Ethanol contributes more than $2 billion annually to the U.S. trade balance.

Ethanol production generates increased economic activity that boosts tax receipts in farm states. These revenues more than offset the cost of the tax exemption, and actually resulted in a net savings of $3.6 billion to the federal budget annually.

Nearly 200 million bushels of Iowa corn are processed annually into ethanol.

In 2001, approximately 1.7 billion gallons of ethanol were produced nationwide. This value-added processing required 680 million bushels of corn.

Performance

Ethanol is the only environmentally-friendly, renewable fuel available for use in fuel cells. In fuel reformers, which convert ethanol and other hydrocarbons to hydrogen, ethanol has demonstrated fewer emissions, higher efficiencies and better performance. Only gasoline and ethanol are available nationwide for fuel cell use and won't require

extensive infrastructure investments. Unlike gasoline, however, ethanol is domestic, renewable and easier to reform in a fuel cell.
E diesel, a blend of up 15% ethanol, 5% blending additive, and at least 80% diesel is being developed. Testing to date has proven that E diesel can lower particulate emissions by 20-30%, reduce sulfur content, and out-perform No. 2 diesel fuel in winter conditions, all without mechanical changes or problems. Additional research is underway to move E diesel toward commercialization.

E-85 as an alternative fuel is growing. Auto manufacturers are working to produce more flexible fuel vehicles (FFVs) capable of operating on E-85 fuel (a blend of 85% ethanol and 15% unleaded gasoline). There are more than one million FFVs currently on America's roadways. DaimlerChrysler, Ford and General Motors provide the flexible fuel engine as standard on several models, including mid-size cars, minivans and trucks. By 2002, even SUVs will be able to use E-85. The number of E-85 fueling stations is also rapidly growing nationwide.

A 10% ethanol-blended fuel is warranted for use by ALL auto manufacturers marketing vehicles in the U.S.

Ethanol guards against gas line freeze by absorbing moisture that may get in the tank during cold weather.

Ethanol is a proven octane enhancer and replacement for lead and other toxic compounds in gasoline.

The blending of 10% ethanol boosts the octane rating of gasoline by an average of three points.

Many auto manufacturers, including General Motors and Chrysler, even recommend the use of oxygenated fuels, such as ethanol, in their vehicles. Click here for Auto Manufacturer's Recommendations.

Ethanol has been important to the state's economy since it was introduced in Iowa in 1978, at five farm cooperatives.

Nationally, since 1978, ethanol has provided motorists with more than two trillion road miles of satisfactory performance. Today, ethanol blends account for 12% of all motor fuels sold in the U.S.

Ethanol-blended fuels are approved for use in small engines too – including outboard motors, snowmobiles, lawn mowers, motorcycles and chain saws. All small-engine manufacturers that have tested a 10% ethanol blend have approved its use. Click here for Small Engine Manufacturer's Recommendations.

Environment

Ethanol reduces particulate emissions, especially fine-particulates that pose a health threat to children, senior citizens, and those with respiratory ailments.
Ethanol is widely used in the federal winter oxygenated fuels program and the reformulated gasoline (RFG) program in cities that exceed public health standards for carbon monoxide and ozone pollution.

Ethanol is the safest component in gasoline today. A recent study by the Governors' Ethanol Coalition concluded that ethanol poses no threat to surface or ground water. Since ethanol is a naturally-occurring substance produced during the fermentation of organic matter, it is expected to rapidly biodegrade in essentially all environments.

Ethanol, a renewable fuel made from agricultural feedstocks, is one of the best tools we have to fight air pollution.

According to a January 1998 study by the Argonne National Laboratory, vehicles that use ethanol actually help offset fossil fuel's "greenhouse gas emissions," which contribute to global warming, by 35-46 percent.

Ethanol lowers harmful carbon monoxide (CO) emissions by 30 percent.

Ethanol reduces carbon dioxide (CO2) emissions by 27 percent.

The U.S. Environmental Protection Agency (EPA) credits reformulated gasolines (that contain ethanol) with reducing and controlling hazardous emissions which threaten air quality in many of America's cities.

Today, more than one-third of the nation's gasoline contains some level of oxygenates (such as ethanol), in order to reduce harmful emissions and improve our nation's air quality.

The use of clean-burning ethanol reduces the amount of noxious fumes and volatile organic compounds (VOCs) that standard gasoline spews into the air. Those VOCs eventually clog our lungs.

Energy Security

Oil imports are now about 60% of total transportation fuel use. The Energy Information Agency is projecting that amount to increase to 70% by 2016.

The U.S. spends roughly $50 billion each year for military protection of Mideast oil.
Increasing the use of renewable fuels in motor vehicle use could displace 302 million barrels of crude oil by 2016.

A minimum renewable fuel requirement could replace 2.9 billion barrels of imported crude oil with domestic, renewable ethanol. This reduction in oil imports would lower the U.S. trade deficit by $63.4 billion over the next 15 years.

Ethanol contains 34% more energy than is used in the production process, including the energy used to grow, harvest and process corn into ethanol. By comparison, ExxonMobil states, "gasoline based fuels retain about 85% of the energy originally contained in the crude oil."

According to the Government Accounting Office, the U.S. has spent more than $130 billion over the last 32 years in government subsidies to the oil industry.

Tripling ethanol use could replace 600,000 barrels of crude oil daily, which is equivalent to the amount imported from Iraq each day.

Ethanol – from Iowa and American corn growers – reduces our demand for imported oil by nearly 128,000 barrels each day.

About 80 percent of the world's proven oil reserves are in the perennially unstable Middle East. Prominent defense and intelligence experts recently stated: "While sitting on only three percent of the world's reserves – yet using 25 percent of the world's oil – nothing could be more short-sighted than for Americans to abandon the incentives for producing transportation fuel from sustainable sources."

One acre of corn can produce 300 gallons of ethanol – enough to fuel four cars for one year with a 10% ethanol-blend.

One less barrel of imported oil is needed for every 28.3 gallons of ethanol used.

According to a 1998 study conducted by the Argonne National Laboratory, the use of corn-based ethanol results in 50-60 percent reductions in fossil energy use.

Renewable ethanol is extremely energy-efficient. Every 100 BTUs of energy used to produce ethanol (including planting, cultivating, harvesting and processing) yield 135 BTUs of ethanol. By comparison, the same 100 BTUs of energy yield only 85 BTUs of gasoline or 55 BTUs of methanol.

Ethanol Facts for Iowa

Ethanol production keeps Iowa's economy on the grow – generating more than $3.4 billion in economic activity and adding 30-35 cents to the value of every bushel of corn.

Ethanol demand boosts Iowa's state and local tax receipts by $111 million – the biggest increase of the Top 10 corn-growing states.

Iowa has the processing capacity to manufacture 480 million gallons of ethanol.

In 2001, 825 million gallons of ethanol-blended fuel were sold in Iowa, a 46-million-gallon increase over the previous year.

One bushel of corn can produce at least 2.5 gallons of ethanol.

57 percent of all gasoline sold in Iowa is a 10% ethanol-blend.

Research Plans – Ethanol from Biomass

SOURCE: http://www.energy.ca.gov/pier/renew/ethanol/ethanol.html
Renewable Energy Technologies

Research Plans - Biomass

A. OVERVIEW OF BIOMASS TO ETHANOL

Ethanol, with the chemical formula, CH3CH2OH, can be produced by chemical synthesis through direct hydration of ethylene (ethylene derived from petroleum), or by biological fermentation using microorganisms. Production of ethanol has been limited to using sources of soluble sugar or starch, primarily in the Midwest, U.S. using corn. Ethanol production grew from 175 million gallons in 1980 to 1.4 billion gallons in 1998, with support from Federal and state ethanol tax subsidies and the mandated use of high-oxygen gasoline. Currently, over 1.5 billion gallons of ethanol is produced in the US. California ethanol production is limited, a modest amount of 6 million gallons per year from food processing wastes and other liquid products, such as cheese whey. Demand for ethanol could increase further if methyl tertiary butyl ether (MTBE) is eliminated from gasoline. In March 1999, Governor Gray Davis announced the phase out of the use of MTBE in gasoline by 2002 in California, which uses 25 percent of the global production of MTBE. It is unclear, however, whether the U.S. Congress will eliminate the minimum oxygen requirement in reformulated gasoline (RFG), an action that would reduce the need for ethanol. If the oxygen requirement is eliminated, ethanol will still be as valuable as an octane booster and could make up some of the lost MTBE volume.

Extending the volume of conventional gasoline is a significant end use for ethanol, as is its use as an oxygenate. To succeed in these markets, the cost of ethanol must be close to the wholesale price of gasoline, currently made possible by the Federal ethanol subsidy. However, the subsidy is due to expire in 2007, and although the incentive has been extended in the past, in order for ethanol to compete on its own merits the cost of producing it must be reduced substantially. The production of ethanol from corn is a mature technology that is not likely to see significant reduction in production costs. Substantial reductions must be possible, however, if lignocellulosic-based feedstocks are used instead of corn. The ability to produce ethanol from low-cost biomass will be key to making ethanol competitive with gasoline. In addition, if an ethanol production system was co-located with biomass power plant certain synergies could occur. In particular, lignin from the ethanol plant could be utilized by the power plant, while steam and electricity from the power plant could be utilized by the ethanol facility. Also, it is likely that the ethanol plant could utilize other existing utilities at the biomass power plant, such as sewage handling, cooling water and other buildings. It is also likely that the ethanol Although lignocellulosic feedstock are less expensive than corn, today they are more costly to convert to ethanol because of extensive processing required.

B. ETHANOL PRODUCTION FROM LIGNO-CELLULOSIC CONVERSION TECHNOLOGIES

Cellulosic biomass is a complex mixture of carbohydrate polymers known as cellulose, hemi-cellulose, lignin, and a small of amount of compounds known as extractives. Examples of cellulosic biomass include agricultural and forestry residues, municipal solid waste (MSW), herbaceous and woody plants, and underused standing forests. Cellulose is composed of glucose molecules bonded together in long chains that form a crystalline structure. Cellulose is a fibrous, tough, water-insoluble substance. Hemi-cellulose is not soluble in water. It is a mixture of polymers made up from xylose, mannose, galactose, or arabinose. Hemi-cellulose is much less stable than cellulose. Lignin is a complex aromatic polymer of phenylpropane building blocks. Lignin is resistant to biological degradation.

For production of ethanol, the cellulosic feedstock is first pretreated to convert hemi-cellulose into soluble sugars such as xylose sugars. The cellulose fraction is hydrolyzed by acids or enzymes to produce glucose, which is subsequently fermented to ethanol. The soluble xylose sugars derived from hemi-cellulose are also fermented to ethanol. Lignin, which cannot be fermented into ethanol, can be used as fuel to produce heat or electricity. There are many pathways to produce ethanol using cellulosic feedstock. The general processes from cellulosic feedstock to ethanol are described in Figure 1.

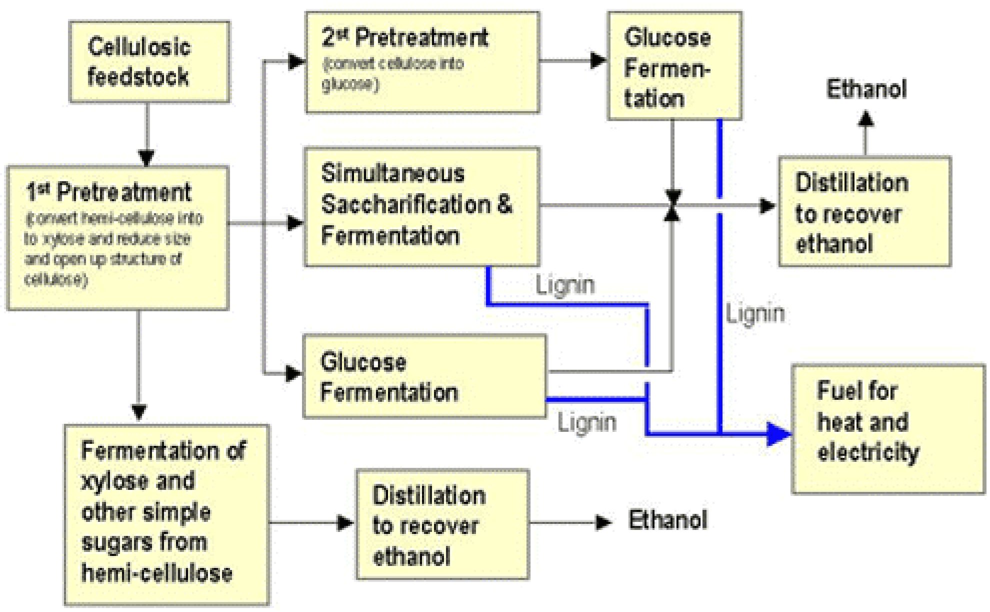


Figure 1. General Pathways for Ethanol Fermentation from Cellulosic Feedstock

C. GENERAL PATHWAYS FOR ETHANOL PRODUCTION FORM CELLULOSIC FEEDSTOCK

1. Enzymatic Hydrolysis

Enzymatic hydrolysis; simultaneous saccharification and co-fermentation (SSCF): The steps in the conversion of cellulosic materials to ethanol in processes featuring enzymatic hydrolysis includes pretreatment, biological conversion, product recovery, and utilities and waste treatment. SSCF is an adaptation to the process, which combines hydrolysis and fermentation in one vessel. Sugars produced during hydrolysis are immediately fermented into ethanol. By fermenting the sugars as soon as they form, eliminates problems associated with sugar accumulation and enzyme inhibition.

2. Dilute Acid Hydrolysis

Dilute acid hydrolysis: This process uses low concentration acids and high temperatures to process the cellulosic biomass. Lignocellulose biomass is pretreated with approximately 0.5% acid in liquid at up to 200ºC to hydrolyze the hemicellulose and expose the cellulose for hydrolysis. The hemicellulose hydrolysis yields most pentose (C5) sugars, principally xylose and arabinose, which are fermented to ethanol and distilled. The remaining solids, cellulose and lignin, enter the second stage hydrolyzer where cellulose is converted to glucose with approximately 2% acid in liquid at up to 240º C. The resulting sugars are then fermented to ethanol and distilled.

3. Concentrated Acid Hydrolysis

Concentrated acid hydrolysis: This process uses high concentration halogen acids and near ambient temperatures to convert cellulosic biomass to sugars. The decrystalization and hydrolysis of cellulose with nearly 100% yields may be accomplished with 40 wt% hydrochloric acid, 60 wt% sulfuric acid, or 90 wt% hydrofluoric acid. The liquid phase hydrochloric acid process is the only halogen process to have reached commercial development.

The feedstock is pretreated with approximately 10 wt% acid liquid stream which is recycled from cellulose hydrolysis. Pretreatment hydrolyzes the hemicellulose into C5 and C6 sugars and exposes the cellulose for hydrolysis. The subsequent liquid acid and sugar stream is separated from the solids, neutralized, fermented and distilled. The solids mostly cellulose and lignin, enter the second stage hydrolyzer and are mixed with 40-90 wt% acid (the concentration depends on acid type). Cellulose is converted into C6 glucose sugars. After another liquid-solid separation step, the liquid containing about 10% acid and 10% glucose is recycled to the hemicellulose hydrolysis / pretreatment vessel. The remaining solids are washed, dried and used as fuel source for power production.

4. Biomass Gasification and Fermentation

D. EXISTING R&D STATUS ON CELLULOSIC BIOMASS TO ETHANOL

The technology behind converting cellulosic biomass to ethanol has yet to pass the most important test of being demonstrated in a commercially viable facility. Despite there being many different technologies available i.e.: dilute acid, concentrated acid, enzyme based hydrolysis, none are in use in a commercial facility in the United States. There are many plans for future facilities at sites all over the United States and Canada, some much more viable than others.

In North America there are seven facilities that we at the California Energy Commission found to be in various stages of planning and or construction. These are listed in the table below.

Site Location	Developer	Feedstock
Sacramento, CA	Arkenol	Agricultural residue
Mission Viejo, CA	Arkenol	Cellulosic biomass
Jennings, LA	Collins Pine, BCI	Wood waste
Gridley, CA	BCI	Rice Straw/Wood waste
Middletown, NY	Masada	Cellulosic biomass
Ottawa, Canada	IOGEN	Cellulosic biomass

The Sacramento (actually Rio Linda, slightly to the north), CA were in the planning stages and have now been abandoned. It is unclear whether Arkenol still owns the site or if it has changed hands, but the important permits that were granted for the site have expired. The site was planned as a joint operation with SMUD (Sacramento Municipal Utilities District) that would use rice straw and other local agricultural residues as feedstock for a 20-MM gal/yr. biomass to ethanol facility.

Arkenol also owns the cellulosic biomass to ethanol facility in Mission Viejo and it is also not a commercial facility. The facility is used as the pilot plant demonstrator of their proprietary hydrolysis and fermentation technology. The plant uses concentrated acid hydrolysis and unknown type of yeast in its fermentation facilities. The small scale (less than 100 gals/batch) of the plant has lead to the use of a batch process system rather than a continuous operating facility. It is also unclear whether or not the facility is still being used at this time.

The Jennings LA project is to determine the technical and economic feasibility of integrating a new biomass-to-ethanol production facility in Jennings LA with an existing biomass power plant, located Chester, California. If feasible, these two facilities would be operate together and become customers for each other's products. The planned facility In Chester, California is to be co-located with the wood waste burning thermal plant at their sawmill. The specifics of the hydrolysis and fermentation are yet to be determined as they are relying on the research being done in Jennings, LA to determine the feasibility of enzymatic or dilute acid hydrolysis. The sawmill in Chester shipped wood waste (forgest thinnings) to Jennings for testing and hydrolysis. So far, no information shows if the pilot tests on ethanol production using forest thinnings have been performed. A stop work order was issued by the California Energy Commission due to the lack of with regards to lack of deliverables due from Subcontractor. A critical project review meeting was held at the Commission on Dec. 20, 2001. The purpose of the meeting was to review the status of the Collins Pine project and the quality of work that had been conducted. The ultimate goal is to find a way to proceed with this project in a way that successfully accomplishes the original intention and objectives.

Gridley, CA project was initial planned to evaluate the technical and economic feasibility of a cellulase technology proved to be promising during the Gridley Phase I study using a feedstock mix consisting of 75000 bdt/yr of rice straw and 175000 bdt/yr of wood waste. By January 1999, it was concluded that the commercial readiness of cellulase enzyme and microorganisms remains a key technical issue. A decision was made by BCI to switch the cellulase technology to the two stage dilute acid hydrolysis process. It was concluded that production of fuel grade ethanol is viable after evaluation of various two-stage hydrolysis scenarios by BCI. It is unclear on current status of the BCI Gridley project.

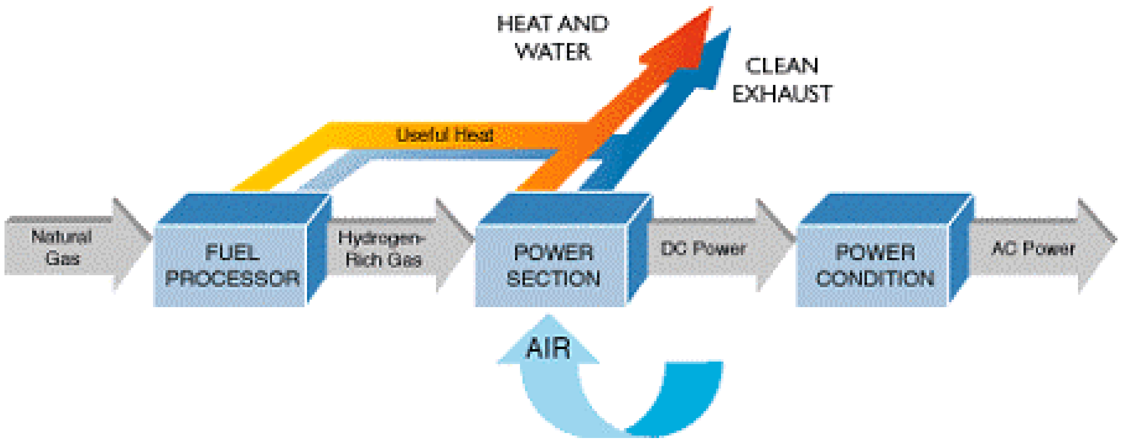
Masada Corporation is planning the cellulosic biomass to ethanol facility in Middletown, NY. Masada uses concentrated acid hydrolysis of MSW based cellulosic biomass then conventional fermentation for the ethanol portion of its comprehensive MSW mitigation package. The facility is planning on using MSW from several local municipalities and is currently under going environmental review and permitting by the local governments. This facility is still several years away from commercial ethanol production.

In Ottawa, Canada the company IOGEN has been pursuing enzymatic hydrolysis for 25 years. The ethanol production facility in Ottawa is co-located with IOGEN1s industrial enzyme production facility. The cellulosic biomass to ethanol facility is currently under construction and is nearing completion; IOGEN is reporting 3-6 months before plant is operational. The technology in use at IOGEN1s facility is steam explosion then enzymatic hydrolysis and a mix of yeast and microbes to ferment the different sugars. Microbes that will allow for SSCF are in testing, but not currently operational. The facility is expected to process approximately 40 tons per day of cellulosic biomass.

Ethanol is the Perfect Fuel for Fuel Cells

SOURCE: http://www.ilcorn.org/Ethanol/ethanol.html

A fuel cell is a device that can obtain 40 to 50% efficiency in conversion of a fuel into useable power (as opposed to approximately 18% efficiency for the average internal combustion engine). This technology is a by-product of the NASA space program, developed to provide a lightweight and efficient power source for use on manned space missions. Some fuel cells use specialized molecular sieves made of complex polymers with some type of anode/cathode properties , and others use expensive platinum catalysts. There are four main types available. Some use pure hydrogen as a fuel source to make electricity. Some are designed to run on propane, but may only have a membrane life expectancy of 3,000 hours (125 days). One of the main problems with any fuel cell is contamination of the membrane. So it seems like a great advantage, then, to use a fuel source which has been distilled and is 99.9999 % pure. The ideal fuel for a fuel cell is ethanol. Plus, this is a biologically derived fuel with no horrible byproducts.



The ideal fuel cell would use ethanol instead of natural gas

Ethanol Research notes**:**

Over the past several years, Arthur D. Little, with support from the Illinois Corn Marketing Board and other organizations, has developed a fuel processor that allows fuel cell powerplants to operate on ethanol. Ethanol used in transportation applications reduces oil dependence and results in lower emissions. Fuel cell applications are particularly desirable for ethanol because:

1. Fuel cells operate very efficiently compared with internal combustion engines, reducing the price gap between utilization of ethanol and cheap imported gasoline.

2. Hydrated ethanol (alcohol which still has some water content, not 200 proof) can be used in a fuel cell system with no loss in efficiency compared with 100 % high-grade ethanol, opening the way for the use of ethanol that can be used at a lower cost.

In a program conducted in 1996 for the ICMB, Arthur D. Little conducted a series of tests to demonstrate the use of hydrated ethanol in an advanced fuel processor. The results of this testing were successful and have been presented at prominent industry gatherings, including the 1996 Fuel Cell Seminar and the 1996 DOE Customer Coordination Meeting. This research is also the subject of a paper entitled, "Evaluation of Hydrated Ethanol in an Advanced Fuel Processor," which has already been accepted for publication and will be presented at The Society of Automotive Engineers Annual Conference in March, 1997. This technical work and publication effort has kept ethanol positioned as a desirable fuel cell vehicle fuel. In the meanwhile, fuel cell vehicle advancements have occurred in other programs at a very rapid pace.

The proposed program for 1997-2000 will continue to promote the use of ethanol in advanced fuel cell powerplants. Arthur D. Little will compete on a team for a $15 million, three-year, cost-shared DOE contract to develop a fuel cell powerplant capable of operating on multiple fuels. In Arthur D. Little's proposed program, ethanol has a visible and attractive role. The designs and tests conducted in this program will highlight ethanol's performance in a 50-kW fuel cell powerplant. By 2000, this powerplant--

capable of operating on both ethanol and ethanol blends--will be ready for integration into a prototype light-duty vehicle or hybrid bus. This program thus positions ethanol as a premier fuel for transportation powerplants of the 21st century.

IMPACT STATEMENT:

This program will demonstrate that ethanol--even low-cost hydrated ethanol--can be used in advanced fuel cell vehicles. Fuel cell buses operating on other fuels are already on the road. Under the Partnership for a New Generation of Vehicles, each of the Big Three is working on fuel cell passenger cars. By 2008, a fleet of 3,000 fuel cell buses and 5,000 fuel cell cars could consume about 18 million gallons of ethanol yearly.

Illinois Corn Marketing Board**:**

Breakthrough research sponsored by the Illinois Corn Marketing Board and the State of Illinois has opened the way for efficient, zero-pollution fuel cell cars and buses powered by ethanol. Fuel cells are up to three times as efficient as conventional vehicles and emit virtually no pollutants. Renewable ethanol made from corn can power these fuel cell vehicles using an ethanol fuel processor developed by Arthur D. Little, Inc., of Cambridge, MA. Ethanol is the ideal fuel for advanced fuel cell vehicles since it reduces oil imports and has fewer negative consequences for the environment than any other practical fuel alternative.

Background

In 1996, several stunning achievements in fuel cell vehicle technology were announced by major automakers. In May, Daimler-Benz unveiled its NeCar II, a second generation fuel cell powered van with a 200-mile range and five-passenger capacity. In October, Toyota showed a fuel cell vehicle based on the highly popular RAV4, a sport utility vehicle. Both companies have announced satisfaction with the progress of fuel cell technology, and both have publicly stated their intent to proceed toward a production decision for fuel cell vehicles. These vehicles are shown in Figure 1. **Automotive News,** the most authoritative (and technologically conservative) source in the industry, covered these developments with front page stories. Discussion in the automotive industry has turned from debate over the practicality of fuel cell vehicles toward a discussion of possible timetables for their introduction.

While the practicability of fuel cell technology has been demonstrated, the issue of which fuel these vehicles will operate on is still very much in flux. Fuel cells ultimately need hydrogen to operate. The Daimler and Toyota vehicles operate directly on hydrogen, which is an impractical transportation fuel for the near term. Daimler, Toyota, General Motors, and Georgetown University all have major programs underway to develop fuel cell powerplants that utilize methanol. The American Methanol Institute is a vocal advocate of methanol as a future fuel. Methanol is not a logical or appropriate fuel since no production or delivery infrastructure currently exists, and its use will not reduce dependence on foreign energy resources. In addition, methanol fuel cell vehicles cannot utilize ethanol.

Over the last several years, Arthur D. Little, with support from the Illinois Corn Marketing Board, the State of Illinois, and the Department of Energy, has worked to keep ethanol positioned as a viable fuel for fuel cell vehicles. In 1994/1995, this involved critical technology demonstrations and design developments that proved that ethanol can be effectively transformed into hydrogen on board a fuel cell vehicle. Figure 2 shows the resulting 50 kW multi-fuel reformer on its test stand. This fuel processor is more advanced and compact than any methanol fuel processor shown to date. Chrysler, General Motors, and Scania have shown keen interest in this design, and it will appear on a static show car in an upcoming North American auto show as a statement of one automaker's intent to build prototype fuel cell vehicles using the ADL reformer technology.

The successful development by Arthur D. Little of a multi-fuel reformer has significantly altered the discussion of fuel choice for fuel cell vehicles. Because it was designed to process ethanol denatured with gasoline, the multi-fuel reformer is also capable of processing straight gasoline. GM and Chrysler, supported by several oil companies, now advocate gasoline fuel cell vehicles as the best interim solution to more efficient, lower polluting vehicles. For ethanol interests, this is a mixed blessing. U.S. industry has become a strong advocate of this technology, resulting in greatly increased private and DOE resources directed toward the development of multi-fuel capable fuel cell powerplants. The bulk of DOE's fuel cell vehicle budget over the next three years (over $30 million) will be directed toward multi-fuel fuel cell powerplant development.

Commercialization of fuel cell vehicle technology can also occur much more rapidly using a widely available fuel such as gasoline since a national fuel infrastructure already exists. However, neither the auto companies nor the oil companies can be expected to highlight this basic fact: Any fuel processor capable of using gasoline can also be designed to utilize ethanol. Many technical aspects of ethanol fuel processing (such as carbon formation and sulfur trapping) are simpler with ethanol than with gasoline.

In 1996, Arthur D. Little continued to refine the multi-fuel fuel processor, working with major automotive companies to integrate this technology into advanced vehicle designs. Arthur D. Little (with support by the Illinois Corn Marketing Board) continued to advance the case for ethanol, a very desirable fuel for fuel cell vehicles. Our technical work program for 1996 was aimed at improving the cost associated with use of ethanol as a fuel cell fuel. We successfully operated our fuel processor on hydrated ethanol, demonstrating that a lower cost feedstock can be used. The successful results of this program have been presented in various public forums including the 1996 Fuel Cell Seminar. Appendix A includes a draft of a technical paper describing the results of our 1996 program to be presented to the Society of Automotive Engineers in March, 1997.

Objectives:

The objective of the proposed project is to ensure that ethanol remains among the most desirable fuels for fuel cell vehicles. In response to an announced solicitation, Arthur D. Little will team with a fuel cell supplier and in early 1997 submit a cost-shared proposal (for approximately $15 million) to DOE to develop a fuel cell powerplant for use in light- and medium-duty vehicles. DOE will require that this powerplant operate on gasoline. However, on behalf of the ethanol industry, we propose to add to our work plan specific design and demonstration tasks to assure that the powerplant developed in this program is fully compatible with ethanol. Specific objectives for ethanol include:

Form a competitive team (including Arthur D. Little, the Illinois Corn Marketing Board, other ethanol interests, a fuel cell developer, and other commercial companies) to successfully compete for a DOE contract for fuel cell powerplant development. Each participating organization, including Arthur D. Little, will be responsible for its own proposal preparation costs. No Illinois Corn Marketing Board funding is requested to achieve this objective.

Include design tasks in the proposed DOE work program to ensure that the powerplant that is developed is fully compatible with ethanol, ethanol blends, and hydrated ethanol.

Include explicit demonstration tasks in the proposed DOE work program to effectively demonstrate ethanol operability in the fuel cell powerplant.

Continue to underscore the positive role of ethanol in fuel cell vehicles in prestigious and visible technology and policy forums.

Procedures:

Specific tasks for the DOE fuel cell powerplant program will not be determined until DOE publishes a full RFP in mid-December, 1996. The full proposal will be submitted to DOE in early 1997. A copy of the completed Technical and Cost Proposals will be provided to the ICMB on request. As we develop the complete DOE Program Plan, we will include tasks consistent with the objectives described above.

Based on preliminary DOE program specifications, the following ethanol specific milestones can be anticipated in the ADL program plan:

The dissemination of results, is a vital step in maintaining ethanol's position as a premier alternative fuel. As shown in Table 1, there are a variety of stakeholders with different influences on the use of ethanol in transportation.

Table 1: Hydrated Ethanol Results Dissemination

Stakeholder	**Role**	**Message**	**Forum**
Ethanol interests including states and producers	Encourage expanded ethanol utilization	Ethanol can be a premium fuel in advanced transportation applications	Governors' Ethanol Conference
Department of Energy / Department of Transportation	Ford ethanol research and demonstrations	Ethanol is a fuel with future vision. Ethanol used in fuel cells is superior to methanol and hydrogen on an economic and technical basis.	DOE Contractors' Meeting

OEMs (Chrysler, Ford, Transit Bus Manufacturers)	Build ethanol vehicles	Ethanol can be used economically in advanced vehicles. Continued investments in ethanol vehicle technology are desirable.	SAE
Fuel Cell Technology Community	Develop advanced powerplants	Ethanol is the preferred fuel for fuel cell powerplants.	Fuel Cell Seminar, Private Briefings

There are a wide variety of forums which are appropriate to disseminating the results of this work. These forums can be selected to influence all of the stakeholders listed above. Example forums are shown above. Written papers submitted for technical meetings such as SAE and Fuel Cell Seminars can also be distributed for further impact.

Arthur D. Little's interest in dissemination of results runs parallel to the Illinois Corn Marketing Board's wishes to be seen as the premier developer of advanced fuel cell technologies. Therefore, our commitment to discussion of this promising development is quite strong. This effort is supportive of our ongoing fuel cell power system business development efforts. Therefore, much of the anticipated cost of dissemination of results will be borne by Arthur D. Little. Our costs shown are primarily for document preparation and production. Costs for attendance at conferences and meetings will be primarily borne by Arthur D. Little.

Justification:

The proposed contributions to this program by the Illinois Corn Marketing Board will ensure a more effective DOE powerplant development program in three ways:

The requested financial commitment over the course of the program will make the Arthur D. Little team more competitive, increasing our chances of successfully obtaining one of the two anticipated contract awards for fuel powerplant development. These are 25% minimum cost-share contracts and Arthur D. Little and other team members will be making cost-sharing commitments as well.

The participation of the Illinois Corn Marketing Board will reinforce the interest of the ethanol community in this program. While DOE has, for the moment, bowed to marketplace reality in adopting a gasoline-based technology strategy for initial fuel cell vehicle introduction, the use of ethanol is far more consistent with the DOE core mission.

By including ethanol-specific design and demonstration tasks, the role of ethanol as a highly desirable fuel cell fuel will be highlighted and preserved. As in the past, Arthur D. Little is committed to conducting a public and vocal discussion in technology and policy forums of the merits of the use of ethanol in advanced vehicles.

The proposed technology demonstration will position ethanol as the preferred fuel for advanced fuel cell transportation systems. This long-term vision provides strong incentive for the expansion of current ethanol IC engine applications. In the near-term, ethanol powered fuel cell transit buses will consume significant quantities of ethanol and provide continued momentum. In the medium-term, fuel cell light-duty vehicles powered by ethanol will provide an extremely robust market. A very feasible market development scenario is illustrated in Table 2.

Table 2: Ethanol Fuel Cell Vehicle Market Development

Vehicle	2000	2003	2008	2015
Fuel Cell Transit Bus Number of Vehicles in Operation Gal Ethanol/yr*	3 15,000	200 1,000,000	3,000 15,000,000	10,000 50,000,000
Light-duty Vehicles Number of Vehicles in Operation Gal Ethanol/yr**	0 0	500 300,000	5,000 3,000,000	1,000,000 600,000,000

***E-95 equiv. based on 5,000 gal/yr per vehicle**

****E-95 equiv. based on 600 gal/yr per vehicle**

The above figures do not account for the strong "halo" effect that the vision of advanced ethanol applications can bring to efforts to expand ethanol IC engine applications.

Budget Summary:

The DOE fuel cell powerplant program will begin in 1997. The budget in Table 3 reflects the requested cost-share participation for the Illinois Corn Marketing Board over the three-year life of the DOE program. The greater requested allocation of funds in later years of this program reflects the anticipated spending rate for the entire program and is predicated on success in earlier years of the program. As discussed in Section C, the second and third years involve increased rates of expenditure consistent with testing of a full-scale ethanol fuel cell powerplant hardware.

Table 3: Annual Requested ICMB Contribution

Year	1997	1998	1999	Total
Cost	$75,000	$100,000	$150,000	$325,000

ADL will team with a leading fuel cell developer and other commercial firms to compete for the pending DOE fuel cell powerplant procurement. The Illinois Corn Marketing Board and possibly other ethanol interests will be shown as co-sponsors of the proposed program. No ICMB funding is being sought for the preparation of the DOE proposal.

How Ethanol is Made

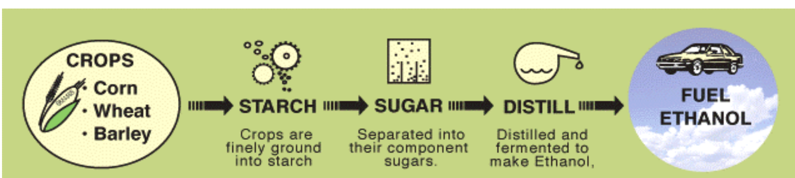
SOURCE: http://www.ethanol-crfa.ca/made.htm

Converting starch into ethanol

Ethanol can be made from a variety of sources - essentially any product that can be fermented into alcohol.

In Canada it has been traditionally made from growing crops (primarily corn, wheat and barley). New technology is providing opportunities to also produce ethanol from forestry products (wood chips) and agricultural residues (straw, grass hay).

The basic process involves the conversion of starch (present in high concentrations in the grain or seed of agricultural crops) to sugars, by enzymes, and the fermentation of these sugars by yeast. During fermentation, yeast converts the sugar to ethanol and carbon dioxide. The non-fermentable part of the grain contains most of the non-starch nutritive elements (protein, oil, fibre) of the kernel and is processed to produce a variety of co-products.



Wet Milling and Dry Milling

There are two distinct processes to produce the starch that is converted into sugar for fermentation.

- In the Wet Milling process, used exclusively for corn, the grain is soaked or steeped to separate and recover the oil before processing. Using this process, one bushel of corn produces 9.5-10 litres of ethanol, carbon dioxide and a variety of co-products.
- In the Dry Milling process, used to produce ethanol from wheat and other grains, the whole kernel is ground. Water is added to form a mash, which is then heated with enzymes present to separate the fermentable sugars. This process

produces 9.8 litres of ethanol from 1 bushel of corn, and is the only process currently used in the production of fuel grade ethanol in Canada.

Co-products of ethanol production

Wet and Dry Milling produce different co-products, all of which are valuable for human or animal nutrition.

	Wet Milling	Dry Milling
Products	Ethanol Carbon Dioxide (used as a refrigerant, in carbonated beverages, to help vegetables grow quicker in greenhouses, and to flush oil wells)	Ethanol Carbon Dioxide
Co-products	Corn oil (used in producing food products for human consumption) Amino Acids (used as animal feed additives) Corn Gluten Meal (used as a high protein livestock feed additive, valued especially in poultry feeds) Corn Gluten Feed (used as a high protein livestock feed supplement, used widely in dairy and beef production)	Dry Distiller¹s Grains (used as a high protein and energy animal feed) Fibrotein (used as a high fibre and protein food additive)

Ethanol Industry Outlook 2003

SOURCE: http://www.ethanolrfa.org/press.shtml

ETHANOL INDUSTRY'S RECORD YEAR HIGHLIGHTED AT RFA's NATIONAL ETHANOL CONFERENCE

Ethanol Industry Outlook 2003 Now Available on Web

Scottsdale, AZ - Kicking off the 8th Annual National Ethanol Conference: Policy and Marketing in Scottsdale, Arizona today, Renewable Fuels Association (RFA) president Bob Dinneen described the state of the ethanol industry as sound and prepared. During his speech, Dinneen unveiled the Ethanol Industry Outlook 2003.

“I can report with confidence that the state of the ethanol industry is sound; buoyed by the enthusiasm of new production, steeled by the technical and market challenges of the past year, prepared to meet the legislative and commercial agenda ahead, and resolved to build a secure energy future for ourselves, our children and our nation,” said Dinneen. “Today, we are releasing this year’s Ethanol Industry Outlook. It documents a record year of achievement for the ethanol industry and highlights the opportunities that still lay ahead."

The Ethanol Industry Outlook 2003 contains vital statistics on the ethanol industry and information on a variety of topics impacting the industry. This year's Outlook notes:

- The U.S. ethanol industry produced a record 2.13 billion gallons in 2002.
- Currently, 68 ethanol plants can produce 2.7 billion gallons annually.
- With 11 plants under construction, annual production capacity will expand to over 3 billion gallons by the end of 2003.
- Ethanol use consumed more than 800 million bushels of corn in 2002.

Ethanol use reduced CO2-equivalent greenhouse gas emissions by more than 4.3 million tons in 2002.
Saluting those in the audience responsible for ethanol's record-breaking year in 2002, Dinneen stated: "Nobody works harder to promote rural economic investment; nobody works harder to protect precious air and water resources for our children; nobody works harder to reduce our dependence on imported oil; and nobody works harder to build a secure energy future for all America than the people in this room."

President Bush Highlights Ethanol As Domestic Source Of Hydrogen For Fuel Cells

SOURCE: http://www.ethanolrfa.org/press.shtml

PRESIDENT BUSH HIGHLIGHTS ETHANOL AS DOMESTIC SOURCE OF HYDROGEN FOR FUEL CELLS

RFA Fuel Cell White Paper Outlines Ethanol/Fuel Cell Synergies

WASHINGTON, DC -- The Renewable Fuels Association (RFA) today applauded President George Bush for highlighting ethanol as a domestic source of hydrogen to power fuel cells. President Bush recently announced a $1.2 billion "Hydrogen Fuel Initiative" to support research and commercialization of fuel cells for automobiles and stationary power generation.

In a speech this afternoon to fuel cell technology leaders, automobile industry executives and U.S. Department of Energy (DOE) staff, the President urged Congress to quickly pass an energy bill and expanded on his vision for a hydrogen-powered future first outlined in the State of the Union Address. Today, the President stated: "And there's a lot of advantages that I want to explain to the American people about why this initiative makes sense. First, the hydrogen can be produced from domestic sources -- initially, natural gas; eventually, biomass, ethanol, clean coal, or nuclear energy. That's important. If you can produce something yourself, it means you're less dependant upon somebody else to produce it."

The RFA recently released a white paper highlighting the potential synergies for ethanol and fuel cells. Ethanol is easily stored and dispensed in the current fueling system and generates fewer greenhouse gas-forming emissions than conventional fuels. Tests have demonstrated that ethanol is more efficient to reform than gasoline to provide hydrogen for fuel cells.

“President Bush is to be commended for not only discussing hydrogen fuel cells, but the question of where the hydrogen will come from,” said Bob Dinneen, RFA president. “In the search for hydrogen to power these new fuel cells, only ethanol combines the ability to utilize the existing fuel distribution infrastructure with the safety and environmentally-friendly attributes that consumers are increasingly demanding. And as a domestic fuel, ethanol helps provide energy security. Clearly, fuel cells represent an important new market for renewable ethanol.”

The DOE has partnered with the State of Illinois, Caterpillar Inc., Nuvera Fuel Cells and Williams Bio-Energy to demonstrate the nation’s first commercial ethanol powered fuel cell. With the design complete and fabrication well underway, the 13-kilowatt stationary fuel cell system is scheduled to power Williams’ visitor center in Pekin, Illinois later this year.

Senate to debate ethanol

Source: Associated Press

Sunday, June 1, 2003 Posted: 6:07 PM EDT (2207 GMT)

WASHINGTON (AP) -- Politicians hail ethanol, the corn-based gasoline additive, as a boon to the environment and a way to reduce America's dependence on foreign oil.

But ethanol also comes with its own environmental problems and scientists disagree over whether producing ethanol actually uses more fossil energy than it replaces.

The Senate this week will decide whether to double the amount of ethanol to be used in gasoline, to 5 billion gallons a year. Critics say the plan is just one more subsidy for corn growers. Supporters make the case that the proposal is essential to an energy policy that is less reliant on oil.

"It will reduce our dependence on foreign oil. It will protect the environment," says Senate Majority Leader Bill Frist, R-Tennessee.

There is skepticism about those claims.

Ethanol's benefits are "a mixed bag," says Blake Early, a lobbyist for the American Lung Association.

Ethanol's clearest air quality benefit is that it significantly cuts carbon monoxide, he says. But ethanol also releases more nitrogen oxide, a key element of smog, and evaporates more easily than gasoline, causing still other air pollution problems, Early says.

On balance, ethanol "certainly isn't worse than gasoline," Early says, but "it's not that helpful from a smog perspective."

The government also has identified ethanol plants as significant air polluters, but has reached deals to curtail plant emissions.

And some scientists now say that ethanol, while not as troublesome as a methanol-based additive known as MTBE, also may complicate cleaning up gasoline spills into waterways and groundwater.

"It certainly is not all that benign," says Tom Curtis, an official of the American Water Works Association, which represents professionals involved in the drinking water supply business.

Curtis cites research indicating that gasoline plumes containing ethanol degrade more slowly in groundwater than plumes of only gasoline. Toxic chemicals such as benzene in ethanol-blended gasoline disperse more widely and take longer to degrade, the studies found.

These studies "are far from conclusive" and should be pursued further, says Monte Shaw, a spokesman for the Renewable Fuels Association, which represents the ethanol industry.

But he maintains that because ethanol replaces 10 percent of the gasoline, there is also less benzene and other toxic chemicals -- normally found in gasoline -- going into the water in the first place. And, he says, refiners can blend their gasoline in ways to counter the air pollution concerns caused by ethanol's evaporation.

Ethanol supporters emphasize that it is a motor fuel made in America and that it is not a fossil fuel -- particularly from another country. That, they argue, makes it perfect for improving America's energy security, as well as helping to fight global warming because greenhouse gases mostly come from the burning of fossil fuels. Critics counter that ethanol does not come through as advertised on either of those points. "Ethanol does not increase energy security," insists David Pimentel, an agricultural ecologist at Cornell University. "It remains a fact that it takes more energy to produce a gallon of ethanol than you get out of it." Pimentel says ethanol, when made from corn, should not even be considered a renewable fuel -- and actually provides little help on global warming. It takes large amounts of nonrenewable natural gas, coal, and oil to make fertilizer and grow the corn, process ethanol and transport it in trucks and rail cars. Pimentel's claims, frequently cited by ethanol critics, have prompted a pile of research. Reports from the Agriculture Department, the Energy Department's Argonne National Laboratory, and by scientists at two other universities concluded that Pimentel is wrong. Michael Wang, a co-author in both the Argonne and Agriculture Department studies, maintains that Pimentel used old data that does not take into account substantial improvements in corn farming and ethanol processing. All of that, he contends, has reduced energy use. In an interview, Piementel dismissed his critics and said he recently updated his findings to reflect current production improvements. Still, he insists, the numbers show a 30 percent net energy loss with ethanol. By contrast, the Argonne lab and Agriculture Department studies conclude 34 percent overall energy gain in using ethanol. Most of the energy used in making ethanol comes from coal or natural gas, domestic sources instead of petroleum-based gasoline that relies on imports, they note.

Woolsey On Alternative Fuels

SOURCE: http://evworld.com/databases/storybuilder.cfm?storyid=507

By Bill Moore

James Woolsey is a unique amalgam of conservative Democrat, military 'hawk' (he's in favor of the war with Iraq) and a strong advocate for energy-efficient vehicles and alternative fuels. He proudly acknowledges that even hawks have to have trees to roost in, so he finds no contradiction in his political and his environmental views, which has seen him fostering alliances between "tree huggers," farmers and 'hawks,' like himself in an effort to encourage the switch from imported petroleum to home-grown alternative fuels.

I had the opportunity to meet Woolsey at the 2002 Clean Cities national conference in Oklahoma City. In a brief exchange, he agree to do an interview with EV World. In the light of the imminent threat of war with Iraq and the growing public debate over the role of Middle East oil in this crisis, I thought I'd take him up on his offer. I got him for half an hour between phone calls and a television interview, during which time we talked about what role alternative fuels could play in helping America reduce its dependence on foreign oil sources, especially those from the troubled Middle East.

The first question I asked him was, "Realistically, can the US become energy independent? Is it even desirable?"

"[It's] not really realistic," was his candid response. "What we may be able to do, and not so much as a result of the war itself, but as a result of policies we adapt here, we may be able to become less dependent on imported oil and oil in general for transportation fuel."

He pointed out that as a result of the OPEC oil embargoes of the 1970s, the US generates little of its electric power from oil. Today, virtually all oil we use -- on the order of about 95% -- is in the transportation sector.

"We're down to generating two percent or less of our electricity from oil, so it really is a transportation fuel issue. But we import 55 to 60 percent of our oil and we have a little over three percent of the world's proven reserves and we use about 25 percent of the world's oil."

Keenly aware of the geopolitical ramifications of this imbalance, he also pointed out that the vast bulk of the world's proven reserves -- he estimated two-thirds to three quarters -

- are located in the Middle East and a broader region surrounding it that also takes in the Caspian Sea basin.

"Because of the volatility in that part of the world, I think we have a serious problem," he told EV World. Besides the political and religious tensions and hatreds seething in that part of the world, there is the issue of the Saudi government's control over the world's "swing" production capacity of up to 3 million barrels of oil a day. Woolsey contends that they can use this for political leverage and added that there are people who believe that every US recession over the last several decades have resulted from political manipulation of oil prices by the Saudis.

In addition -- and this may account for his advocacy for war with Iraq -- Woolsey contends that after occupying Kuwait in 1991, Saddam Hussein was within 100 miles of Saudi Arabia's main oil fields. Iraq's dictator could have effectively dominated half of the world's proven oil reserves had he chosen to move his forces south.

"So there are a number of vulnerabilties attached to our oil reliance, but we're never going to be completely independent of the outside world. We really should want to be and we don't need to be."

Hydrogen A Distant Promise

Woolsey said that he was glad the Bush Administration has decided to fund research into hydrogen, but he also believes that it is sufficiently far in the future that it can make no meaningful contribution to reducing the nation's reliance on fossil fuels right now.

Referring to Bush's state-of-the-union comment about a child born today someday getting their driver's license in vehicle powered by hydrogen, the former CIA director feels that this is just too distant a goal to practically address our current vulnerability.

"I think that sixteen years is not what our time line ought to be," he stated. "I think we ought to focus on things that will pay off sooner."

He sees three things that should be done immediately. The first is to concentrate on finding and helping develop petroleum resources outside of the Middle East. He cites Russia's vast oil reserves but deteriorating production infrastructure as a prime example of just such a resource. The country needs investments in more pipelines and ports to get its oil into the world market.

His second action item is to develop alternative fuels that can use America's existing production and delivery infrastructure.

Converting Waste to Transportation Fuels

"One reason I have been interested in ethanol is that it takes only a modest modification of vehicles to burn up to 85 percent ethanol in cars that we drive now. Flexible fuel vehicles [FFV], as they are called, can burn up to 85 percent ethanol." He pointed out that the only real difference between a FFV and a conventional car is the plastic used in the fuel line and a minor modification to the computer processor chip that tells the engine what percentage of ethanol-to-gasoline the car is using."

Woolsey acknowledges that there is a very real issue with respect to the amount of energy it takes to make ethanol from corn, which is why he's a strong advocate of using other forms of biomass -- grasses, fast-growing poplars, etc. -- instead of corn.

[Editor's note: The ethanol industry is aware of this issue and has studied it extensively. They contend that using the most energy efficient farming practices and state of the arts ethanol production methods, its possible to produce ethanol from corn at up to a 1:2.4 energy ratio. This means that for every BTU of energy put into the making of ethanol from planting to distilling, 2.4 BTUs can be produced. .]

"What we want to move to, I think, is ethanol made from biomass, essentially agriculture waste, forest waste, kudzu, grasses, brush and so on..." he continued. "The secret here is genetic engineering of the bio-catalysts, the enzymes and yeasts substitutes that can break-down most of what grows into constituent sugars and ferment them into ethanol."

Woolsey thinks that this approach will ultimately reduce the cost of ethanol production and enable it to be introduced in other areas of the world, not just America's mid-section. What he didn't mention was that Brazil is the world leader in ethanol production from sugar cane waste and at one point in the 1980s it powered something like three-quarters of its automobiles with ethanol. Falling oil prices through the 1980s and 1990s hurt the industry.

In addition to ethanol production, he also sees promise in a new technology called Thermo-Depolymerization. In partnership with Conagra Foods, a large food processor in the United States, a small company called Changing World Technologies, has installed a system that will take agriculture waste from a turkey processing plant in Carthage, Missouri and convert it into a short-chain hydrocarbon gas similar to natural gas and a high-grade bio-diesel fuel, among other bi-products.

"This technology is applicable to a wide range of waste from used tires to hog manure," he said.

A third technology makes use of one of America's most abundant fossil fuels, coal. Woolsey explained that a technology developed by the Germans and used extensively during World War Two to produce liquid fuels from gasified coal -- called Fischer-Tropf after its inventors -- also may play an important part in reducing dependence on fossil fuels. He explained during the era of Apartheid, the government of South Africa refined the technology. It enabled them to produce affordable liquid fuels from the country's abundant coal reserves, circumventing UN oil sanctions.

Jim Woolsey explained that an American company in Pennsylvania has developed a way to use Fischer-Tropf to make diesel fuel not from coal but from the mountains of coal slag that results from coal mining, both underground and strip mining. He company, he noted, just received a $100 million dollar grant from the US Department of Energy to develop their system. The benefits of this are obvious. A nation can clean up an environmental hazard and produce diesel fuel at the same time.

The fourth technology he holds out promise for is a new, small, mobile liquefied natural gas technology. While LNG has been around for a long time, it has traditionally required large refinery facilities to manufacture from methane/natural gas. This new system will enable LNG to be manufactured from small, isolated deposits of methane such as that found in city landfills and abandoned coal mines. The LNG can then be used as a transportation fuel.

Woolsey sees these four -- and others -- as very real, near-term viable ways to reduce a nation's dependence on imported oil while also cleaning up the environment and reducing CO2 emissions that contribute to global warming.

"I think that's a nice combination," he stated.

No Silver Bullet

A "Skoop Jackson" conservative Democrat, as he refers to himself, Woolsey thinks that it is just as important to look at conservation and energy efficiency technologies as waste-to-fuel technologies. He said that we have to engage all of these approaches because there is no one "silver bullet" that will solve our energy problems.

"If you're moving on all these fronts at once, the cumulative effect can be quite substantial," he remarked. "The technology that find immediately interesting is gasoline-electric hybrids." While he thinks small gains in automotive design and in the internal combustion engine are important, they are nowhere near as "dramatic" as that offered by hybrid-electric systems like those found in the Honda Civic, which he had just been looking at in a local DC-area dealership.

He thinks that what carmakers need to be doing is expanding the range of offerings of such fuel efficient vehicles including SUVs. He said there are families that do need large vehicles and in addition to making them safer, carmakers need to be improving their fuel efficiency.

"A hybrid SUV that gets 30 miles to the gallon is a better deal from the point of view of fuel economy than a regular four passenger vehicle that get's twenty-nine miles to the gallon."

Woolsey is in favor of giving tax credits and other incentives to encourage consumers to buy hybrids. He also would like to see those hybrids be able to use alternative fuels. He doesn't see any technical reason why a hybrid can't also be made a flexible fuel vehicle, one that can run on 85 percent ethanol, for example.

[Editor's note: EV World burns a 10% blend of ethanol and gasoline in our Honda Insight].

He calculates that a 30 mpg SUV burning 85% ethanol would be equivalent to getting close to 200 mpg of gasoline.

"These technologies are not pie-in-the-sky," he emphasized saying there are over a hundred thousand gasoline electric hybrids on the road today and millions of flexible fuel vehicles. He thinks that government incentives will encourage people to buy and use these vehicles, which themselves use our existing fueling infrastructure, "rather than always looking 15 to 20 years off in the future, an obvious reference to Bush's "FreedomCAR" and "FreedomFuel" proposals.

James Woolsey is a firm believer in alternatives fuels, especially those derived from biomass or plant matter, as a means of reducing America's dependence on imported oil. He calculates that the nation could eventually replace two-thirds of its current oil consumption, most of which is used in transportation, with a combination of biomass fuels and hybrid-electric vehicle systems.

The sugars found in all plants can be fermented into alcohol-based fuels, either methanol or ethanol. It's an ancient science that dates back to the first whiskey distilleries. While it's possible to use methanol directly as a fuel -- it's what Indy League Racing cars have run on for more than a decade -- ethanol is typically blended with gasoline to make a compatible fuel. Corn-based ethanol is one of the most widely used such fuels.

For his part, however, Woolsey is less than enthusiastic about ethanol fermented from corn (maize). Despite it being the current industry leader among a growing selection of alternative fuels made from plant matter, it isn't the ideal source for ethanol. Woolsey agrees with critics who assert that it takes nearly as much energy to make corn-based ethanol fuel as found in the fuel itself.

"It is nearly an equal trade," he explains comparing the energy input versus ethanol's potential output. "The reason is you have to plow, you have to harvest, you have to fertilize, and fertilizer takes fossil fuels to produce. By the time you get it done, you've used about six gallons of petroleum to produce 7 gallons of ethanol. That's why you don't want to stay with corn."

He says corn ethanol has served a useful role in getting the industry started, but what we need to do is move to using waste plant matter instead of corn, which has other valuable uses. He cites the example of rice straw. It has to be removed from the fields at the end of every growing season or the silica in the straw will eventually ruin the field. Traditionally rice farmers have simply burned it, creating a pollution problem. Woolsey sees converting the straw to ethanol as a way to turn a problem into a solution.

Another good candidate is prairie switch grass. Here again, he envisions this natural grass, which requires no fertilizers or irrigation, being cut, harvested and converted to ethanol. "You just mow it. You're not using anywhere near the amount of energy you do producing corn."

He and US Senator Richard Lugar co-authored an article several years ago that calculated switch grass-derived ethanol could be produced at a ratio of 1 to 7. It would take one gallon of fossil fuels to cut and transport the grass to the distillery to produce seven gallons of ethanol. The ethanol industry calculates the ratio for "best-practices" corn-based ethanol production from field-to-fuel is 1 to 2.4. So, if Woolsey's estimates prove accurate, the vast prairies of America could someday be producing fuel to drive the nation, though that raises the question of the nation someday having to choose between food and fuel. It's an issue Woolsey has also thought about.

He points out that some 60 million acres of land lies idle very year on various state and federal programs. Half of this is set aside in "soil bank" or CRP programs, which forbid farmers from even cutting hay on these fields. Woolsey favors letting farmers harvest the grasses on these set aside lands so it can be turned into biomass fuels.

Citing a study by Dartmouth professor Lee Lynn, Woolsey tells EV World that just using the current inventory of CRP lands for bio-fuel production, without taking any land out of food production or adding marginal lands, it is theoretically possible to replace 20% of the oil America currently uses for transportation, at today's current fuel efficiency rates. Adding agricultural waste to this in the form of rice straw, corn stalks, etc. would raise the percentage to about one-third.

Next, if the nation's auto fleet fuel efficiency could be raised to hybrid-electric standards, Woolsey estimates the United States could produce two-thirds of its transportation fuels from renewable biomass. He does, however, admit there is some disagreement around how much land would be required to shift to a biomass energy system. Much of the debate centers around crop yields and fuel efficiency standards. He explains that if you take very low crop yields and combine that with no improvements in fuel efficiency then a "scary" set of numbers appear that requires hundreds of millions of acres of land dedicated to fuel production. This scenario would mean choosing between food and fuel.

"But I think that is really a scare tactic by people who really don't want to go this direction ," Woolsey observes. 'If you focus on making a series of improvements; improving gasoline mileage, using waste products, etc., I think you could make a very substantial dent in our gasoline and diesel use without doing anything negative to our farm land, without putting marginal land into cultivation, without replacing feed crops with specialized crops."

Using locally-grown biomass fuels has another increasingly critical advantage: reducing America's burgeoning trade deficit, which Woolsey estimates at about $100 billion a year for imported oil alone.

"As the world holds more and more dollars because of our huge trade deficits, some people understandably get worried about the dollar's stability. As long as everything goes fine, it's probably not a problem. A dollar for a Japanese or Chinese holding a US government bond is one of the better long term investments.

"But if as a result of terrorist attacks -- or anything -- people should lose confidence in the dollar and start moving into things like the Euro and the like, there could be some serious problems associated with it, " Woolsey cautions.

"So, if we have an alternative that is affordable and makes sense from the point of view of efficiency, it seems to me it would make a great deal of sense to try to use some of that hundred billion or so a year to employ Americans, particularly in rural parts of the United States that didn't feel the boom of the 1990s, and a lot of them are hurting bad economically."

He notes that because biomass fuels are produced most efficiently close to the source of the plant feed stock where transportation costs are kept to a minimum, this means ethanol processing plants must be located in rural areas, offering much needed jobs and economic revival to these hard-hit communities.

Woolsey points to the fact that America has an abundance of two important resources, farm land and coal. He envisions a future energy system that makes use of both agricultural waste and coal slag. He believes this approach can address the twin problems of energy and preserving the environment.

"You're helping the dollar and you're helping us be more independent of the Middle East," he comments, adding that reports circulated around Washington, D.C. several months ago about how the pilot for the Saudi crown prince refused to talk to female air traffic controllers while flying the prince to George Bush's ranch in Crawford, Texas. Woolsey says that whether its wanting to reduce Saudi influence over US policy or to send a message about Western attitudes on female rights, a shift towards alternative fuels like biomass ethanol can also have a positive role in the developing world.

"If you look at a country like Nigeria," he observes, " the Niger delta has one of the world's great oil supplies and it's sitting there pumping. People who live on top of it aren't getting any benefit from that. There are rebellions from time to time. They are poor tribesmen. Nobody is using [the oil] to help them. If they are subsistence farmers and they have an acre or two of land to grow crops for their family, if they can take the agricultural waste to a nearby biomass ethanol facility and produce transportation fuel, that's an extra bit of income for them, maybe if its only fifty or a hundred dollars a year, and they are making only three or four hundred dollars a year, that's substantial change."

Woolsey adds that micro-loan payments in the third world have a very positive impact on the lives of loan recipients. "It makes a huge change in people's lives." He says that people will use the money to buy a sewing machine or some pigs or set up some sort of business. "It helps develop the beginnings of greater prosperity."

"And one of the things this country ought to be about is helping that sort of thing occur around the world. You just don't want to give people money, you don't want to give them fish. You want to teach them how to fish."

He sees the introduction of small scale biomass technology in developing countries without oil reserves and often saddled by huge international debt, as a way to help those countries ease themselves out from these financial burdens. "A large part of that is for imported petroleum," he tells EV World. "I call this a potential alliance between the cheap hawks, the do-gooders, the farmers and the tree-huggers. We've got the beginnings of a fairly substantial coalition," he concludes, as he offers his apologies. He has a television interview to run to.

After talking to him personally, I have the impression that James Woolsey is a hard-noised pragmatist with a soft heart. Whether or not you agree with his position on war with Iraq, he can still be an important ally in the struggle to move America... and the world... towards a sustainable energy and transportation system.

XVIII. Appendix G- Hydrogen References

A Hydrogen Economy Is a Bad Idea

SOURCE: http://www.alternet.org/

By David Morris
February 24, 2003

When George Bush proposed a $1.7 billion program to promote hydrogen-fueled cars in the State of the Union Address, both sides of the aisle applauded. Almost everyone supports a hydrogen economy – conservatives and liberals, tree huggers and oil drillers. Such unanimity forecloses serious discussion. That's unfortunate. An aggressive pursuit of a hydrogen economy is wrongheaded and shortsighted.

To understand why, we need to start with the basics. Hydrogen is the most abundant element on the planet. But it cannot be harvested directly. It must be extracted from another material. There is an upside to this and a downside. The upside is that a wide variety of materials contain hydrogen, which is one reason it has attracted such widespread support. Everyone has a dog in this fight.

Renewable energy is a very little dog. Environmentalists envision an energy economy where hydrogen comes from water, and the energy used to accomplish this comes from wind. Big dogs like the nuclear industry also foresee a water-based hydrogen economy, but with nuclear as the power source that electrolyzes water. Nucleonics Week boasts that nuclear power "is the only way to produce hydrogen on a large scale without contributing to greenhouse gas emissions."

For the fossil fuel industry, not surprisingly, hydrocarbons will provide most of our future hydrogen. They already have a significant head start. Almost 50 percent of the world's commercial hydrogen now comes from natural gas. Another 20 percent is derived from coal.

The automobile and oil companies are betting that petroleum will be the hydrogen source of the future. It was General Motors, after all, that coined the phrase "the hydrogen economy".

What does all this mean? A hydrogen economy will not be a renewable energy economy. For the next 20-50 years hydrogen will overwhelmingly be derived from fossil fuels or with nuclear energy.

Consider that it has taken more than 30 years for the renewable energy industry to capture 1 percent of the transportation fuel market (ethanol) and 2 percent of the electricity market (wind, solar, biomass). Renewables are poised to rapidly expand their presence. A hydrogen economy would be a potentially debilitating diversion.

As the President's 2004 budget demonstrates, any new money for hydrogen will be taken largely from budgets for energy efficiency and renewable energy. From a federal point of view, then, the more aggressively we pursue hydrogen, the less aggressively we pursue more beneficial technologies.

To be successful, a hydrogen initiative will require the expenditure of hundreds of billions of dollars to build an entirely new energy infrastructure (pipelines, fueling stations, automobile engines). Much of this will come from public money. Little of this expenditure will directly benefit renewables. Indeed, it is likely that renewable energy will have about the same share of the hydrogen market in 2040 as it now has of the transportation and electricity markets.

Far better to spend the billions the President wants to spend on hydrogen to increase renewable energy's share of the energy market from 1-2 percent to 25, 35, or even 50 percent in the same time frame.

Not only will a hydrogen economy do little to expand renewable energy, it will increase pollution. Making hydrogen takes energy. We are using a fuel that could be used directly to provide electricity or mechnical power or heat to instead make hydrogen, which is then used to make electricity. Back in 1993 William Hoagland, senior project coordinator at the National Renewable Energy Laboratory's hydrogen program, prophetically told Time Magazine, "I can't see why anyone would invest in additional equipment to make hydrogen rather than simply putting the electricity on the grid."

We can, for example, run vehicles on natural gas or generate electricity using natural gas right now. Converting natural gas into hydrogen and then hydrogen into electricity increases the amount of greenhouse gases emitted.

There is another energy-related problem with hydrogen. It is the lightest element, about eight times lighter than methane. Compacting it for storage or transport is expensive and energy intensive. A recent study by two Swiss engineers concludes, "We have to accept that [hydrogen's] ... physical properties are incompatible with the requirements of the energy market. Production, packaging, storage, transfer and delivery of the gas ... are so energy consuming that alternatives should be considered."

The most compelling rationale for making hydrogen is that it is a way to store energy. That could benefit renewable energy sources like wind and sunlight that can't generate energy on demand. But batteries and flywheels can store electricity directly. The all-electric vehicle has not yet found a commercial market, but we should acknowledge the rapid advances made in electric storage technologies in the last few years.

Many people see the new hybrid vehicles as a bridge to a new type of transportation system. I agree, but with a different twist. Toyota and Honda are selling tens of thousands of cars that have small gas engines and batteries. American automobile companies will soon join them. Toyota and Honda and others are looking in the future to substitute a hydrogen fuel cell for the gasoline engine. That work should continue, but policymakers should also develop incentives and regulations that channel engineering ingenuity into improving the electric storage side of the hybrid system.

Currently, a Toyota Prius may get 5 percent of its overall energy from its batteries and could only go a mile or so as a zero emission vehicle. A second generation Prius might get 10 percent of its energy from batteries and might have a range of 2-3 miles. Why not encourage Toyota and Honda and others to increase the proportion of the energy they use from the batteries?

We need to get beyond the glib, "we can run our cars on water," news bites and soberly assess the value of a massive national effort to convert to a hydrogen economy. When we do so, I believe, we will conclude that the hydrogen economy has serious, perhaps fatal shortcomings.

David Morris is vice-president of the *Institute for Local Self-Reliance*.

Is Bush's Fuel Cell Plan Hot Air?

SOURCE: http://www.wired.com/news/technology/0,1282,49834,00.html
By John Gartner Jan. 22, 2002

Earlier this month, Secretary of Energy Spencer Abraham said the Bush administration is junking the existing plan to improve fuel efficiencies, and would instead focus on developing "hydrogen as a primary fuel for cars and trucks."

But while experts laud the positives in zero-emission fuel-cell vehicles, some of those same critics argue that the administration's plan bets heavily on technology of the future while paying little attention to the urgent need to reduce oil consumption now.

Some predict that the Bush plan would do nothing to stop America's increasing dependence on foreign oil for at least a decade, probably more.

At the Detroit Auto Show, Abraham announced that the Bush Administration was ending the Partnership for a New Generation of Vehicles, a Clinton initiative started in 1993, and replacing it with the "FreedomCAR."

Abraham's decision to kill the PNGV is contrary to a report last year from the National Research Council, which mostly praised the PNGV program. The report lauded the PNGV's accomplishments in helping to improve fuel efficiencies, such as advances in manufacturing and the development of hybrid cars.

But Abraham used the PNGV's failure to achieve its most ambitious goal as a reason to scrap the program. PNGV sought to create by 2004 a family sedan with an 80-mpg fuel rating, equal to three times the efficiency of a 1994 vehicle. Although each of the Big Three automakers has demonstrated a concept car, none has created a commercial vehicle.

"It's not a minor matter that after a billion dollars that we still don't have these (fuel-efficient) cars," said Therese Langor, transportation program director of the American Council for an Energy-Efficient Economy.

However, Langor said solely focusing on fuel-cell vehicles could put us on the road to ruin. "It will be at least another 10 years before (fuel-cell) vehicles will become a serious response to the need to conserve energy."

Langor said that without improvements in fuel efficiencies, American dependence on foreign oil would continue to increase significantly. The DOE estimates that over the next 20 years, U.S. light-duty vehicle consumption of oil will rise more than 40 percent, while reliance on foreign oil during this period will increase from 52 percent to more than 60 percent.

"My concern is that we don't let the long-term objectives interfere with the desperately needed short-term goals," Langor said.

Fuel cells combine hydrogen and oxygen using a catalyst to produce electricity. The only byproducts of this electrochemical process are energy and water.

Also, a new infrastructure must be created that is convenient for cars to be refueled, Lynn said. "We want something as ubiquitous as today's gas stations."

Lynn said that with the right government incentives aimed at creating hydrogen-refueling stations across the country, between 200,000 and 300,000 fuel-cell vehicles could be on the road by 2012.

Lynn believes that fuel cells will become popular as stationary power generators and as batteries for mobile devices long before they show up on the highway.

The DOE has said that the cost of the FreedomCAR plan will be made known as part of the president's 2003 budget, which is due out on Feb. 4.

"The administration is replacing a completely useless program with something that only sounds good," said Alex Veitch, who works for the Sierra Club's global warming and energy program.

Veitch said the FreedomCAR would be just another billion-dollar waste of taxpayer money. "The Japanese (including Toyota and Honda) are making hybrids right now that you can actually buy, without all of those government subsidies."

Veitch said the government is spinning its wheels by focusing on hydrogen fuels instead of improving technologies currently in use. "We need to stop pretending that in 10 years we will all be driving fuel-cell cars. They use that as an excuse for inaction."

What the government really needs to do, Veitch said, is to update the federal fuel efficiency standards (CAFE), which "haven't been meaningfully updated since 1975." Compelling the automakers to upgrade their vehicles is the only way get more miles to the gallon, because the "Big Three don't pay for gasoline, drivers do."

Car crazy America reluctant to change

SOURCE: news.bbc.co.uk

America has a long-standing love of large cars

By Justin Webb

BBC Washington correspondent

The Island Packet - the daily newspaper of Beaufort county, south Carolina - has a big story on the front page.

There in black and white - is the shocking revelation that Beaufort county planners have been meeting to discuss a regional transportation system.

The paper explains what this is - it would link the county to outlying areas including the nearby city of Savannah, Georgia and the holiday resort of Hilton Head.

People wouldn't have to use their cars. But outraged residents want to use their cars - and they fear the kind of people who use public transport just would not fit in these parts.

There are environmentally aware Americans - they mostly wear beads and live in Seattle. The rest of the nation drives past them hardly noticing their presence

"We're not that kind of community", one of them is quoted as saying - and that is the rub.

'Car-driving society'

America is not that kind of community. It is a car-driving society - not in an easy going, take-it-or-leave-it "oh we'll try something else" sense, but in a profound, almost religious way.

The right to drive is a deeply valued blessing - and one that will not be given up lightly, in fact will not be given up at all.

> There is no alternative to driving. To fly would be hugely expensive - there is no train and long distance bus travel is grim

There are environmentally aware Americans - they mostly wear beads and live in Seattle. The rest of the nation drives past them hardly noticing their presence.

When I say the nation drives past them - I really mean the nation. One of the most striking things about living in America is the automotive energy of the place.

Everyone is driving. I was somewhere in North Carolina recently on route 95, the road that curves thousands of miles from the southern tip of the nation in Florida up to the north-east border with Canada.

Route 95 is a motorway served by thousands of pit-stop communities along the way - little agglomerations of cheap restaurants, garages and hotels that sprawl in gaudy fume-laden oases at strategic turnoffs.

The bigger ones have everything - McDonalds, Burger King, Hardees, Dunkin' Donuts, Kentucky Fried Chicken - and the best of them have a chain called Cracker Barrel which serves quite pleasant food.

Here you tend to find the savvy long-distance brigade - this being America there are rich and poor and everything in between all eating together. But what they have in common is miles under their belts.

At a Cracker Barrel somewhere on route 95 I met a granny and her two grandchildren who'd been staying with her in northern Florida. She was taking them home to Wichita, Kansas.

This is a journey of 1,000 miles and they do it several times a year.

No alternative

There is no alternative to driving. To fly would be hugely expensive - there is no train, and long distance bus travel is grim.

Of course there is something that would keep ordinary Americans off the road and would keep that granny from her grandchildren at least a few times a year - a hike in the price of petrol.

Sports utility vehicles are growing in popularity

But petrol here is still much cheaper than mineral water - under $1.50 a gallon. Americans, by the way, still use gallons - the litre is a measure too small to be of interest here.

Any attempt to raise the fuel price with taxes would almost certainly lead to a revolution. Particularly since 11 September, Americans have been feasting themselves on new cars.

An orgy of comfort buying brought on by fear of flying but also by a desire to be close to loved ones.

If you are going to spend more time in your car you're going to want it to be more comfortable. American cars - after a lean decade or two are getting bigger again.

Sadly those cruising monsters with tailfins and chrome from the 1950s are dead forever, but instead of being wide modern American cars are tall.

Driving in Mobile, Alabama a few days ago I stopped at some traffic lights and thought I'd take a chance to inspect my fellow motorists. Alas I couldn't.

I was driving a compact car - that means normal size - everyone around me on both sides appeared to be driving tanks. All I could see was bumpers and paintwork.

Environmental ignorance

In the hotel in Mobile I saw on American television a mention of the development summit and a discussion about the plight of the Maldives - that gorgeous island archipelago which we are told is threatened with inundation as sea levels rise.

When I say a discussion - well it wasn't quite that - by the time they had worked out where they were and marvelled at how small they were there was no time to talk about saving the islands.

Do Americans know that the rest of the world is ganging up on them again and accusing them of polluting the planet? - yes vaguely.

Do they care? Not much.

Environmentalism is part science, but let's face it it's also part religion - dependant on faith not proven fact. Here in the land of the Sports Utility Vehicle - they worship different gods.

Dartmouth researchers put recycling in perspective

SOURCE: http://www.eurekalert.org/pubnews.php
Better individual decisions can have a greater environmental impact

HANOVER, N.H. – Three Dartmouth researchers have found that resisting the temptation to buy an SUV can benefit the environment much more than recycling. They say that while recycling of some materials does contribute to overall environmental improvement, other personal decisions, such as what kind of car you drive, have a much greater environmental impact.

Andrew J. Friedland, professor and chair of environmental studies, and his colleagues Tillman U. Gerngross, associate professor at Dartmouth's Thayer School of Engineering, and Richard B. Howarth, associate professor of environmental studies, conducted the research which appears in the April issue of the Elsevier journal, "Environmental Science & Policy." They examined two individual activities, recycling and use of automobiles, and compared their relative environmental benefits.

The authors found that during the past 20 years or so, the amount of material recycled has steadily gone up, and during that same time, fuel efficiency has gone down, because Americans are choosing less fuel efficient vehicles. The authors argue that if the mix of cars and SUVs (which in this study includes sport utility vehicles, light trucks and minivans) had stayed at the 1989 level, it would have saved 75 times more energy a year than what has been saved by recycling plastic, and four times more energy than what has been saved by recycling aluminum.

"Individuals in our society have good intentions," says Friedland, the lead author. "They want to do something good for the environment. I was struck by the perception that many people think that recycling is the most important thing that they could do. In fact, making better transportation decisions would have more environmental benefit."

In this study, the researchers focused on energy use, which is a good indicator of environmental impact, because it affects a variety of environmental factors such as air and water pollution, global warming, and in some cases, local species.

The researchers considered recycling plastic and aluminum and used life-cycle analysis (LCA), which measures the energy and materials required to create an item and again to recycle it. For example, the study states that making a can from recycled material requires 94 percent less energy than making one from new aluminum. Assessing the benefits of plastic recycling is more difficult. Once it arrives at a recycling center, plastic is washed and chopped up, and the energy expended in this process is almost half of the energy required to produce brand new plastic, according to the study. The additional energy used by the consumer to clean the plastic before it's recycled is difficult to measure and quantify.

For comparison purposes, the researchers looked at the number of SUVs, light trucks and minivans registered from 1989 to 1999, which increased from 31 to 44 percent of all cars registered. They used data from the US Bureau of Transportation statistics for information on miles driven and fuel consumed to measure energy use.

"People see recycling as pure good," says Howarth, "but it's more complicated than that."

Friedland agrees. "It's a lot harder to get people to drive less or drive a more fuel-efficient car. Those are harder things to market and to convey to people."

The authors also argue that government policy appears to favor recycling over choosing fuel-efficient vehicles, public transportation and less travel.

"Our study illustrates how poorly consumers understand the environmental impact of their actions and how public policy is driven by a very superficial understanding of the relevant issues as well," says Gerngross.

Ford Unveils Hydrogen-Fueled Generator

SOURCE: http://www.evworld.com/databases/shownews.cfm?pageid=news080802-06

DEARBORN, Mich. (Reuters) - Ford Motor Co. and Canadian fuel cell developer Ballard Power Systems Inc. jointly unveiled on Wednesday what they described as the world's first hydrogen-fueled internal combustion engine-driven generator.

The power source, demonstrated during a news conference at Ballard's Dearborn, Michigan, plant, was touted as a clean and attractive alternative to small turbines or combustion engines using other fuels.

"In addition to providing customers with clean, siteable power, this product will provide Ballard with early revenue opportunities, will increase public awareness of alternative fuels and power solutions and assist in the development of hydrogen infrastructure," said Ross Witschonke, head of Ballard's electric drives and power conversion division.

Commercial production of the hydrogen-fueled generator is set to begin by year-end, and Ford and Ballard said the initial market for the product would be utilities for peak power applications.

The generator, covered by Ballard's Ecostar trademark, uses a standard 6.8 liter Ford production engine that has been modified and warranted by Ford Power Products for hydrogen use.

Ford Power Products is the division of the world's second-largest automaker that supplies and markets Ford powertrains for use in non-automotive applications.

Ford shares were down 6 cents at $12.10 in midday trading on the New York Stock Exchange. Shares of British Columbia-based Ballard were down 51 cents on the Nasdaq, meanwhile, at $12.17.

General Motors Corp. announced late last month that it will enter the mutibillion-dollar market for backup power systems by 2004 by selling stationary fuel cells to businesses that are highly dependent on reliable energy supplies.

Ballard and GM are among the world leaders in developing proton exchange membrane fuel cells, which create electricity through an electrochemical process using hydrogen and oxygen.

GM and Ford have both said they see fuel cells as environmentally-friendly alternatives to standard internal combustion engines in cars and trucks. But GM, which has committed itself to being the first automaker to sell one million fuel cell vehicles, does not expect to see a significant number of them on the road until late this decade.

Fuel Cells that Fit in a Laptop

SOURCE: http://www.wired.com/news/technology/0,1282,49717,00.html

By Reiner Gaertner Jan. 23, 2002

COLOGNE, Germany -- In the world of portable electronic devices "Whose lasts longest?" is usually more relevant than "Whose is the strongest?"

Working on that theme, a startup from Munich, Smart Fuel Cell GmbH, has developed a micro fuel cell that runs on methanol and provides much longer life than any other portable battery

The race for micro fuel cells that power devices is heating up. Several companies -- among them Mechanical Technologies, Motorola, Manhattan Scientifics, Ball Aerospace, Fraunhofer Institute and Samsung -- are frantically working on developing micro fuel cells for mobile and portable devices.

While many micro fuel cell companies have yet to show any real product, Smart Fuel Cell has been rapidly advancing its micro fuel cell line. In late January, the Bavarian company will roll out a pilot production of its first portable methanol fuel cells -- just three months after having unveiled its first prototype.

A fuel cell is an electrochemical device that produces electric power from either hydrogen or alternative fuels such as methanol, propane, butane or natural gas.

So far, most of the fuel cell companies have focused their methanol fuel cell research on hybrids, a combination of batteries and fuel cells as backup; mostly in "sub watt" categories such as mobile phones and lights that fit in a pocket. Smart Fuel Cell's device is the first to not require any standard batteries. It is aimed at power-hungry devices such as notebook computers, camcorders and specific applications for the environmental and the transportation markets.

"Our first potential OEM (original equipment manufacturer) customers are already holding their first units in their hands," said Manfred Stefener, CEO of Smart Fuel Cell.

In the following years, the company's ambitious goal is to increase its output by tenfold. By the year 2004, Smart Fuel Cell expects to produce at least 100,000 units, enough for mass production.

Nevertheless, portable fuel cells are in their infancy. Investment costs to generate 1 kilowatt are still very high, around $10,000 to $100,000 dollars per produced kilowatt.

But Stefener said portable fuel cells may swiftly become cost competitive. "Just in a couple of years, micro fuel cells could be competitive with Lithium-ion batteries, which are commonly used in notebook computers."

Still, the success of micro fuel cells will likely be highly dependent on the infrastructure and their ease of use. Smart Fuel Cell has designed small tamper-proof methanol cartridges that snap right into the unit.

Recharging the battery will only involve replacing the liquid fuel and won't require shutting down the computer. "The content of our prototype cartridge holds 120 ml methanol and generates about 150 Wh -- enough to power a 15W notebook computer for 10 hours," Stefener explained.

So how much is a refill going to cost? The availability and cost of methanol is probably not going to be the roadblock. According to the Methanol Institute in Washington, D.C., the current U.S. methanol production capacity stands at 35.7 million tons per year, and the wholesale spot market price for methanol is 33 cents per gallon.

Costs for packaging, logistics and marketing are going to be much more significant. "A filled cartridge may cost the consumer around $3 to $5," said Stefener, if the technology has sufficient market penetration, support and interest from consumer electronics firms. "In the long run, methanol fuel containers have to be widely available at gas stations and newsstands," he said.

Meanwhile, a team of Fraunhofer ISE in Freiburg is also working on micro fuel cells, so-called PEM (proton exchange membrane) fuel cells that run on hydrogen.

"Fraunhofer ISE is going to introduce a new generation of fuel cell powered camcorder at the Hannover Fair in April," said Ulf Groos, marketing manager with Fraunhofer ISE. "Right now, we're working on contracts for a 'mobile office' application. We also just finalized two notebook projects," he said. Fraunhofer ISE is also following DMFC developments for micro power appliances.

PEM or DMFC (direct methanol fuel cells): The race is on. But when it comes to true portability, fans of simple alcohol seem to have one striking argument.

"There is no way hydrogen is ever going to be allowed aboard an airplane," Stefener said. In this case, "Whose travels fastest?" may even match "Whose lasts longest?"

GM's Billion-Dollar Bet

SOURCE: http://www.wired.com/wired/archive/10.08/fuelcellcars.html

Issue 10.08 - Aug 2002

The hydrogen car has been a long time coming. GM is betting $1 billion that the end of internal combustion is near.

By Dan Baum

VIEWED from the proper angle, Detroit's Renaissance Center — six medium-high office towers surrounding a cylindrical 73-story giant — is a mighty glass hand giving the finger. Hulking by the iron-gray waters of the Detroit River, this is the führerbunker of the tired old industrial economy: the headquarters of General Motors.

These days, the company is on a PR tear to tell the world it is "reinventing the automobile." At the Detroit Auto Show in January, the company rolled out a radical prototype called the AUTOnomy, and a drivable proof-of-concept version debuts in September at the Paris Auto Show. How radical is it? It dispenses with just about everything that makes a car a car, such as the engine, transmission, steering wheel, and gas tank. Rather than spitting out carbon monoxide and other smog-causing gases, it emits nothing but water because it runs on hydrogen. With few moving parts, it will last for decades. It will generate more electricity than it uses and be equipped to apply the surplus to power the owner's house. Manufacturing will cost a fraction of what it takes to build a traditional car, because the AUTOnomy will contain many fewer components. And it will be ready for mass production by the end of the decade, which in the automotive world is a week from Tuesday.

I park my rented Pontiac Sunfire in the Renaissance Center garage and open the trunk to retrieve my laptop. As I do, a slab of snow slides down the rear window and straight into the open trunk. I stand for a minute contemplating this. The same people who are promising to reinvent the automobile can't figure out how to design a car that doesn't dump snow into the trunk. I'm reminded that, out of bullheaded arrogance, GM has lost more than half its 60 percent market share since the 1960s by making ugly, often slipshod vehicles. It missed the rise of the small car in the '70s and the SUV in the '90s. Now ponderous, elephantine General Motors is claiming not only to be able to read the post-gasoline future but to accelerate it as well. What's going on here?

WHAT'S GOING on is that after decades of tinkering with nonpolluting cars in a desultory, "chump change budget to satisfy the enviros" kind of way, GM is getting serious. To be sure, there is cause for skepticism. The hydrogen fuel cell has long been the miracle that remains perpetually 10 years over the horizon. Wired itself wrote in 1997, "Fuel cell momentum is now so great that its emergence as a predominant technology appears just short of inevitable." GM CEO Rick Wagoner is fond of calling the fuel cell car "the Holy Grail," which may be a truer assessment than he intends. "The Holy Grail is something you spend your entire life looking for," grumbles David Redstone, editor of the newsletter Hydrogen & Fuel Cell Investor. "The whole point is that you never find it."

Detroit's eco-car efforts have been largely a matter of public relations. As they cynically wrap themselves in the Earth Day flag by promising hydrogen-powered cars, automakers have been using their muscle to keep federal fuel-efficiency standards exactly where they were when enacted in 1975. Freed of stringent regulation, the Big Three have reaped billions selling high-profit, gas-guzzling SUVs. Look at the window stickers on GM's current crop, arrayed in the Renaissance Center lobby - Chevrolet Avalanche: 13 city, 17 highway. GMC Denali: 12, 15. Cadillac Escalade: 12, 15. My Pontiac GTO got better mileage than this 33 years ago. Individual engines have become more efficient, but because "light trucks" (SUVs, pickups, and minivans) constitute half of all vehicle sales (54 percent for GM last year), national average fuel economy is at its lowest since 1980: 20.4 mpg.

In January, the Bush administration scrapped a $1.5 billion Clinton-era program to develop an 80-mpg car by 2004. Instead, the White House launched FreedomCAR (the "CAR" stands for cooperative automotive research), promising $125 million next year plus more later to help automakers in pre-competitive hydrogen power research. The initiative set no hard goal or deadline for producing an H2-powered car, so environmentalists see it as a Big Oil/Big Three/GOP plot to distract the public from the need to mandate immediate, radical increases in fuel efficiency. The New York Times wrote that the only freedom that FreedomCAR will bestow is on "the manufacturers, now relieved of the obligation (absent strong new fuel economy standards) to produce serious breakthroughs in the next few years."

Which may be true. Point is, though, it doesn't matter. Even if Bush's hydrogen-car initiative is a cynical ploy, even if the Big Three are hiding behind hydrogen promises to prolong the reign of the V-8 and oilmen secretly want to strangle the fuel cell in its cradle, simple geology is carrying us toward a post-gasoline future. Petroleum's days are numbered. GM executives themselves understand that. Some say the oil will last 20 more years and some say 50, but nobody says forever. "The internal combustion engine is an incredibly efficient source of power, but we've wrung the towel," Wagoner concedes.

That's why every automaker in the world has a merry band of H2istas who are developing fuel cells. At least eight major companies have drivable prototypes, most of them designed around fuel cells built by Ballard Power Systems of Vancouver. Even so, most automakers seem to see their fuel cell projects as a grudging long-term hedge against the dark day when the recoverable oil runs out, and they talk in terms of 20 or 30 years before putting such cars in showrooms.

GM executives, on the other hand, promise to deliver the AUTOnomy in less than a decade, and sometimes find themselves rather giddily wishing the gasoline would end sooner rather than later so they can start making real money. GM is the only US automaker developing its own fuel cell in-house: at the company's Warren, Michigan, research facility; at a 300-engineer skunk works near Rochester, New York, that recently expanded by 80,000 square feet; and at a third center in Mainz-Kastel, Germany.

But GM is different in a more important way. Most carmakers see the combination of a fuel cell with a big electric motor as a simple replacement for the internal combustion engine: DaimlerChrysler's fuel cell Voyager looks and drives like a Voyager and Ford's fuel cell Focus looks and drives like a Focus. That puts the fuel cell at a brutal cost disadvantage to the internal combustion engine, making a fuel cell car economically impossible.

GM took a radically different approach. Realizing that a fuel cell system could allow for an utterly new shape, the designers tossed out the design requirements of a conventional engine and devised a car from scratch. Once GM walked through that door, a universe of possibilities opened up; except for the familiar four wheels, the AUTOnomy bears almost no resemblance to a traditional auto. The implications go way beyond design and deep into the economics of manufacturing. By replacing most of the hardware in today's cars with wires and circuits that will be standard across multiple models, the AUTOnomy will allow GM to streamline its production system and drastically cut costs. That's the trick that might make the fuel cell car a reality in eight years instead of 30. Moreover, GM sees this as a way to extend car ownership to the 88 percent of the world's population that can't afford one today, opening the door to exponential increases in profits. It turns out that concentrating on the car, instead of just on the fuel cell, makes all the difference. And nobody is more surprised than General Motors.

LAWRENCE BURNS is GM's vice president of R&D and planning; this being GM, I expect a square-headed fossil in a charcoal suit — something along the lines of Donald Rumsfeld or Bob McNamara.

Burns jumps out of his seat as I walk in, looking more like a leonine yoga instructor in a tight black turtleneck, his outsize head wreathed in boyish blond curls. He's a car guy from way back, having started in GM's R&D department at age 18 while getting his undergraduate engineering degree at General Motors Institute. At 51, he's a high priest of the internal combustion engine, yet all he wants to talk about is hydrogen. "We've been working on internal combustion engines for a hundred years, and conceptually they're the same as they ever were," he says. "The fuel cell is as big a change from the internal combustion engine as the internal combustion engine was from the horse."

Burns is one of 15 mandarins on the so-called Automotive Strategy Board that charts the course of the world's third-largest company. Because GM leadership has undergone several shake-ups since the early '90s - when the carmaker bottomed out — Burns and his fellow top execs can blame GM's legendary mistakes on "the old regime."

While the company was recovering in the mid-1990s, it began developing a fuel cell system that would extract hydrogen from gasoline on board a vehicle; the prototype was unveiled last August in a Chevy S-10 pickup. The engineers knew gasoline fuel cells would be an interim technology on the path to a pure-hydrogen cell, but it would be cleaner and more efficient than a conventional engine and take advantage of the existing gas station infrastructure. In 1998, the year the Strategy Board was formed, GM opened the Global Alternative Propulsion Center, an in-house organization to advance fuel cell technology.

The basics have been understood for a long time. The first fuel cell was tested in 1839, and improved versions powered the Apollo spacecraft of the '60s and '70s. Think of the fuel cell as an atomic sieve: The nuclei of hydrogen atoms pass through a coated plastic membrane, then combine with ambient oxygen to form water - the only emission. The electrons, meanwhile, are siphoned off as electricity.

There are problems, of course. Because fuel cells are wet inside, they tend to freeze and stop working in cold weather. Because they are delicate, they aren't suited for bumpy roads. Because they require rare metals such as platinum to coat their membranes, they are expensive. It currently takes more energy to extract hydrogen from natural gas or other fuels than the hydrogen itself delivers. And researchers have yet to figure out how to store enough hydrogen on board a fuel cell car to deliver the obligatory 300-mile range.

Beyond the technological roadblocks, there's a huge chicken-and-egg quandary: Nobody is going to create a network of hydrogen fueling stations comparable to the existing 175,000 gas stations in the US until enough cars on the road require them, and nobody is going to buy — or build — a hydrogen-powered car until it can be refueled anywhere.

Fuel cells for stationary applications — backup power for computers, home generators, even laptop batteries — could appear within a couple of years. Nextel, for example, is beginning to test fuel cells made by Hydrogenics of Toronto as backup power for cell phone towers. But while cars may be the most difficult application of the fuel cell, from the point of view of the environment and national energy independence they're the most important — two-thirds of the oil consumed in the US goes to transportation, mostly to cars and trucks.

The ascent of fuel cells has been oversold in recent years, yet it's also true that a rough variant of Moore's law has applied. In the past decade, their power density (output per weight) has increased by a factor of 10; they've gone from being bus-sized to fitting in tiny cars; and their cost has dropped from a thousand times more expensive than the gasoline engine to only 10 times more.

Like every other car company, GM's dream originally went only as far as dropping in a fuel cell and a big electric motor where a gasoline engine once stood. Then, in June 2000, Burns hired Christopher Borroni-Bird, a frustrated British physicist from DaimlerChrysler's engineering department, to be the director of design and technology fusion.

"At Chrysler, we tended to develop the shape of a car and then look in the parts bin to see how we could make it," says Borroni-Bird, whose spiky hair and slight build make him look younger than his 37 years. "I thought, why not create a group that fuses design and technology from the start?"

He got his chance at GM, where the fuel cell people weren't thinking of the design implications, and the design people weren't thinking about the fuel cell. At first, Borroni-Bird saw the technology as a way to free Detroit's designers from the constraints of a traditional car - unlike the internal combustion engine, fuel cells could be configured flat enough to fit into a car's floor. Eight months after Borroni-Bird took the job, a group of engineers from the Swedish company SKF gave GM a preview of a project called Filo they were readying for the 2001 Geneva Auto Show. Though conventionally powered, Filo did away with mechanical steering, clutch, and braking hardware, replacing it all with wires and circuits controlled by a joystick. Combine a pure-hydrogen fuel cell with this kind of drive-by-wire technology and put an electric motor in each wheel, Borroni-Bird thought, and the last constraints on car design go out the window.

What emerged from Borroni-Bird's nine-designer shop early last year was the blueprint for a contraption that looks like a giant skateboard, with motors in the wheels and the power supply and controls built into the 6-inch-thick chassis - a blank slate upon which the permutations of body style and interior are endlessly drawn. Seats don't have to lie in rows. The trunk can run the length of the car. The driver can choose where to sit.

Borroni-Bird's big idea might have been shoved into a deep drawer full of futuristic concept cars, were it not for Larry Burns. Burns saw that its implications went beyond design and into manufacturing, and he had the muscle to make things happen. Look under a modern car at all the hardware that steers and brakes it. Look at the transmission. Imagine how many people and acres of factory floor it takes to design, machine, assemble, and ship all that iron. Then imagine all of it gone.

IT COSTS nearly a billion dollars to bring a new Chevrolet or Buick to market. Every engine GM makes requires its own factory, and every car model a unique set of running gear. Fuel cells, on the other hand, easily scale. "You can make a 25-kilowatt fuel cell stack and a 1,000-kilowatt stack in the same plant" by adding or subtracting layers of membrane, GM's Burns says. And the AUTOnomy has no mechanical running gear. Everything needed to power and control the car is built into the skateboard chassis. This means fewer factories devoted to manufacturing the car's power source, and no factories at all making steering and braking hardware. Moreover, a single chassis can serve as the basis of every GM model from sports car to SUV, which means economies of scale that Henry Ford could never have imagined. Even if the cost of the fuel cell never drops to the level of a gasoline engine, the car built around it might be economical enough to offset the greater expense. "It's adding drive-by-wire that really makes the fuel cell plausible," Burns says.

So the AUTOnomy might prove to be even cheaper than today's cars. But as Burns spins it, even if the AUTOnomy turns out to cost more than a conventional car, people might be willing to pay more because it will do things today's cars cannot - such as last 20 years. As it will have almost no moving parts except for the suspension, there will be little to wear out, and its owner could simply buy new bodies when styles change instead of trading in the whole car. Depending on how cleverly GM can engineer the hardware that will hold the body to the chassis, it's conceivable you could own both a summer convertible body and a winter hardtop, or even slap on the roadster for a Saturday drive and the pickup for a run to the dump. The AUTOnomy will accelerate like an F-111 because its electric motors will deliver instant torque to the wheels. It will be silent. The wheels will be controlled independently, allowing the car to swivel and move sideways, doing away with the cumbersome three-point turn. And like other fuel cell cars, the AUTOnomy will generate more than enough juice to power a house, helping you reduce reliance on the power grid. "Perhaps they will be mortgaged instead of financed like today's cars," Burns muses.

Cars that last 20 years don't sound like a moneymaker for General Motors; however, GM could make up for lower repeat sales in the US by cracking the global markets long sought by the industry. "Just 12 percent of the world's population can afford to own a car or truck," Burns says. "We want to grow that penetration, and even if they were cheap enough you couldn't do it with the internal combustion engine. If you want to expand from the current 700 million cars in the world to even a billion, can the world sustain that? You have to get at emissions and affordability."

AUTOnomy's greatest untapped market might be in China, where there isn't already an entrenched gasoline network. In GM's dreams, the AUTOnomy becomes ready to debut at about the time China's billion-plus people are economically ready for car ownership. China builds a system to deliver hydrogen without ever having one in place for gasoline, the way some African countries are leapfrogging telephone cables and moving straight to cellular. Chinese farmers are given the chance to use a single chassis for both tractor and market truck, and, if they hook up to their houses at night, they make wiring rural China for electricity unnecessary.

Sounds far-fetched, but GM is bent on pursuing this vision. The AUTOnomy has catapulted a back-burner, maybe-someday project of GM's H2istas into mainstream play. Burns won't reveal his exact R&D budget but says fuel cells are "the biggest item on our budget by several orders of magnitude ... bigger by a long shot than improving the internal combustion engine." The company has spent "in the high hundreds of millions of dollars" on the fuel cell, which approaches the $1 billion it costs to bring an entirely new conventional car to market. In addition to its direct R&D investments, GM has been on a shopping spree, buying up shares in fuel cell-related concerns. In 2000, it took a 30 percent share of a new joint venture with Giner Electrical Systems, which made fuel cells for the Navy and NASA. Last year, GM acquired 24 percent of Hydrogenics; 20 percent of Quantum Technologies, a hydrogen-storage company; and 15 percent of General Hydrogen of Vancouver. (It has not disclosed how much it spent for these.) It has also launched a hydrogen fuel cell research partnership with Suzuki Motor of Japan and collaborations with ExxonMobil and Chevron/Texaco to develop the gasoline-powered fuel cell as an "interim strategy until a hydrogen infrastructure is established."

Burns says that for business reasons he's picked 2010 as the year the AUTOnomy will be mass-produced. "If we're not there by then, we'll have dug too deep a hole to recover the time value of that money," well over a billion dollars if the current rate of expenditure continues.

"We're coming up on the moment when GM is going to have to choose between the old and new ways," he says. "Investments in internal combustion engines last 15 to 20 years, so we're going to sit down in 2005 and decide whether to create a new six-cylinder engine to appear in 2008 and still be used in 2020."

He sits forward and raises a finger. "Or," he goes on, "we will decide those resources are better spent on fuel cells. That will be a fascinating meeting, and it will happen during my career."

BYRON McCORMICK, the phlegmatic 56-year-old physicist in charge of GM's program, has been working on fuel cell cars for decades, first at Los Alamos National Labs. He arrived at General Motors in 1986, but the company's fuel cell efforts date back to 1966 and an experimental, 7,000-pound two-seat behemoth called Electrovan. McCormick says the company is on its way to solving the problem of fuel cells freezing; by tweaking the design and reducing the amount of water inside the stack, GM's H2istas can start up a fuel cell within 15 seconds at 20 below zero. The company is also experimenting with replacing the platinum on the membranes with hemoglobin, which would radically reduce their cost. "But the problem that keeps me up at night," he says, "is storage."

For all the talk of throwing away the rule book, GM executives are loathe to break this tenet: The Amount of Sacrifice Americans Will Be Willing to Make to Drive a Nonpolluting Car Is Exactly Zero. Any future vehicle — even one that pirouettes — must be able to go at least 300 miles between fuelings and take no longer than five minutes at the pump. GM's plug-in electric car, first offered to the public in 1997, could do neither of these things, and so, though it was quick, fun, silent, and nonpolluting, GM pulled it from the market in 1999. Now McCormick wonders how to get enough hydrogen on board the car to give it the 300-mile range drivers expect.

Pressurized tanks won't do it. Even if you could double their current pressure and wedge enough of them into a car, people would reject this approach for fear the tanks would explode. For a while, GM scientists experimented unsuccessfully with "nanotube" storage — microscopic tubes of carbon mesh that hold single rows of H2 molecules lined up like billiard balls. The current hope is a variety of metal hydrides, blocks of specialized metal that soak up hydrogen like a sponge and release it on demand. GM's hydrides now store about half as much hydrogen as will be required to give the AUTOnomy a 300-mile range, and Burns concedes the 300-mile fuel cell may be as chimeric as the 300-mile battery.

So he and McCormick play the same game with AUTOnomy's price tag: They envision the future two ways. While genuflecting before the tyranny of consumer preference, they gingerly approach the unthinkable by wondering if they can change expectations. Specifically, if GM can't crack the storage nut, can it bring along other technologies to compensate for the inconvenience? What if you could make your own hydrogen out of water, right in the garage? The technology is already available; you electrolyze water by more or less running a fuel cell in reverse. At the moment, this takes more electricity than the hydrogen would ultimately generate. Giner Electrical, which GM just bought, is developing an electrolyzer the size of a dishwasher and GM wants to accelerate its refinement.

"If you can reform natural gas or electrolyze water at home, you can also do it at rest areas, gas stations, and McDonald's," Burns says. "If you can do that, will a 200-mile range do it?"

GM CEO Rick Wagoner is the yin to Burns' yang, the man who tethers the H2istas' dreams to grim Detroit reality. "Consumers aren't in any way motivated to buy anything but the vehicle they want," Wagoner says, "and if you don't sell them what they want, they'll buy somebody else's." The plug-in-car experience, Wagoner explains, taught everyone the folly of asking the public to adapt to technology instead of the other way around.

As for government regulation forcing change, heaven forfend. "[Federal efficiency standards] are a failure for good reason," Wagoner says. "They force automakers to make small cars people don't want." He embraces only one government role: The Feds are the single entity big enough to break the chicken-and-egg problem by providing the incentives to build a hydrogen-fueling infrastructure. Gestures like FreedomCAR, modest as they are, indicate to Wagoner that Washington may be willing to step in when the time is right.

To Wagoner, the AUTOnomy — even without China — offers the chance to take the car industry into the post-gasoline future without consigning the world to bloodless little transport pods or, shudder, public transportation. "The payoff for us," he says, "could be huge."

Get real, I reply. From here atop the Renaissance Center, does it really look as though the future of General Motors is in something other than the internal combustion engine — the old-fashioned motor? Will the Pistons change their name to the Membranes?

"We're not betting the ranch," he says, leaning back and hooking his thumbs into his belt loops. "But if you want to be a big player in the auto industry," you have to embrace fuel cells in a real way. "And we're big. We wanna play."

H2PAC

SOURCE: http://www.h2pac.org/

H2 PAC
Mission Statement

The Hydrogen Political Action Committee (H2 PAC) is a non-profit, non-partisan political organization whose primary objective is to support legislation that will accelerate the transition from oil and other fossil and nuclear fuels to solar hydrogen energy systems that can make the United States energy independent and essentially pollution-free.

Hydrogen is the only zero carbon emission "universal fuel" that can power virtually any engine or appliance, from the family automobile, commercial aircraft, moon rockets, power plants, or a Coleman stove on a mountain top. When hydrogen is used as fuel, pure water is returned as the combustion byproduct, thus no pollution is generated, and nothing is consumed in the process. Hydrogen is completely non-toxic in the event of a spill, and unlike electricity, it can be transported by pipelines, ships and tanker trucks to energy markets worldwide. Hydrogen can be extracted from water with any source of electricity, and it is the only carbon-free fuel that can displace oil, coal, natural gas and nuclear fuels on a global scale.

Extensive field tests over many decades by NASA and BMW have shown hydrogen to be much safer than gasoline or other hydrocarbon fuels when accidents do occur. This is because hydrogen is the lightest element in the universe, thus if it is released, it dissipates in seconds. Indeed, if the two aircraft which impacted the World Trade Center were fueled with liquid hydrogen, the resulting fire would have only lasted a few seconds. As a result, the steel support structures within the buildings would not have melted, and the World Trade Center would not have collapsed.

Osama bin Laden and his supporters have been financed by oil revenues, most of which have been provided by the U.S. and our allies. As such, it is now time to shift from oil to hydrogen with wartime speed. For more information on how you can join this "transition of substance," contact H2 PAC at (602) 977-0888 or info@h2pac.org.

Study: Hydrogen Fuel May Make Earth Cooler, Cloudier

SOURCE: http://www.planetark.org/dailynewsstory.cfm/newsid/21240/story.htm
13 Jun 2003 19:23 BST

WASHINGTON (Reuters) - Hydrogen fuel cells, the widely hailed pollution-free energy source of the future, may turn out not to be so kind to the Earth, scientists said on Friday.

Providing the hydrogen needed by all those fuel cells might create a cloudier, cooler planet, with larger and longer-lasting atmospheric ozone holes over the poles, said researchers from the California Institute of Technology in Pasadena.

Hydrogen fuel cells are seen as potentially emissions-free energy sources for everything from automobiles to homes, replacing fossil fuel engines and eliminating the noxious pollutants that damage lungs and build up heat-trapping gases cited in theories of global warming.

But in producing and transporting hydrogen needed to fuel the aspiring technology, roughly 10 percent to 20 percent of the gas can be expected to leak into the atmosphere, the report in the journal Science said.

Quadrupling the levels of hydrogen gas -- actually two molecules of hydrogen -- in the air from the current 0.5 parts per million would create more water vapor in the stratosphere as the hydrogen combines with oxygen, resulting in more cloud cover, the report said.

Computer models used by study author Tracey Tromp suggested stratospheric temperatures could cool by 0.5 degrees Celsius, slowing the arrival of spring in the North and South polar regions and expanding the size, depth and longevity of the ozone holes.

Less ozone in the upper atmosphere, which allows more of the sun's dangerous rays to reach the Earth and has increased skin cancer risks, is widely blamed on mankind's release of now-banned chlorofluorocarbons, chemicals used in refrigerants and as propellants.

The ozone layer was expected to recover in 20 to 50 years as chlorofluorocarbon levels ease, though an injection of hydrogen into the atmospheric mix might worsen the problem, the report said.

More hydrogen in the air would likely also have a direct impact on the Earth's teeming surface, as it is a nutrient for microbes, it said.

Hydrogen is No Gas, Yet

SOURCE: http://www.wired.com/news/technology/0,1282,59322,00.html

By Mark Baard 02:00 AM Jun. 23, 2003 PT

The hydrogen economy is getting off to a shaky start.

Toyota in May recalled its fuel-cell hybrid vehicle in Japan when one of the cars sprung a leak from its hydrogen tank. Last week, researchers from the California Institute of Technology, in a Science magazine report, argued that large amounts of hydrogen leaking into the atmosphere will damage the ozone layer.

And consumers of natural gas -- already the primary source of hydrogen for everything from hydrogenated foods to NASA rockets -- learned this week that natural-gas supplies are at their lowest levels in 25 years.

While much of the news has been bad, many scientists believe they can cultivate alternative resources for hydrogen and fix leaky gas tanks. They also cast doubt on the hydrogen leak estimates from the Caltech researchers. But they concede that fuel-cell stacks, which mix hydrogen with oxygen to make electricity, are still too fragile and expensive to be practical for automobile use.

The bad news about natural-gas supplies is a boon to advocates of renewable energy, however. They see hydrogen fuel cells as an aid to the development of energy sources other than fossil fuels. "Fuel cells are a critical technology because of their high efficiency and low impact," said Charles Chamberlin, co-director of the Schatz Energy Research Center at Humboldt State University. "We can use excess wind and solar energy to electrolyze water and produce hydrogen, and then draw that out of storage for use in the fuel cells."

Scientists also said that transporting hydrogen from fossil fuel plants to automobile filling stations will be more difficult than anyone has anticipated.

"There is no infrastructure for getting hydrogen from the oil or gas company to the gas station safely, cost effectively and in a way that is environmentally beneficial," said Andrew Bocarsly, director of graduate studies for chemistry at Princeton University.

The estimates that the Caltech researchers used to predict ozone damage are based in part on leaks from hydrogen in transport. To be moved efficiently, hydrogen must be pressurized, cryogenically stored or mixed in a liquid such as sodium borohydride. But leaks from cryogenically stored hydrogen can be easily recaptured, said Bocarsly, minimizing damage to the Earth's ozone layer.

The Caltech report, which predicts that 10 percent to 20 percent of the hydrogen produced will leak into the atmosphere, actually came as welcome news to those who want to make hydrogen on demand instead of storing it for long-distance delivery.

HydrogenSource, a company formed by UTC Fuel Cells and Shell Oil, is developing hydrogen processors for use at gas stations. The company also is working on an on-board gasoline-to-hydrogen processor. Users of the on-board system would fill their tanks with gasoline, which would be chemically converted to hydrogen inside the car's fuel cell.

HydrogenSource's on-board processor would not release the carbon monoxide, nitrogen dioxide and particles that are products of internal combustion engines. It would, however, release carbon dioxide, a greenhouse gas. "We can't make this gigantic jump from where we are today," said Ignacio Aguerrevere, marketing manager at HydrogenSource. "We're creating a bridge from the existing fossil-fuel structure to the hydrogen economy."

Regardless of how hydrogen gets into cars, engineers have yet to build fuel-cell stacks with parts that are affordable and can last 5,000 hours, which translates to about 150,000 to 200,000 miles. "And people are not going to be happy if their hydrogen car is in the shop all the time," said Bocarsly. At the moment, proton exchange membrane, or PEM, fuel cells -- which are the most highly developed -- only last for thousands of hours when nursed along on laboratory benches.

PEM fuel cells, most notably those using DuPont's Nafion membrane, decay rapidly under the stresses of chemical reactions, pressures and heat. Nafion membranes for fuel cells are approximately 125 microns thick, and can be easily perforated or torn, Bocarsly said.

Extra membrane layers can prolong the life of a fuel-cell stack, but Nafion, which is closely related to Teflon, is one of the most expensive parts of a fuel-cell stack. "You have to balance cost of the fuel cell with durability," said Noordin Nanji, vice president of corporate strategy and development at Ballard Power Systems, a producer of PEM fuel cells based in Vancouver, British Columbia.

Ballard, which claims 10 of the world's largest automakers among its customers, is looking into less-expensive, sturdier membranes and components for fuel stacks in an effort to reduce hydrogen leaks. DuPont, 3M, Ballard and other companies are developing alternatives to the current Nafion membrane.

Nanji is confident Ballard can build a robust PEM fuel-cell stack for automobile use. Said Nanji: "We already have had a stationary lab stack run up to 20,000 hours continuously."

Hydrogen Car Slow in Coming

SOURCE: http://technology.nzoom.com/cda/printable/1,1856,192945,00.html

General Motors' Hy-wire - a car with no engine, steering wheel or brake pedal - swerved between orange cones in a Trenton parking lot.

Don't think about trying this stunt at home, because you can't - and probably won't be able to for 10 or 20 years, if that.

The Hy-wire is the car of the future, and it runs on the energy of tomorrow: hydrogen fuel cells, which combine hydrogen and oxygen to produce electricity. Their only emission is water, which steams harmlessly out the tailpipe.

US President George W Bush made hydrogen a surprise star of his January State of the Union speech. He suggested the element could be fuelling America's cars by 2020, reducing environmentally harmful emissions and cutting the nation's dependence on foreign oil. He has proposed spending $2.9 billion (US$1.7 billion) over five years on research projects patriotically named FreedomCar and FreedomFuel.

And so here it is, a glimpse of freedom. The Hy-wire seats five, in an entirely flat-floored passenger compartment. Its maximum speed is about 160 kilometers per hour, but it can only go about 145 km between fill-ups.

"We've probably put over $1.7 billion ($US1 billion) into this technology over the last several years," said Greg Ruselowski, director of finance for GM's fuel cell business. He said that's more than the company invests in a programme to create a traditional new car model, "so this is a serious effort."

The Hy-wire is controlled using something called an X-drive that resembles a video-game controller. Grab its two rubber handgrips and twist either one forward to make the car move. The whirring electric motor rises in pitch like a blender as it speeds up. There's no noisy engine under the hood. There's no hood.

Squeezing either handgrip applies the brakes. Rotating the X-drive like a steering wheel turns the car, but there's no hand-over-hand turning and no steering column connecting it to the wheels. Wires that run through a computer do it all.

The drive-by-wire feature and other space age gadgets built into Hy-wire - it has video screens instead of mirrors - really have nothing to do with hydrogen. They're just to show off what designers can do when a car doesn't need an engine and mechanical connections.

"It shows you some of the design freedoms you get with a fuel cell," said Ruselowski. For example, the X-drive controller can slide from the left side to the right, so you can change drivers without switching seats, in case that ever becomes legal.

The first real hydrogen-powered cars for consumers will look traditional. GM brought four conventional-looking but fuel-cell-based minivans to Washington and will be loaning them to members of Congress.

Later this year, DaimlerChrysler plans to deliver 60 Mercedes A-Class sedans powered by fuel cells, 20 of them going to the United States, most likely in Washington, said spokesman Max Gates.

In October, Shell Hydrogen will open the first hydrogen refuelling pump at an existing US retail petrol station. It'll also be in Washington, where carmakers are shipping their prototype hydrogen-guzzlers to impress legislators.

"The intent is that the car drives up, and the driver goes through the same procedure they do now for petrol," said Phil Baxley, Shell Hydrogen's vice president of business development.

Still even hydrogen's supporters admit that reaching that fuel-and-go future on a mass scale is way off.

Hydrogen may be Earth's most plentiful element and number one on the periodic table, but it doesn't naturally exist in pure form. You have to extract it from other substances. Today, more than 90 per cent of the hydrogen produced in the United States comes from natural gas, or methane, and extracting hydrogen produces carbon emissions.

You can get hydrogen by applying electricity to water. But the concern is that "you might move emissions out of the tailpipe, but you'll still have them," said Gates, because most electricity is still produced by polluting sources such as coal.

The hope hydrogen holds for environmentalists is that it at least opens the door to cleaner energy sources, such as wind or solar power. "Nuclear power actually is an interesting possibility," said Baxley.

Other obstacles include building a national infrastructure for distributing hydrogen. There are many ways for storing hydrogen in a car, including as gas or liquid, but no standard. Meanwhile, few prototype hydrogen cars top 320 km between fill-ups.

Hydrogen Vehicle Won't be Viable Soon, Study Says

SOURCE: http://web.mit.edu/newsoffice/tt/2003/mar05/hydrogen.html

Hydrogen Vehicle Won't be Viable Soon, Study Says

By NANCY STAUFFER

Laboratory for Energy and the Environment

Even with aggressive research, the hydrogen fuel-cell vehicle will not be better than the diesel hybrid (a vehicle powered by a conventional engine supplemented by an electric motor) in terms of total energy use and greenhouse gas emissions by 2020, says a study recently released by the Laboratory for Energy and the Environment (LFEE).

And while hybrid vehicles are already appearing on the roads, adoption of the hydrogen-based vehicle will require major infrastructure changes to make compressed hydrogen available. If we need to curb greenhouse gases within the next 20 years, improving mainstream gasoline and diesel engines and transmissions and expanding the use of hybrids is the way to go.

These results come from a systematic and comprehensive assessment of a variety of engine and fuel technologies as they are likely to be in 2020 with intense research but no real "breakthroughs." The assessment was led by Malcolm A. Weiss, LFEE senior research staff member, and John B. Heywood, the Sun Jae Professor of Mechanical Engineering and director of MIT's Laboratory for 21st-Century Energy.

Release of the study comes just a month after the Bush administration announced a billion-dollar initiative to develop commercially viable hydrogen fuel cells and a year after establishment of the government-industry program to develop the hydrogen fuel-cell-powered "FreedomCar."

The new assessment is an extension of a study done in 2000, which likewise concluded that the much-touted hydrogen fuel cell was not a clear winner. This time, the MIT researchers used optimistic fuel-cell performance assumptions cited by some fuel-cell advocates, and the conclusion remained the same.

The hydrogen fuel-cell vehicle has low emissions and energy use on the road-but converting a hydrocarbon fuel such as natural gas or gasoline into hydrogen to fuel this vehicle uses substantial energy and emits greenhouse gases.

Iceland Wants to Become World's First Hydrogen-Powered Economy

SOURCE: http://www.icelandnews.com/

TOKYO -- Iceland could become the world's first economy free from the fossil fuels that add to global warming if it manages to produce enough hydrogen using renewable energy sources to run fuel cells, an official said here.

"Iceland has the goal to have become a hydrogen economy by the year 2040," said the country's ambassador to Japan, Ingimundur Sigfusson.

"However, to realize this vision Iceland is dependent upon the development of fuel cell technology and the technology for storage of hydrogen, which is still a handicap," he told AFP.

Fuel cells produce electricity through a reaction between hydrogen (H_2) and oxygen (O_2), which leaves behind water (H_2O). But a large part of the hydrogen must still be produced using natural gas, which generates carbon dioxide (CO_2) that adds to global warming.

A volcanic country with plentiful sources of natural hot water, as well as waterfalls which generate hydropower, Iceland uses renewable energy to generate more than 70 percent of its power -- 50 percent comes from geothermal means and 20 percent from waterfalls.

About 90 percent of Iceland's houses are heated by hot water from under the ground and a growing portion of the nation's electricity is produced using steam generated from geothermal resources.

The fact that just 17 percent of its geothermal and hydro energy resources have been harnessed has encouraged the Atlantic Ocean island of 288,000 inhabitants to strive to become fully independent of fossil fuels.

"We are optimistic that by using these sources of power to produce hydrogen and by converting to hydrogen for transport between 90 and 95 percent of our total energy needs will be met from renewable sources," Iceland's Prime Minister David Oddsson declared last September at the Earth Summit in South Africa.

Iceland is taking part in a European environmentally friendly power project, Ecological City Transport System (ECTOS), and aims to have three DaimlerChrysler hydrogen buses driving through the streets of Reykjavik starting on August 31. The cost of the project is covered 40 percent by the European Union.

A plan to create a fishing fleet that is also powered by hydrogen is a longer-term project, however.

A number of companies are conducting research into this area, including Japanese machinery giant Ishikawajima-Harima Heavy Industries.

Why Hydrogen?

Source: http://www.rmi.org/

Why Hydrogen?

Hydrogen, first on the periodic table of the elements, is the least complex and most abundant element in the universe. Using hydrogen as fuel can fundamentally change our relationship with the natural environment.

As a nearly ideal energy carrier, hydrogen will play a critical role in a new, decentralized energy infrastructure that can provide power to vehicles, homes, and industries. Hydrogen boasts many important advantages over other fuels: it is non-toxic, renewable, clean to use, and packs much more energy per pound. Hydrogen is also the fuel of choice for energy-efficient fuel cells.

Health and Environmental Safety

Hydrogen, which exists as a gas under normal atmospheric conditions, is odorless, colorless, and tasteless. It is both non-toxic and safe to breathe. It can also be safely transported. In a hydrogen-based energy economy, environmental disasters like the Exxon Valdez debacle would be relegated to history. Because hydrogen dissipates when leaked, a major hydrogen spill would amount to little more than a waste of precious fuel.

The Many Problems with Fossil Fuels

To appreciate the various benefits of hydrogen as an energy carrier, it is important to understand the shortcomings of fuels we depend upon today. Conventional petroleum-based fuels like gasoline or diesel, as well as natural gas and coal, all contain carbon. When these fuels are burned, their carbon recombines with oxygen from the air to form carbon dioxide (CO_2), the primary greenhouse gas that causes global warming.

Furthermore, combustion of fossil fuels at the high temperatures and pressures reached inside an internal combustion (IC) engine (what powers most vehicles) or in an electric power plant produces other toxic emissions. Carbon monoxide (a poison), oxides of nitrogen and sulfur (NO_x and SO_x), volatile organic chemicals, and fine particulates are all components of air pollution attributable to the refining and combustion of fossil fuels. When released into the atmosphere, many of these compounds cause acid rain or react with sunlight to create ground-level smog. Vast ecosystem damage, increased lung disease and cancer are the ultimate price we pay for consuming these fossil fuels.

Superior Efficiency

Modern industrial development relied upon the widespread exploitation of these carbon-rich fuels. Mined in abundance, they were burned with little regard for overall system efficiency. But the search for alternatives has exposed another major shortcoming of carbon-based fuels: their energy is difficult to capture. Harnessing explosions—the process by which an IC engine converts chemical energy into mechanical energy—is inherently inefficient. Even after more than a century of refinement, most IC engines capture only 15–20% of the energy in gasoline. The rest of that energy is lost as waste heat and vibrational noise. Centralized electricity generation is similarly inefficient. The U.S.'s current electric system converts 33% of fuel energy into electricity and squanders most of the remaining heat.

In stark comparison, fuel cells running on pure hydrogen are dramatically more efficient. By harnessing the fuel's energy via a chemical reaction rather than combustion, a fuel cell can convert 40–65% of hydrogen's energy into electricity. While a hydrogen-burning IC engine pollutes less than one running on gasoline, its energy efficiency is still less than half that of a fuel cell.

Because a fuel cell's energy efficiency is not scale-dependent, stationary fuel cells can be sited locally where the waste heat can be used. This cogeneration of heat and power brings a fuel cell's energy efficiency close to 90%. All the while, this unparalleled energy efficiency arises from a reliable device that emits only drinkable water and scant traces of other emissions.

Decarbonization: the Trend Towards Clean Renewables

Post-industrial nations tend to favor energy-fuel decarbonization—a migration toward fuels with lower concentrations of carbon (exemplified by the shift from coal- to natural gas-fired electricity in the U.S.). Less carbon implies a greater concentration of hydrogen, which boasts a much greater specific energy density and burns more cleanly. As the trend progresses, pure gaseous hydrogen fuel waits as the ultimate goal.

Looking ahead, it is also important to consider that fossil fuels are finite: we will eventually run out of them. This is not the case with hydrogen. Because this renewable energy carrier can be made from the electrolytic decomposition of water, and becomes water again when joined with oxygen in a fuel cell, hydrogen is inexhaustible. And when the process of electrolysis is powered by renewable electricity, the energy lifecycle of hydrogen is entirely pollution-free. In the meantime, transitional methods exist to make hydrogen with relatively moderate environmental impact.

We currently consume fossil fuels 100,000 times faster than they are made, inspiring much speculation about how long our worldwide supplies will last. But the actual date of empty wells is largely irrelevant. The many benefits of hydrogen will make petroleum fuels obsolete at low prices before their scarcity sends drilling costs skyward. In the coming years, we will begin to see our energy economy, now rooted in fossil fuels, replaced by a hydrogen economy.

How Hydrogen Can Save America

Source: http://www.wired.com/wired/archive/11.04/hydrogen.html

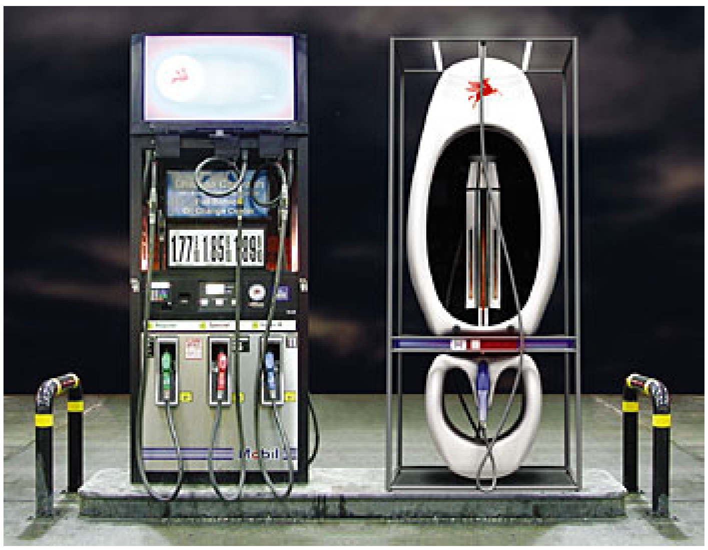
The cost of oil dependence has never been so clear. What had long been largely an environmental issue has suddenly become a deadly serious strategic concern. Oil is an indulgence we can no longer afford, not just because it will run out or turn the planet into a sauna, but because it inexorably leads to global conflict. Enough. What we need is a massive, Apollo-scale effort to unlock the potential of hydrogen, a virtually unlimited source of power. The technology is at a tipping point. Terrorism provides political urgency. Consumers are ready for an alternative. From Detroit to Dallas, even the oil establishment is primed for change. We put a man on the moon in a decade; we can achieve energy independence just as fast. Here's how.

By Peter Schwartz and Doug Randall

Four decades ago, the United States faced a creeping menace to national security. The Soviet Union had lobbed the first satellite into space in 1957. Then, on April 12, 1961, Russian cosmonaut Yuri Gagarin blasted off in Vostok 1 and became the first human in orbit.

President Kennedy understood that dominating space could mean the difference between a country able to defend itself and one at the mercy of its rivals. In a May 1961 address to Congress, he unveiled Apollo - a 10-year program of federal subsidies aimed at "landing a man on the moon and returning him safely to the Earth." The president announced the goal, Congress appropriated the funds, scientists and engineers put their noses to the launchpad, and - lo and behold - Neil Armstrong stepped on the lunar surface eight years later.

The country now faces a similarly dire threat: reliance on foreign oil. Just as President Kennedy responded to Soviet space superiority with a bold commitment, President Bush must respond to the clout of foreign oil by making energy independence a national priority. The president acknowledged as much by touting hydrogen fuel cells in January's State of the Union address. But the $1.2 billion he proposed is a pittance compared to what's needed. Only an Apollo-style effort to replace hydrocarbons with hydrogen can liberate the US to act as a world leader rather than a slave to its appetite for petroleum.



Tronic Studio

Money can do more than ease the pain of lost income. It can turn oil companies into the hydrogen economy's standard bearers.

Once upon a time, America's oil addiction was primarily an environmental issue. Hydrocarbons are dirty - befouling the air and water, possibly shifting the climate, and causing losses of biodiversity and precious coastal real estate. In those terms, the argument is largely political, one of environmental cleanliness against economic godliness. The horror of 9/11 changed that forever. Buried in the rubble of the World Trade Center was the myth that America can afford the dire costs of international oil politics. The price of the nation's reliance on crude has included '70s-style economic shocks, Desert Storm-like military adventures, strained relationships with less energy-hungry allies, and now terror on our shores.

George W. Bush arrived in Washington, DC, as a Texan with deep roots in the oil business. In the days following September 11, however, he transformed himself into the National Security President. Today, his ambition to protect the United States from emerging threats overshadows his industry ties. By throwing his power behind hydrogen, Bush would be gambling that, rather than harming Big Oil, he could revitalize the moribund industry. At the same time, he might win support among environmentalists, a group that has felt abandoned by this White House.

According to conventional wisdom, there are two ways for the US to reduce dependence on foreign oil: increase domestic production or decrease demand. Either way, though, the country would remain hostage to overseas producers. Consider the administration's ill-fated plan to drill in the Arctic National Wildlife Refuge. For all the political wrangling and backlash, that area's productivity isn't likely to offset declining output from larger US oil fields, let alone increase the total supply from domestic sources. As for reducing demand, the levers available are small and ineffectual. The average car on the road is nine years old, so even dramatic increases in fuel efficiency today won't head off dire consequences tomorrow. Moreover, the dynamism at the heart of the US economy depends on energy. Growth and consumption are inextricably intertwined.

There's only one way to insulate the US from the corrosive power of oil, and that's to develop an alternative energy resource that's readily available domestically. Looking at the options - coal, natural gas, wind, water, solar, and nuclear - there's only one thing that can provide a wholesale substitute for foreign oil within a decade: hydrogen. Hydrogen stores energy more effectively than current batteries, burns twice as efficiently in a fuel cell as gasoline does in an internal combustion engine (more than making up for the energy required to produce it), and leaves only water behind. It's plentiful, clean, and - critically - capable of powering cars. Like manned space flight in 1961, hydrogen power is proven but primitive, a technology ripe for acceleration and then deployment. (For that, thank the Apollo program itself, which spurred the development of early fuel cells.)

Many observers view as inevitable the transition from an economy powered by fossil fuels to one based on hydrogen. But that view presupposes market forces that are only beginning to stir. Today, power from a fuel cell car engine costs 100 times more than power from its internal combustion counterpart; it'll take a lot of R&D to reduce that ratio. More daunting, the notion of fuel cell cars raises a chicken-and-egg question: How will a nationwide fueling infrastructure materialize to serve a fleet of vehicles that doesn't yet exist and will take decades to reach critical mass? Even hydrogen's boosters look forward to widespread adoption no sooner than 30 to 50 years from now. That's three to five times too long.

Adopting Kennedy's 10-year time frame may sound absurdly optimistic, but it's exactly the kick in the pants needed to jolt the US out of its crippling complacency when it comes to energy. A decade is long enough to make a serious difference but short enough that most Americans will see results within their lifetimes. The good news is that the technical challenges are issues of engineering rather than science. That means money can solve them.

How much money? How about the amount spent to put a man on the moon: $100 billion in today's dollars. With that investment, the nation could shift the balance of power from foreign oil producers to US energy consumers within a decade. By 2013, a third of all new cars sold could be hydrogen-powered, 15 percent of the nation's gas stations could pump hydrogen, and the US could get more than half its energy from domestic sources, putting independence within reach. All that's missing is a national commitment to make it happen.

It'd be easy - too easy - to misspend $100 billion. So the White House needs a plan. The strategy must take advantage of existing infrastructure and strengthen forces propelling the nation toward hydrogen while simultaneously removing obstacles. There are five objectives:

1. Solve the hydrogen fuel-tank problem.

2. Encourage mass production of fuel cell vehicles.

3. Convert the nation's fueling infrastructure to hydrogen.

4. Ramp up hydrogen production.

5. Mount a public campaign to sell the hydrogen economy.

By pursuing all five at once, the government can create a self-sustaining cycle of supply and demand that gains momentum over the coming decade and supplants the existing energy market in the decades that follow. Rather than waiting to build a hydrogen infrastructure from scratch, the US can start building the new fuel economy immediately by piggybacking on existing petroleum-based industries. Once customers are demanding and producers are supplying, there will be time to create a cleaner, more efficient hydrogen-centric infrastructure that runs on market forces alone.

1. Solve the hydrogen fuel-tank problem

The fuel cell, essentially a battery with a replaceable energy storage medium, isn't new. The basic ideas were in place by the mid-1800s, and the first proton-exchange membrane fuel cell - the type most practical for use in automobiles - was built by General Electric in the early '60s. Unlike a combustion engine, in which exploding gas pushes pistons, a fuel cell engine strips electrons from hydrogen and uses the resulting electrical current to power a motor. Then it combines the remaining hydrogen ions (protons) with oxygen to form water, the only byproduct. (A hybrid electrical engine is something else: a gasoline engine that powers a battery.)

In 1993, Canadian fuel cell manufacturer Ballard Power Systems began using the technology in buses, which could accommodate huge first-generation hydrogen engines and fuel tanks. The engines have since become smaller, but carrying enough hydrogen for 400 miles of driving - the range consumers generally expect - remains a challenge.

The Bush administration should spend $15 billion to solve this problem. The main question is whether to carry the fuel in gas, liquid, or solid form, each of which offers its own advantages and disadvantages. Until the industry settles on a standard, the market won't support mass production or ubiquitous filling stations.

The simplest option is gaseous hydrogen. The problem: It takes up a lot of room, so the gas must be compressed, but this requires a tank capable of withstanding high pressure. To carry enough fuel for 400 miles of travel, the tank would need to withstand 10,000 pounds per square inch - 50 times the pressure in a combustion engine's cylinders - and to keep it from bursting in an impact, it would need to tolerate 20,000 pounds per square inch. More research is needed to find materials strong enough to do the job yet light enough to carry and cheap enough to mass-produce.

Liquid hydrogen also has pros and cons. It exerts far less pressure on the tank, but it must be cooled to -423 degrees Fahrenheit at the pump and kept that way in the vehicle. This refrigeration demands a significant amount of energy, and insulating the tank can multiply its size. What's more, even with the best insulation, as much as 4 percent of the liquid evaporates daily, creating pressure that can only be relieved by bleeding off the vapor. As a result, a car left at the airport for two weeks would lose half its fuel. Scientists need to find a way to eliminate or utilize this boil-off.

In the long run, the most promising approach is to fill the tank with a solid material that soaks up hydrogen like a sponge at fill-up and releases it during drive time. Currently, the options include lithium hydride, sodium borohydride, and an emerging class of ultraporous nanotech materials. Unlike gaseous hydrogen, these substances can pack a lot of power into a small space of arbitrary shape. And unlike liquid hydrogen, they can be kept at room temperature. On the other hand, energy is required to infuse the solid medium with hydrogen, and in some cases very high temperatures are required to get the fuel back out, exacting a huge toll in efficiency. Also, filling the tank can take far more time than pumping gasoline. Government money could bridge the gap between today's experiments and a viable solution.

2. Encourage mass production of fuel cell vehicles

Once the storage problem has been solved, carmakers should be encouraged to gear up for mass production of fuel cell vehicles.

Detroit is already moving in that direction. To date, DaimlerChrysler, Ford, and General Motors have spent roughly $2 billion developing fuel cell cars, buses, and trucks, with the first products due to hit the market this year. Ford chair William Clay Ford Jr. has proclaimed that fuel cells will "finally end the 100-year reign of the internal combustion engine."

To make sure the transition doesn't take another century, though, the Bush administration should allocate $10 billion to help automakers manufacture fuel cells efficiently and cheaply, either on their own (like GM) or through contracts with government-approved fuel cell developers. Funding should be contingent on the companies adhering to a strict schedule for bringing hydrogen-based vehicles to market (coordinated, of course, with the schedule for bringing fueling stations online).

A mandatory portion should be set aside for marketing. Detroit will face a tremendous hurdle of consumer acceptance, and it should take full advantage of Madison Avenue's skills to convince the public that fuel cell cars aren't just viable, but desirable. This isn't a fantasy. Toyota's Prius, the first mass-produced gasoline/electric hybrid car, has sold more than 100,000 units since its 1997 debut, proving that the public will embrace a radically different automobile.

3. Convert the fueling infrastructure to hydrogen

Of course, no one will drive a hydrogen-powered car off the lot unless they're confident they'll be able to get fuel when and where they need it. That's why the Bush administration must focus on infrastructure as well as vehicles.

Like the car companies, oil producers have already taken steps toward an oil-free future. Over the past 15 years, corporations like Shell and Exxon have ceded their leadership in oil production to a dozen state-owned enterprises in countries such as Venezuela, Brazil, and Norway. Instead they've focused on adding value farther down the supply chain by refining crude into gasoline and distributing and selling it through filling stations. They know they could play the same role in a hydrogen economy, which is why Shell and BP have invested hundreds of millions of dollars in hydrogen storage and production technology. Indeed, BP, formerly British Petroleum, has rebranded itself Beyond Petroleum.

The major oil companies are already extracting hydrogen from gasoline for industrial uses at nine refinery complexes throughout the United States. With a little push, these plants could serve as hubs for a nascent hydrogen-distribution network.

Converting filling stations is bound to cost billions of dollars over several decades. But it should cost relatively little to retrofit clusters of stations in proximity to both a hydrogen-producing refinery and a population center where fuel cell vehicles are sold. Oil companies could meet initial demand by trucking hydrogen from refineries to these stations. As the number of fuel cell vehicles on the road rises, stations that aren't served by refinery hubs could install processors, called reformers, that use electricity to extract hydrogen from gasoline or water. The White House should ask for $5 billion - roughly $30,000 for each of the nation's 176,000 filling stations - to get the ball rolling.

In the long run, a pipeline piggybacking on existing natural gas pipelines might deliver most of the fuel, either from high-volume plants or more widely distributed facilities. The administration should set aside $10 billion for incentives like interest-free loans to encourage oil companies to construct a national hydrogen pipeline. It might also grant five-to-ten-year monopoly rights to pipeline builders.

Hydrogen's fuel-efficiency offers immediate benefits to transportation companies that maintain their own vehicles and use them for limited, predictable distances. In fact, FedEx and UPS plan to phase in fuel-cell trucks over the next five years. The Bush administration should take advantage of this synergy between early adopters and the national interest by offering $10 billion in tax breaks to companies that invest in hydrogen-powered fleets. Also, in regions served by a refinery hub, $5 billion should be allocated for fuel cell police cars, ambulances, maintenance trucks, and other municipal vehicles. The military is another sensible target, since 60 percent of its logistics budget is devoted to transporting gasoline.

The critical need to build infrastructure along with vehicles brings to mind an earlier Apollo-like initiative: Eisenhower's National Defense Highway Act. As an officer during World War II, Ike struggled to move troops across the US and saw how Germany's highways conferred a military advantage. Once in the Oval Office, he called for $300 billion in today's dollars to build an interstate highway system. Funded by a gas tax, that program's dramatic success proved that national security can motivate federal infrastructure projects on a grand scale.

4. Ramp up hydrogen production

But where will the hydrogen come from? Ironically, while hydrogen is the most plentiful element in the universe, it rarely appears in its pure form. It must be extracted from substances that contain it, like fossil fuels and water. The problem is that the extraction itself requires power. Currently, the least expensive method is a process known as steam reforming, in which natural gas reacts chemically with steam to produce hydrogen and carbon dioxide, a greenhouse gas. Far preferable would be to use carbon-free resources like solar, wind, and hydropower to produce electricity for electrolysis, which splits water into hydrogen and oxygen. Hydrogen would make renewable energy practical, acting as a storage medium for the modest amounts of energy such resources produce. Wind power, especially, lends itself to this sort of use. This and other renewables should receive $10 billion as a seed for long-term development.

This suggests a role for a clean, efficient, and much neglected energy source: nuclear. Like the fuel cell, the nuclear generator is a technology ripe for exploitation. Unlike the solid-core reactors of the past, pebble-bed modular reactors such as the one at Koeberg, South Africa, don't get hot enough to risk melting down. Koeberg uses small graphite-covered uranium balls rather than plutonium rods, and the reactor's cooled by helium rather than water. This new design is so efficient, it might make nuclear competitive with coal and oil. In any event, the nuclear power industry is in dire need of research for everything, from generation to waste treatment. Thus, $10 billion should be allocated to developing and securing nuclear technology that can power the hydrogen revolution.

Nuclear power will serve as a stopgap, enabling the US to achieve energy independence while allowing wind, solar, and hydropower a chance to mature. Given the choice between powering the carbon-free hydrogen economy with fossil fuels or nuclear energy, even Greenpeace might embrace nuke plants as the lesser evil.

As all the various subsidies kindle a self-sustaining economy, they should be tapered and the money shunted to the other major power in the conversion from oil to hydrogen: electric utilities. Within a decade, outlays to power companies should be aimed at connecting hydrogen pipelines to the power stations.

5. Mount a Public Campaign To Sell the Hydrogen Economy

With a growing federal deficit and a stagnant economy, this might seem like a singularly bad time to unleash an immense tide of new subsidies. And let's be honest: Even framed as a national security issue, a $100 billion proposal won't go down easily on Capitol Hill or in Peoria. This is why the Bush administration's campaign to sell the hydrogen economy must be even more vigorous than its campaign to sell the war against Iraq.

Financially, the case is compelling. One hundred billion dollars is less than a quarter of what the federal government plans to spend annually on defense within five years. A 5 cent per gallon increase in the gasoline tax - less than the seasonal variation in gasoline prices - would pay for part of it. For the rest, the government could issue "H Bonds." Like Liberty Bonds during World Wars I and II, "securities for security" would give citizens a way to take part in the cause while providing an attractive investment. Like war bonds, they could be promoted by celebrities, sold by Boy and Girl Scouts, and paid for via payroll deduction plans.

Convincing Congress will take all the finesse the administration can muster, but some states are already pushing the hydrogen agenda with tax credits, research funding, and other policies to create jobs in fuel cell manufacture. "We want to collaborate with the federal government and industry to make California a leader in hydrogen," says Alan Lloyd, chair of California's Air Resources Board, an EPA suboffice in a state where SUVs sport **SAVE THE EARTH** bumper stickers. (The city of Los Angeles bought its first fuel-cell vehicle from Honda last December.) States that foster hydrogen technology companies will be rewarded with tax revenue from sales to Europe and Asia, which are also looking into it.

Even before he sells the plan to Congress, the president will have to sell it to the oil and auto industries. After all, hydrogen power is a potent threat to their current business, and they own the fueling infrastructure and manufacturing capacity necessary to bring that power to market. The prospect of massive subsidies will help; these industries are squeezed between shrinking profits and rising costs. But the money can do more than relieve their pain. It can set them on a sustainable course for the future, turning the biggest obstacles to the hydrogen economy into its standard bearers.

Petroleum suppliers and auto manufacturers alike understand the need to disentangle their business models from crude. By most estimates, the worldwide oil supply has nearly stopped growing. Thanks to new discoveries, the total reserve increased by 56 percent between 1980 and 1990 but only 1.4 percent between 1990 and 2000. Pessimistic geologists argue that production will begin to decline as early as 2006, while optimists point at 2040. What's more, it's now clear that oil consumption is at least partly to blame for global warming, prompting ever-louder calls for alternatives. It shouldn't take much persuasion to convince the oil and car industries that the most profitable course is to adapt to hydrogen sooner with government money rather than later without.

The most important market over the next decade, of course, is the US consumer. The administration should allocate $25 billion to persuade Americans to buy fuel cell cars and invest in hydrogen technology. This budget would pay for a $2,000 tax rebate on vehicle purchases, and fund local incentives such as preferential parking, freeway lanes, and free registration for fuel cell cars. At least $1 billion a year - equal to Nike's 2001 advertising budget - should be devoted to public-service announcements, posters, lectures, contests, and other ways of sending the message that achieving energy independence through hydrogen is a patriotic duty.

There are good reasons to wonder whether any government initiative, even one that's critical to national security, can bring about such a radical change. Federal energy programs don't have much of a track record, and past efforts to promote hydrogen itself - after the oil crises of 1973, 1978, and 1980, for instance - have failed to take root.

These attempts foundered mainly because the US continued to have access to cheap oil. Energy independence briefly became top priority after OPEC raised prices from $3 to $12 per barrel between 1973 and 1975, but momentum dissipated as the crisis ended and prices fell. As a result, the political will to make tough energy decisions vanished. The threat to national security means that politics no longer stands in the way: Better to make hard choices today than send your children off to fight for oil tomorrow.

Earlier initiatives were also hampered by primitive technology. Today, however, fuel cells have reached the point where hydrogen is a credible substitute for oil. Outdoor-product maker Coleman recently released the first commercial fuel cell product, an emergency power generator for home use, and large fuel cells have been installed as backups in office buildings throughout the country. Hydrogen-powered buses are already operating in Toronto and Chicago, and soon will be in London, Madrid, and Hamburg. Iceland has embarked on an ambitious effort to convert its public transit and fishing fleets to hydrogen. The most encouraging sign is the investment by oil and car companies, not to mention venture capitalists.

If President Bush can implement this program, or something comparably aggressive, by 2013, all major car companies will sell fuel cell vehicles, and several new manufacturers will probably emerge to produce specialty hydrogen-powered items like sports cars and SUVs. Filling stations in the nation's six largest cities will carry hydrogen as well as gasoline; many will offer only the new fuel. Some refineries will be selling more hydrogen than gasoline, measured by both dollars and volume.

Imagine how the hydrogen economy will change geopolitics. OPEC will no longer be a factor in foreign policy. Relations with oil-producing nations will be based on common interests. The US will be free to promote democracy in countries like Nigeria, Saudi Arabia, and Iran. Bases in Saudi Arabia, Kuwait, and Qatar will be dismantled and naval forces in the Mediterranean and Persian Gulf sent home.

Even at that point, the transition will be far from complete. It will take decades to get every conventional car off the road, and even longer before hydrogen can be mass-produced using clean energy. In the long run, automobile fuel cells themselves might be tied to the grid, making it possible for vehicles to feed power into the system rather than simply consume energy. That is, electrical meters might run backward some of the time. Futurist Amory Lovins envisions a peer-to-peer energy network in which spot power is distributed to users from the nearest source, be it a utility station or a station wagon. Such a system would make the grid more efficient and power less expensive. This cheaper energy could be sold in bulk to businesses looking to cut costs, creating further momentum for the new fuel system.

In time, US fuel cell and hydrogen-extraction technology will provide enormous opportunities for developing nations like China and India, which will be the fastest-growing consumers of energy in coming decades. Because they don't have an adequate petroleum-based infrastructure today, these nations will be quick to take full advantage of hydrogen, leapfrogging developed countries. Cheaper than oil, the new fuel will empower poor countries, reducing their trade deficits and security threats.

The stakes are higher today than they were in Sputnik's wake. Unlike space travel, energy independence bears directly on US self-determination. The dangerous turmoil in the Middle East, the growing national security budget, the promise of technology that needs only a financial push - all these things make this the right moment to launch an Apollo-scale commitment to hydrogen power. The fate of the republic depends on it.

10 YEARS OF ENERGY INNOVATION

1995

General Motors rolls out an electric car, the Impact (later refined into the EV1), at the Greater LA Auto Show.

GE introduces the H System, a natural gas-burning turbine that uses gas, steam, and heat-recovery technologies.

1997

In Japan, Toyota unveils the Prius, the first mass-produced gas-electric hybrid.

1999

Chicago spends $8 million installing solar panels in old industrial sites to light municipal buildings and parks.

2000

The South African company Eskom begins construction on the first pebble-bed modular reactor, a safer kind of nuclear plant.

2001

Clean Energy Systems develops a power plant that runs on natural gas and releases steam and carbon dioxide.

2002

Honda leases the first of five fuel cell cars to Los Angeles. The 80-horsepower FCX's only emission: water.

Ireland approves the world's largest offshore wind park, 200 turbines on a sandbank 15 miles long and a mile wide.

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Hydrogen Production and Delivery

http://www.eere.energy.gov/hydrogenandfuelcells/hydrogen/production.html

Hydrogen Production Technologies

The choice of production methods will vary depending on the availability of feedstock or resource, the quantity of hydrogen required, and the required purity of hydrogen. Researchers are developing a wide range of processes for producing hydrogen economically and in an environmentally friendly way. These processes can be divided into three major research areas:

Thermochemical Production Technologies
Electrolytic Production Technologies
Photolytic Production Technologies

Thermochemical Production Technologies

Natural Gas Steam Reforming

Although today most hydrogen is produced from fossil materials, such as from natural gas at this oil refinery, the Program is exploring a variety of ways to produce hydrogen from renewable resources.

The production of hydrogen from natural gas is an integral part of the strategy to introduce hydrogen into the transportation and utility energy sectors, by reducing the cost of conventional and developing innovative hydrogen production processes that rely on cheap fossil feedstocks. Today, nearly all hydrogen production is based on fossil raw materials. Worldwide, 48% of hydrogen is produced from natural gas, 30% from oil (mostly consumed in refineries), 18% from coal, and the remaining (4%) via water electrolysis.

Modification of the conventional steam methane reforming (SMR) process to incorporate an adsorbent in the reformer to remove CO2 from the product stream may offer a number of advantages over conventional processes. Upsetting the reaction equilibrium in this way drives the reaction to produce additional hydrogen at lower temperatures than conventional SMR reactors. Although still in the research stage, the cost of hydrogen from this modified process is expected to be 25%-30% lower, primarily because of reduced capital and operating costs. In addition, the adsorption of the CO2 in the reforming stage results in a high-purity CO2 stream from the adsorbent regeneration step. This has interesting implications in a carbon-constrained world.

Partial Oxidation/Ceramic Membrane Reactor

Scientists are developing a ceramic membrane reactor for the simultaneous separation of oxygen from air and the partial oxidation of methane. If successful, this process could result in improved production of hydrogen and/or synthesis gas compared to conventional reformers.

Biomass Gasification and Pyrolysis

The Program is exploring ways in which to produce hydrogen from biomass, such as this switchgrass, via pyrolysis and gasification.

The thermal processing techniques for plant material (biomass) and fossil fuels are similar, with a number of the downstream unit operations being essentially the same for both feedstocks. Using agricultural residues and wastes, or biomass specifically grown for energy uses, hydrogen can be produced via pyrolysis or gasification.

Biomass pyrolysis produces a liquid product (bio-oil) that, like petroleum, contains a wide spectrum of components that can be separated into valuable chemicals and fuels.

Unlike petroleum, bio-oil contains a significant number of highly reactive oxygenated components derived mainly from constitutive carbohydrates and lignin. These components can be transformed into products, including hydrogen. Coproduct strategies are designed to produce high value chemicals, such as phenolic resins, in conjunction with hydrogen.

A promising option for hydrogen production from renewable resources is electrolysis, in which electricity is used to disassociate water into hydrogen and oxygen. Photo courtesy of the Schatz Energy Research Center, Humboldt State University

Electrolytic Production Technologies

Water Electrolysis

Until the 1950s, water electrolyzers were in widespread use for hydrogen (or oxygen) production. Currently, electrolysis provides only a small percentage of the world's hydrogen, most of which is supplied to applications requiring small volumes of high purity hydrogen (or oxygen, such as for breathing atmospheres for submarines). There is significant renewed interest in the use of electrolyzers to produce hydrogen as a fuel for automotive applications, with a number of refueling stations installed around the world. In addition, research continues in the integration of intermittent renewable resources (PV and wind) with electrolyzers, for producing hydrogen to be used as a fuel or for energy storage.

Reversible Fuel Cells/Electrolyzers

Operating the proton exchange membrane (PEM) fuel cell "in reverse" as an electrolyzer is possible, but optimum operating conditions for the power production mode and for the hydrogen production mode are significantly different. Design issues for the reversible fuel cell system include thermal management, humidification, and catalyst type and loading.

Photolytic Production Technologies

Photobiological

A set of bio-reactors use can use light (sunlight or artificial light) and the natural activities of enzymes in green algae to produce hydrogen from water. Photobiological production of hydrogen is a promising renewable option for the long term.

Certain photosynthetic microbes produce hydrogen in their metabolic activities using light energy. By employing catalysts and engineered systems, hydrogen production efficiency could reach 24%. Photobiological technology holds great promise but because oxygen is produced along with the hydrogen, the technology must overcome the limitation of oxygen sensitivity of the hydrogen-evolving enzyme systems. Researchers are addressing this issue by screening for naturally occurring organisms that are more tolerant of oxygen, and by creating new genetic forms of the organisms that can sustain hydrogen production in the presence of oxygen. A new system is also being developed that uses a metabolic switch (sulfur deprivation) to cycle algal cells between a photosynthetic growth phase and a hydrogen production phase.

Unlike cyanobacteria or algae, photosynthetic bacteria do not oxidize water. They do, however, evolve hydrogen from biomass (previously generated from sunlight, water, and carbon dioxide). These bacteria use several different enzymatic mechanisms with near-term commercial potential for biological hydrogen production from biomass. One mechanism in particular looks promising for applications as a biological conditioning agent for upgrading thermally generated fuel gases to a level where they can be directly injected into hydrogen fuel cells. This same system has potential to subsequently evolve into a second-generation photobiological method to produce hydrogen from water.

Photoelectrolysis

Another promising option for the long term is photoelectrolysis. Here, light shining on a photoelectrochemical cell immersed in water produces bubbles of hydrogen and oxygen.

Multijunction cell technology developed by the PV industry is being used for photoelectrochemical (PEC) light harvesting systems that generate sufficient voltage to split water and are stable in a water/electrolyte environment. Theoretical efficiency for tandem junction systems is 42%; practical systems could achieve 18%-24% efficiency; low-cost multi-junction amorphous silicon (a-Si) systems could achieve 7%-12% efficiency. This is one of the advantages of a direct conversion hydrogen generation system. Not only does it eliminate most of the costs of the electrolyzer, but it also has the possibility of increasing the overall efficiency of the process. Research results for the development of PEC water splitting systems have shown a solar-to-hydrogen efficiency of 12.4% lower heating value (LHV) using concentrated light. Low-cost a-Si tandem designs with appropriate stability and performance are also being developed. An outdoor test of the a-Si cells resulted in a solar-to-hydrogen efficiency of 7.8% LHV under natural sunlight.

Hydrogen Storage

Source: http://www.eere.energy.gov/hydrogenandfuelcells/hydrogen/storage.html

Hydrogen Storage Technologies

Hydrogen storage is a key enabling technology for the advancement of fuel cell power systems in transportation, stationary, and portable applications. For transportation, the overarching technical challenge for hydrogen storage is how to store the amount of hydrogen required for a conventional driving range (>300 miles), within the vehicular constraints of weight, volume, efficiency, safety, and cost. Durability over the performance lifetime of these systems must also be verified and validated and acceptable refueling times must be achieved.

Low cost, energy efficient off-board storage of hydrogen will also be needed throughout the hydrogen delivery system infrastructure. For example, storage is required at hydrogen production sites, hydrogen refueling stations, and stationary power sites. Temporary storage may also be required at terminals and/or intermediate storage locations. Requirements for off-board bulk storage are generally less restrictive than on-board requirements; for example, there may be no or less restrictive weight requirements, but there may be volume or "footprint" requirements.

The DOE hydrogen storage program element will focus primarily on developing on-board storage materials and technologies.

Read on to learn more about

- DOE Hydrogen Storage Objectives
- Technical Barriers
- Current Approaches to Hydrogen Storage

- [Current DOE Storage Activities]
- [Hydrogen Storage Technical Targets (PDF 139 KB)] [Download Acrobat Reader].
- [Status]

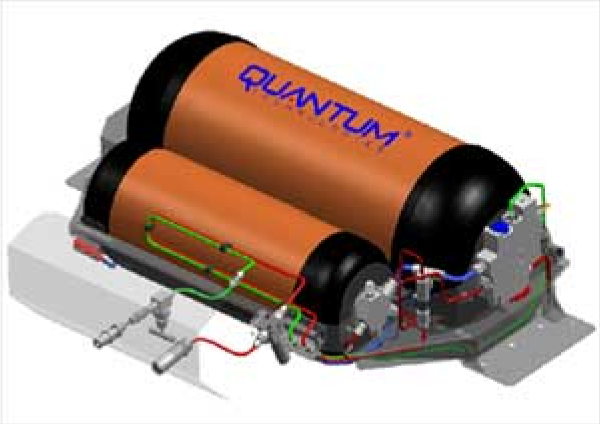
DOE Hydrogen Storage Objectives

The objectives of the DOE Hydrogen Storage activity are:

- BY 2005, develop and verify on-board hydrogen storage systems achieving 1.5 kWh/kg (4.5 wt%), 1.2 kWh/L, and $6/kWh by 2005.
- By 2010, develop and verify on-board hydrogen storage systems achieving 2 kWh/kg (6 wt%), 1.5 kWh/L, and $4/kWh.
- By 2015, develop and verify on-board hydrogen storage systems achieving 3 kWh/kg (9 wt%), 2.7 kWh/L, and $2/kWh.
- By 2015, develop and verify low cost, off-board hydrogen storage systems, as required for hydrogen infrastructure needs to support transportation, stationary and portable power markets.

Technical Barriers

- **Cost.** The cost of on-board hydrogen storage systems is too high, particularly in comparison with conventional storage systems for petroleum fuels. Low-cost materials and components for hydrogen storage systems are needed, as well as low-cost, high-volume manufacturing methods.
- **Weight and Volume.** The weight and volume of hydrogen storage systems are presently too high, resulting in inadequate vehicle range compared to conventional petroleum fueled vehicles. Materials and components are needed that allow compact, lightweight, hydrogen storage systems while enabling greater than 300-mile range in all light-duty vehicle platforms.
- **Efficiency.** Energy efficiency is a challenge for all hydrogen storage approaches. The energy required to get hydrogen in and out is an issue for reversible solid-state materials. Life-cycle energy efficiency is a challenge for chemical hydride storage in which the by-product is regenerated off-board. In addition, the energy associated with compression and liquefaction must be considered for compressed and liquid hydrogen technologies.



- **Durability.** Durability of hydrogen storage systems is inadequate. Materials and components are needed that allow hydrogen storage systems with a lifetime of 1500 cycles.
- **Refueling Time.** Refueling times are too long. There is a need to develop hydrogen storage systems with refueling times of less than three minutes, over the lifetime of the system.

- **Codes & Standards.** Applicable codes and standards for hydrogen storage systems and interface technologies, which will facilitate implementation/commercialization and assure safety and public acceptance, have not been established. Standardized hardware and operating procedures, and applicable codes and standards, are required.
- **Life-Cycle and Efficiency Analyses.** Lack of analyses of the full life-cycle cost and efficiency for hydrogen storage systems.

Current Approaches to Hydrogen Storage
Possible approaches to hydrogen storage include physical storage via compression or liquefaction, and storage in materials via reversible sorption processes or chemical reaction.

Pressurized Storage Tanks

In the area of on-board hydrogen storage, the state-of-the-art is compressed hydrogen and liquid hydrogen tanks.

Compressed H2 tanks [5000 psi (~35 MPa) and 10,000 psi (~70 MPa)] have been certified worldwide according to ISO 11439 (Europe), NGV?2 (U.S.), and Reijikijun Betten (Iceland) standards and approved by TUV (Germany) and The High-Pressure Gas Safety Institute of Japan (KHK). Tanks have been demonstrated in several prototype fuel cell vehicles and are commercially available. Composite, 10,000-psi tanks have demonstrated a 2.35 safety factor (23,500 psi burst pressure) as required by the European Integrated Hydrogen Project specifications.

Advanced lightweight pressure vessels, with minimum permeation losses, have been designed and fabricated. These vessels use lightweight bladder liners that act as inflatable mandrels for composite overwrap and as permeation barriers for gas storage. These tank systems have demonstrated 12wt% hydrogen storage at 70 MPa (~10,000 psi).

Liquid tanks are being demonstrated in hydrogen-powered vehicles and a hybrid tank concept combining both high-pressure gaseous and cryogenic liquid storage is being studied. These hybrid insulated pressure vessels are lighter than hydrides, more compact than ambient-temperature pressure vessels, and require less energy for liquefaction and have less evaporative losses than liquid hydrogen tanks.

Storage in Materials
There are presently three generic routes known for the storage of hydrogen in materials:

- absorption, e.g. simple metal hydrides
- adsorption, e.g. carbon and zeolite materials
- chemical reaction, e.g. complex metal hydrides and chemical hydrides

In absorptive hydrogen storage, hydrogen is absorbed directly into the bulk of the material. In simple crystalline metal hydrides, this absorption occurs by the incorporation of atomic hydrogen into interstitial sites in the crystallographic lattice structure.

Adsorption may be subdivided into physisorption and chemisorption, based on the energetics of the adsorption mechanism. Physisorbed hydrogen is more weakly energetically bound to the material than is chemisorbed hydrogen. Sorptive processes typically require highly porous materials to maximize the surface area available for hydrogen sorption to occur, and to allow for easy uptake and release of hydrogen from the material.

The chemical reaction route for hydrogen storage involves displacive chemical reactions for both hydrogen generation and hydrogen storage. For reversible hydrogen storage chemical reactions, hydrogen generation and hydrogen storage take place by a simple reversal of the chemical reaction as a result of modest changes in the temperature and pressure. Sodium alanate-based complex metal hydrides are an example. For irreversible hydrogen storage chemical reactions, the hydrogen generation reaction is not reversible under modest temperature/pressure changes, so that storage requires larger temperature/pressure changes or alternative chemical reactions. Sodium borohydride is an example.

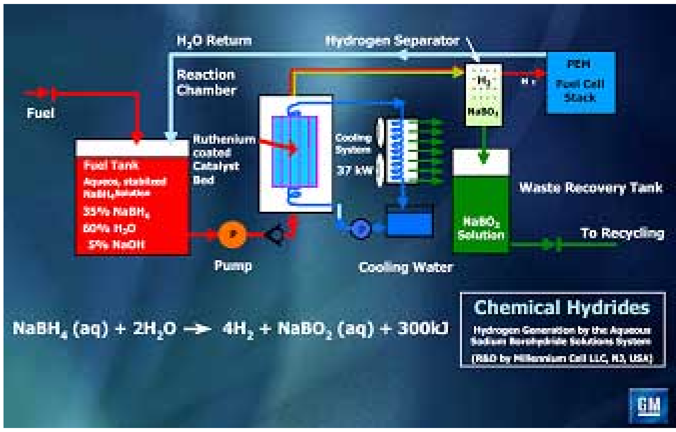
Currently, three classes of materials are being investigated:

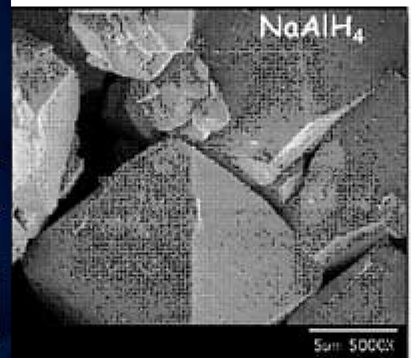
- Metal hydrides - reversible solid-state materials regenerated on-board,
- Chemical hydrides - hydrogen is released via chemical reaction (usually with water); byproduct is regenerated off-board;
- Carbon- based materials - reversible solid-state materials regenerated on-board.

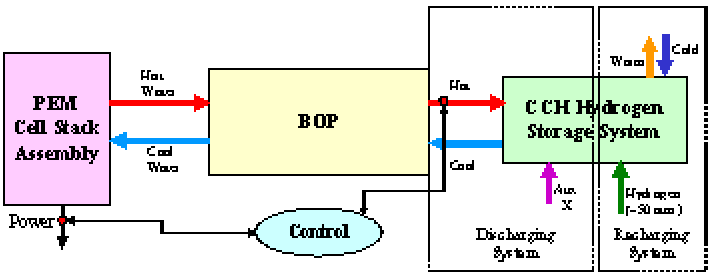
Metal Hydrides (High and Low Temperature)

Conventional high capacity metal hydrides require high temperatures (300°-350°C) to liberate hydrogen, but sufficient heat is not generally available in fuel cell transportation applications. Currently existing low temperature hydrides, however, suffer from low gravimetric energy densities and require too much space on board or add significant weight to the vehicle. Researchers are developing low-temperature metal hydride systems that can store 3-5 wt% hydrogen. Alloying techniques have been developed that result in high-capacity, multi-component alloys with excellent kinetics, albeit at high temperatures. Additional research is required to identify alloys with appropriate kinetics at low temperatures.

Various pure or alloyed metals can combine with hydrogen, producing stable metal hydrides. The hydrides decompose when heated, releasing the hydrogen. Hydrogen can be stored in the form of a hydride at higher densities than by simple compression. Using this safe and efficient storage system depends on identifying a metal with sufficient adsorption capacity operating under appropriate temperature ranges.







Alanates are considered to be the most promising of the complex hydrides studied to date for on-board hydrogen storage applications. They have been the focus of extensive research to increase the storage capacity of the materials, extend the durability and cycle lifetime and uptake and release reproducibility. A thorough thermodynamic and kinetic understanding of the alanate system is needed in order to serve as the basis for systematically exploring other complex hydride systems. In addition, engineering studies must be initiated to understand the system level issues and to facilitate the design of optimized packaging and interface systems for on-board transportation applications.

Chemical Hydrides

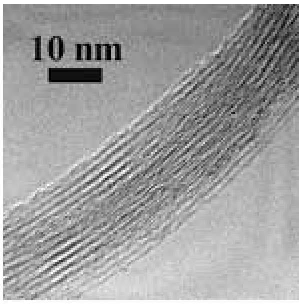
An approach for the production, transmission, and storage of hydrogen using a chemical hydride slurry or solution as the hydrogen carrier and storage medium is being investigated. There are two major embodiments of this approach. Both require some degree of thermal management and regeneration of the carrier to recharge the hydrogen content. Significant technical issues remain regarding the regeneration of the spent material and whether regeneration can be accomplished on-board. Life cycle cost analysis is needed to assess the costs of regeneration.

In the first embodiment, a slurry of an inert stabilizing liquid protects the hydride from contact with moisture and makes the hydride pumpable. At the point of use, the slurry is mixed with water and the consequent reaction produces high purity hydrogen.

2LiH + 2H2O ® 2LiOH + 2H2

An essential feature of the process is recovery and reuse of spent hydride at a centralized processing plant. Research issues include the identification of safe, stable, and pumpable slurries and the design of the reactor for regeneration of the spent slurry.

The second, and most advanced, embodiment is sodium borohydride. The sodium borohydride is combined with water to create a non-toxic, non-flammable solution that produces hydrogen when exposed to a catalyst.



NaBH4 + 2H2O + catalyst à 4H2 + NaBO2

When the sodium borohydride solution and catalyst are separated, the solution stops producing hydrogen. After being in contact with the catalyst, the fuel is spent and goes into a waste tank. This waste is recyclable into new fuel.

The borohydride system has been successfully demonstrated on prototype passenger vehicles such as the Chrysler Natrium.

Carbon

Adsorption of hydrogen molecules on activated carbon has been studied in the past. Although the amount of hydrogen stored can approach the storage density of liquid hydrogen, these early systems required low temperatures (i.e., liquid nitrogen). Subsequent work showed that hydrogen gas can condense on carbon structures at conditions that do not induce adsorption within a standard mesoporous activated carbon.

Carbon materials present a long-term potential for hydrogen storage and several carbon nanostructures are being investigated with particular focus on single-wall nanotubes(SWNTs). However, the amount of storage and the mechanism through which hydrogen is stored in these materials are not well-defined. Fundamental studies are directed at understanding the basic reversible hydrogen storage mechanisms and optimizing them.

Therefore, a coordinated experimental and theoretical effort is needed to characterize the materials, to understand the mechanism and extent of hydrogen absorption/adsorption, and to improve the reproducibility of the measured performance. These efforts are required to obtain a realistic estimation of the potential of these materials to store and release adequate amounts of hydrogen under practical operating conditions.

Current Doe Hydrogen Storage Activities

Technology
Organizations
Project Focus
Compressed Hydrogen Tanks
Quantum
10,000 psi Composite Tanks

Johns Hopkins University, Lincoln Composites
Conformable Tanks

Lawrence Livermore National Laboratory
Lightweight Composite Tanks
Liquid Hydrogen Tanks
Lawrence Livermore National Laboratory
Insulated Pressure Vessels

Complex Metal Hydrides
University of Hawaii
Alanates - Kinetics, Mechanisms

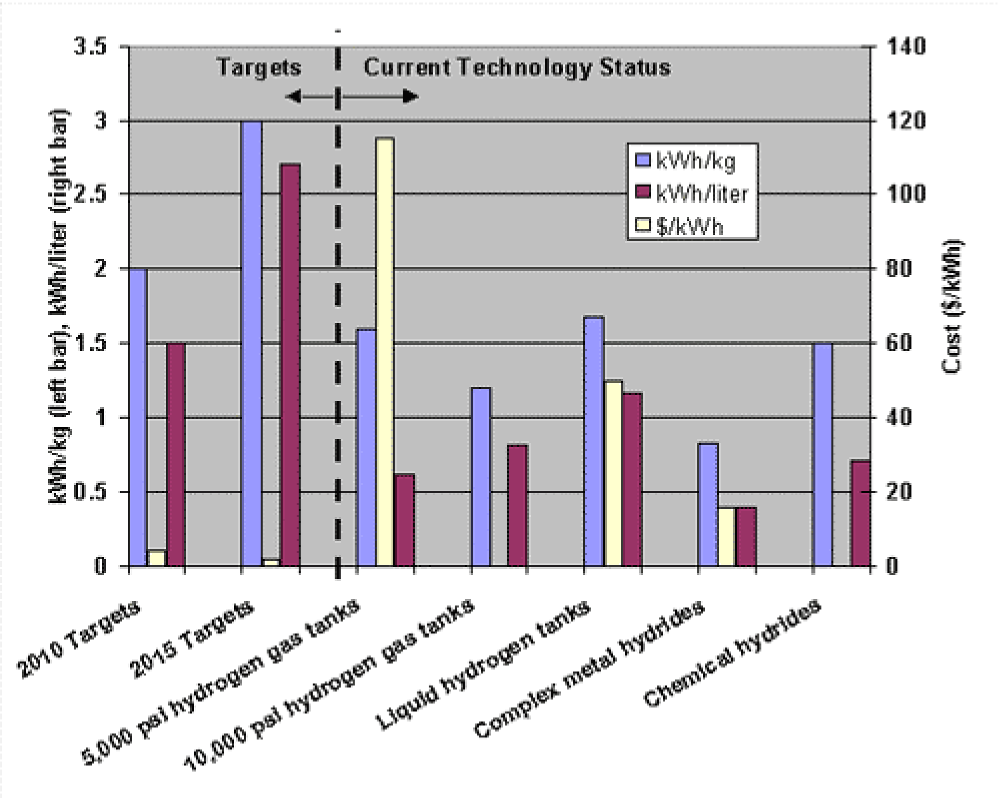
Sandia National Laboratory - Livermore
Alanates - Kinetics, Mechanisms, Engineering

United Technologies Research Center
Alanates - Cycle Life, System Engineering, Safety
Carbon
National Renewable Energy Laboratory
Nanotubes - Kinetics, Mechanism
Testing and Evaluation
Southwest Research Institute
Standard Test Protocol, Independent Test Facility

[Hydrogen Storage Workshops]

[Hydrogen Storage Financial Opportunities]

Status
As shown in the figure below, none of the current approaches to hydrogen storage meets the DOE 2010 or 2015 objectives.



XIX. Appendix H– Methanol References

What is Methanol?

Source: http://www.afdc.doe.gov/altfuel/met_general.html

Methanol (CH_3OH) is an alcohol fuel. Today most of the world's methanol is produced by a process using natural gas as a feedstock. However, the ability to produce methanol from non-petroleum feedstocks such as coal or biomass is of interest for reducing petroleum imports.

The alternative methanol fuel can be used today in vehicles as M-85. In the future, neat methanol, or M-100, may also be used. Methanol is also made into an ether, MTBE, which is blended with gasoline to enhance octane and to create oxygenated gasoline.

Chemical Properties: As engine fuels, ethanol and methanol have similar chemical and physical characteristics. Methanol is methane with one hydrogen molecule replaced by a hydroxyl radical (OH). See the fuel properties table (PDF 116 KB) for more information.

How is Methanol Made?

http://www.afdc.doe.gov/altfuel/met_made.html

Methanol is predominantly produced by steam reforming of natural gas to create a synthesis gas, which is then fed into a reactor vessel in the presence of a catalyst to produce methanol and water vapor. Although a variety of feedstocks other than natural gas can and have been used, today's economics favor natural gas.

Synthesis gas refers to combinations of carbon monoxide (CO) and hydrogen. While a large amount of synthesis gas is used to make methanol, most synthesis gas is used to make ammonia. As a result, most methanol plants are adjacent to or are part of ammonia plants. The synthesis gas is fed into another reactor vessel under high temperatures and pressures, and CO and hydrogen are combined in the presence of a catalyst to produce methanol. Finally, the reactor product is distilled to purify and separate the methanol from the reactor effluent.

Methanol Benefits

http://www.afdc.doe.gov/altfuel/met_benefits.html

Methanol's physical and chemical characteristics result in several inherent advantages as an automotive fuel. Some methanol benefits include low emissions, high-performance, and less flammable than gasoline. In addition, methanol can be manufactured from a variety of carbon-based feedstocks such as natural gas, coal, and biomass (e.g., wood) and the use of methanol would help reduce U.S. dependence on imported petroleum. On the down side, methanol produces a high amount of formaldehyde in emissions.

In addition, methanol can easily be made into hydrogen. Some researchers are currently working to overcome the barriers to using methanol as a hydrogen fuel source. So methanol may potentially be used to create hydrogen for hydrogen fuel cell vehicles in the future.

Methanol Fuel Cells to Replace Batteries

http://www.sysopt.com/forum/showthread.php?threadid=140383
Posted by Chris Emmerson-Pace on 6/30/03 @ 12:33 pm

NEC Corp. Monday revealed a prototype laptop computer that is powered by a methanol fuel cell instead of a traditional rechargeable battery pack.

The company also stated that it plans to make a PC within two years using the same technology. According to NEC, a PC utilizing methanol fuel for power has the potential of running for 40 consecutive hours.

Methanol fuel cells produce electricity through an electrochemical reaction that uses oxygen and hydrogen, resulting in a lack of pollutants.

NEC is not the first to experiment with alternate power supplies for computers. Toshiba Corp. in March claimed to develop the world's first prototype of a methanol-type fuel cell system to run notebook PCs and plans to commercialize its product in 2004.

Not to be left behind, Sony Corp., Casio Computer Co. and Hitachi Ltd. also are working on fuel cell technologies.

XX. Appendix I – Flex Fuel Vehicle References

Ethanol Vehicle Challenge

SOURCE: http://www.transportation.anl.gov/evc2000/index.html

The Ethanol Vehicle Challenge, a three-year vehicle design competition, began in 1998. It gives students real-world engineering experience as they convert new vehicles built for gasoline into optimized vehicles fueled solely by E-85 (a blend of 85% denatured ethanol and 15% gasoline-like hydrocarbon primer). The goal is an ethanol-fueled vehicle with greater fuel economy and lower exhaust emissions, but with the driveability, performance, and consumer appeal of a conventional gasoline vehicle.

Student from universities in the United States and Canada are replacing and upgrading major engine and fuel system components for ethanol operation. As they work on their vehicles, the students solve real-life engineering problems and make complex decisions by applying creative, innovative thinking. Their solutions may someday become a part of a production ethanol-fueled vehicle ready for use on the road.

Competition Highlights

- **FUEL EFFICIENCY**: In 1998, eight vehicles had better fuel efficiency than the stock Malibu. Vehicles achieved the same range on one tank of ethanol as the stock Malibu achieved on one tank of gasoline. This success continued in 1999 when 11 teams achieved better fuel efficiencies than the gasoline Silverado. The winning team, University of Illinois-Chicago, demonstrated a greater-than-10% increase in fuel efficiency.

- **EMISSIONS TESTING**: In 1998, the University of Waterloo came close to meeting California Air Resources Board Low-Emission Vehicle (LEV) emission standards. In 1999, three teams met LEV and were within 0.020 grams of THCE per mile of meeting Ultra-Low-Emission Vehicle (ULEV) standards - impressive for a half-ton, 4x4 truck!

- **COLD START**: The teams have demonstrated that cold-start problems, due to the lower vaporization of E-85 fuel, can be overcome. Some of the innovative cold-start technologies include an onboard distillation system, glow-plug ignited fuel system, electric supercharger, quick-heat intake manifold, a liquid-heated fuel injector rail, and a phase-changing catalyst.

- **PERFORMANCE**: The 1999 competition vehicles outperformed the stock Silverado. Twelve vehicles out-accelerated the stock truck; Cedarville College reached 60 mph in 15.29 seconds on the quarter-mile track, beating the stock truck by 1.5 seconds. In the hill climb event, 12 vehicles outperformed the stock

Silverado; the Minnesota State University at Mankato vehicle reached the top of the hill in 36.20 seconds - almost 10 seconds faster than the gasoline-powered truck.

- **EDUCATION**: In 1999, more than 70% of the graduating seniors who participated in the EVC accepted jobs in the automotive industry. They take with them an unparalleled engineering experience as well as a direct, hands-on knowledge of ethanol as an automotive fuel.

In the final year of the competition, Ethanol Vehicle Challenge 2000, student teams will continue to optimize their ethanol-fueled Chevrolet Silverado pickup trucks for lower emissions and greater fuel economy.

GM Partners With National Ethanol Vehicle Coalition To Advance The Use Of E85

SOURCE: http://www.gm.com/cgi-bin/pr_display.pl?3416
Campaign Aimed At Increasing Alternative Fuel Use

FOR RELEASE: February 25, 2003

CHARLOTTE, N.C. - General Motors Corp. today announced a new, multi-million dollar campaign to promote the use of corn-based ethanol fuel E85 as an alternative to gasoline.

The public awareness effort is a 2-year partnership with the non-profit National Ethanol Vehicle Coalition (NEVC) focused on increasing ethanol use in flexible fuel vehicles. Flexible fuel vehicles are designed to use either ethanol or gasoline; E85 Flexible Fuel Vehicles can be powered by gasoline or a mixture of 85 percent ethanol and 15 percent gasoline.

According to Phil Lampert, executive director of the NEVC, "The limited number of ethanol fueling stations available - about 140 in 22 primarily Midwestern states - make it a challenge for people to utilize this alternative fuel source. We believe this effort will help increase the use of ethanol, which will benefit the environment and help reduce the nation's dependency on foreign oil."

The ethanol promotion effort, announced today at the NEVC annual meeting, will begin in six key states: Missouri, Wisconsin, Colorado, Minnesota, Michigan and Illinois. The campaign will include a variety of tactics, including information made available to customers at dealerships, direct mail, advertising and on-line activities.

Ethanol is alcohol that is currently made from domestically produced corn. It costs about the same and delivers performance similar to regular gasoline. Throughout the past 5 years, the demand for E85 has increased ten-fold to about 10 million gallons a year.

"Every gallon of ethanol used reduces our reliance on foreign oil," said Phil Lampert. "Our hope is that by increasing awareness we can help solve the chicken and egg problem - spurring more market demand which will lead to more fueling stations, and ultimately, more E85 vehicles on the road."

Today, ethanol made from corn reduces the demand for imported oil by 98,000 barrels per day -- representing a .1 billion reduction in the U.S. trade deficit. In the future, production of ethanol can come from bio-mass such as corn and wheat stalks and forestry waste. Ethanol is an alternative to imported petroleum because it is made from renewable resources and it does not deplete petroleum energy supplies.

"E85 alternative fuel is only beginning to become available in many areas," said Gary Herwick, director of alternative fuels for General Motors. "Working together, we can make a difference when it comes to alternative fuels. GM is manufacturing E85 compatible vehicles and we are encouraging industry and consumers to do their part by continuing to develop the E85 infrastructure, and by using E85 in their GM Flexible Fuel Vehicles whenever possible."

There are currently more than 3 million E85 vehicles on American roads -- more than 1 million of them produced by GM. All GM full size SUVs equipped with the Vortec 5300 engine are E85-capable, including the Chevrolet Tahoe and Suburban and the GMC Yukon and Yukon XL. The Chevrolet Silverado and GMC Sierra full size pickups also are available with E85 capability.

"These vehicles are just one example of an entire range of technologies we have developed to eventually remove the automobile from the environmental debate," said Elizabeth Lowery, GM's vice president for environment and energy. "In the long term, our goal is to replace the internal combustion engine entirely with a hydrogen powered fuel cell, but until such time that the technology is commercially viable, we are working to improve fuel efficiency on a variety of fronts."

Other fuel-saving technologies currently available include continuously variable transmissions and Displacement on Demand. Displacement of Demand saves fuel by deactivating half the engine's cylinders in light-duty conditions. In 2004, GM will introduce its first hybrid vehicles, the Chevrolet Silverado and GMC Sierra Flexpower, powered by an electric battery and a gasoline internal combustion engine. Eleven other hybrid models come to market in the next several years.

The National Ethanol Vehicle Coalition is the nation's primary advocate dedicated to the use of 85 percent ethanol as a form of alternative transportation fuel. It is a coalition of corn growers, ethanol producers and auto manufacturers based in Jefferson City, Missouri. For more information, visit www.e85fuel.com.

General Motors (NYSE: GM), the world's largest vehicle manufacturer, designs, builds and markets cars and trucks worldwide, and has been the global automotive sales leader since 1931. GM employs about 355,000 people around the world. More information on GM can be found at www.gm.com.

XXI. Appendix J – Fuel Cell Vehicle References

How Fuel Cells Work

Source: http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/how.html

Fuel Cell Components & Function

A fuel cell is a device that uses hydrogen (or hydrogen-rich fuel) and oxygen to create electricity by an electrochemical process. A single fuel cell consists of an electrolyte sandwiched between two thin electrodes (a porous anode and cathode). While there are different fuel cell types, all work on the same principle:

- Hydrogen, or a hydrogen-rich fuel, is fed to the anode where a catalyst separates hydrogen's negatively charged electrons from positively charged ions (protons).
- At the cathode, oxygen combines with electrons and, in some cases, with species such as protons or water, resulting in water or hydroxide ions, respectively.
- For polymer exchange membrane (PEM) and phosphoric acid fuel cells, protons move through the electrolyte to the cathode to combine with oxygen and electrons, producing water and heat.
- For alkaline, molten carbonate, and solid oxide fuel cells, negative ions travel through the electrolyte to the anode where they combine with hydrogen to generate water and electrons.
- The electrons from the anode side of the cell cannot pass through the membrane to the positively charged cathode; they must travel around it via an electrical circuit to reach the other side of the cell. This movement of electrons is an electrical current.

The amount of power produced by a fuel cell depends upon several factors, such as fuel cell type, cell size, the temperature at which it operates, and the pressure at which the gases are supplied to the cell. Still, a single fuel cell produces enough electricity for only the smallest applications. Therefore, individual fuel cells are typically combined in series into a fuel cell stack. A typical fuel cell stack may consist of hundreds of fuel cells.

Direct hydrogen fuel cells produce pure water as the only emission. This water is typically released as water vapor. Fuel cells release less water vapor than internal combustion engines producing the same amount of power.

Click here to see how a polymer electrolyte membrane (PEM) fuel cell works.□

Fuels

Most fuel cells systems use pure hydrogen or hydrogen-rich fuels, such as methanol, gasoline, diesel, or gasified coal, to produce electricity. Both fuel types have advantages and limitations.

Pure Hydrogen

Most fuel cell systems are fueled with pure hydrogen gas, which is stored onboard as a compressed gas. Since hydrogen gas has a low energy density, it is difficult to store enough hydrogen to generate the same amount of power as with conventional fuels such as gasoline. This is a significant problem for fuel cell vehicles, which need to have a driving range of 300-400 miles between refueling to be competitive gasoline vehicles. High-pressure tanks and other technologies are being developed to allow larger amounts of hydrogen to be stored in tanks small enough for passenger cars and trucks.

In addition to onboard storage problems, our current infrastructure for getting liquid fuel to consumers can't be used for gaseous hydrogen. New facilities and delivery systems must be built, which will require significant time and resources. Costs for large-scale deployment will be substantial.

Hydrogen-rich Fuels

Fuel cell systems can also be fueled with hydrogen-rich fuels, such as methanol, natural gas, gasoline, or gasified coal. In many fuel cell systems, these fuels are passed through onboard "reformers" that extract hydrogen from the fuel. Onboard reforming has several advantages:

- It allows the use of fuels with higher energy density than pure hydrogen gas, such as methanol, natural gas, and gasoline.
- It allows the use of conventional fuels delivered using the existing infrastructure (e.g., liquid gas pumps for vehicles and natural gas lines for stationary source).

There are also several disadvantages to reforming hydrogen-rich fuels:

- Onboard reformers add to the complexity, cost, and maintenance demands of fuel cell systems.
- If the reformer allows carbon monoxide to reach the fuel cell anode, it can gradually decrease the performance of the cell.
- Reformers produce carbon dioxide (a prominent greenhouse gas) and other air pollutants, but less than typical fossil combustion processes.

High-temperature fuel cell systems can reform fuels within the fuel cell itself—a process called internal reforming—removing the need for onboard reformers and their associated costs. Internal reforming, however, does emit carbon dioxide, just like onboard reforming. In addition, impurities in the gaseous fuel can reduce cell efficiency.

Fuel Cell Systems

The design of fuel cell systems is quite complex and can vary significantly depending upon fuel cell type and application. However, most fuel cell systems consist of four basic components:

1. A fuel processor
2. An energy conversion device (the fuel cell or fuel cell stack)
3. A current converter
4. Heat recovery system (typically used in high-temperature fuel cell systems used for stationary applications)

Though they are not discussed here, most fuel cell systems include other components and subsystems to control fuel cell humidity, temperature, gas pressure, and wastewater.

Fuel processor

The first component of a fuel cell system is the fuel processor. The fuel processor converts fuel into a form useable by the fuel cell. If hydrogen is fed to the system, a processor may not be required or it may only be needed to filter impurities out of the hydrogen gas.

If the system is powered by a hydrogen-rich conventional fuel such as methanol, gasoline, diesel, or gasified coal, a reformer is typically used to convert hydrocarbons into a gas mixture of hydrogen and carbon compounds called "reformate." In many cases, the reformate is then sent to another reactor to remove impurities, such as carbon oxides or sulfur, before it is sent to the fuel cell stack. This prevents impurities in the gas from binding with the fuel cell catalysts. This binding process is also called "poisoning" since it reduces the efficiency and life expectancy of the fuel cell.

Some fuel cells, such as molten carbonate and solid oxide fuel cells, operate at temperatures high enough that the fuel can be reformed in the fuel cell itself. This is called internal reforming. Fuel cells that use internal reforming still need traps to remove impurities from the unreformed fuel before it reaches the fuel cell.

Both internal and external reforming release carbon dioxide, but less than the amount emitted by internal combustion engines, such as those used in gasoline-powered vehicles.

Energy Conversion Device - The Fuel Cell Stack

The fuel cell stack is the energy conversion device. It generates electricity in the form of direct current (DC) from chemical reactions that take place in the fuel cell. The fuel cell and fuel cell stack are covered under Fuel Cell Components and Function.

Current Inverters &Conditioners

The purpose of current inverters and conditioners is to adapt the electrical current from the fuel cell to suit the electrical needs of the application, whether it is a simple electrical motor or a complex utility power grid.

Fuel cells produce electricity in the form of direct current (DC). In a direct current circuit, electricity flows in only one direction. The electricity in your home and work place is in the form of alternating current (AC), which flows in both directions on alternating cycles. If the fuel cell is used to power equipment using AC, the direct current will have to be converted to alternating current.

Both AC and DC power must be conditioned. Power conditioning includes controlling current flow (amperes), voltage, frequency, and other characteristics of the electrical current to meet the needs of the application. Conversion and conditioning reduce system efficiency only slightly, around 2 to 6 percent.

Heat Recovery System

Fuel cell systems are not primarily used to generate heat. However, since significant amounts of heat are generated by some fuel cell systems—especially those that operate at high temperatures such as solid oxide and molten carbonate systems—this excess energy can be used to produce steam or hot water or converted to electricity via a gas turbine or other technology. This increases the overall energy efficiency of the systems.

Transportation

Source: http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/transportation.html

The transportation sector is the single largest consumer of petroleum in the United States, accounting for nearly two-thirds of our annual consumption. Most of this, about 75 percent, is used to power fuel highway vehicles, such as cars, trucks, and buses. In addition, highway vehicles are responsible for over 60 percent of the carbon monoxide emissions and about 20 percent of greenhouse gas emissions. A transportation system powered by hydrogen and fuel cells would significantly improve our national energy security and reduce emissions of harmful pollutants and greenhouse gases.

The HFC&IT Program is working closely with the FreedomCAR and Vehicle Technologies Program to further the state of the art of fuel cell systems for highway vehicles, with the goal of moving these technologies toward commercialization. While scientists and industry continue to make breakthroughs, several technical challenges for automotive fuel cell power systems remain.

- Reducing component and system costs (including reducing precious metal requirements)
- Developing high-volume manufacturing capability
- Demonstrating component and system durability
- Reducing system startup time, especially for gasoline-powered fuel cell systems
- Developing high-efficiency air management subsystems

Industry has the expertise to integrate fuel cell technology into vehicles, DOE has concentrated its efforts into supporting research into core technologies to improve fuel cell systems and the various subsystems and components that comprise them. These technologies include

- Direct hydrogen and reformate polymer electrolyte membrane (PEM) fuel cell systems
- Direct methanol fuel cell systems and components
- Analysis tools for evaluating and projecting the costs and performance of fuel cell systems and fuel cell vehicle designs
- Large-scale component manufacturing processes, especially for stack components
- Fuel processing subsystems and components, such as quick-start gasoline reformers and water-gas shift catalysts
- Fuel cell stack subsystems and components, such as low-platinum catalysts, bipolar plates, and carbon monoxide sensors

- Air management subsystems and components, such as turbocompressors, blowers, and hybrid compressor/expander modules

Current R&D projects (PDF 1.2 MB) to advance transportation fuel cell systems are listed in the HFC&IT 2002 Annual Progress Report. In addition to fuel cell system research, DOE is sponsoring research to improve fuel cell subsystems and components.

Dual Pathway Development
DOE is pursuing a dual pathway in developing fuel cell systems for fuel cell vehicles (FCVs):

PEM fuel cell systems fueled directly by hydrogen
PEM fuel cell systems fueled by hydrogen reformed onboard from gasoline, methanol, ethanol, or natural gas
Direct hydrogen PEM fuel cell systems are more technically mature and face fewer challenges than systems with onboard fuel processors, but several significant issues remain, including the lack of a refueling infrastructure, onboard hydrogen storage, cost, durability, size, and weight. Therefore, DOE is also pursuing development of onboard fuel processors to produce hydrogen from gasoline and alternative fuels. On-board reforming would allow fuel cell vehicles to run on fuels that would be compatible with the existing refueling infrastructure. This would allow a more gradual transition to direct hydrogen fuel cell technology.

However, on-board fuel processing presents serious technical and economic challenges of its own that may not be overcome in the required "transition" time frame. Consequently, DOE is deciding whether to continue onboard fuel processing R&D beyond the end of FY 2004. Identification of decision criteria (such as energy required for startup) and metrics is in the early stages.

Auxiliary Power Units
HFC&IT is also sponsoring the development of auxiliary power units (APUs) that run on reformate fuels for use on commercial trucks. Since these APUs would most likely run on diesel, research is focused on diesel fuel processors that can produce hydrogen with minimal amounts of sulfur in the reformate.

Challenges

Source: http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/challenges.html

Although the potential benefits of fuel cells are significant, many challenges, technical and otherwise, must be overcome before fuel cell vehicles will be a successful, competitive alternative for consumers.

Cost
Cost is the greatest challenge to fuel cell development and adaptation, and it is a factor in almost all other fuel cell challenges as well. Several fuel cell designs require expensive, precious-metal catalysts, while others require costly materials that are resistant to extremely high temperatures. Costs are also associated with fuel cell

durability and operating lifetime, fuel delivery and storage, and other aspects of fuel cell use.

Durability & Dependability

Another technical challenge facing fuel cells is the need to increase durability and dependability. High-temperature fuel cells, in particular, are prone to material breakdown and shortened operating lifetimes. PEM fuel cells must have effective water management systems to operate dependably and efficiently. Finally, all fuel cells are prone, in varying degrees, to catalyst poisoning, which decreases fuel cell performance and longevity. Research into these areas is ongoing, and DOE is sponsoring and participating in demonstration programs to test the durability of new components and designs.

Fuel Issues

A number of fuel-related challenges exist for fuel cells, especially those powered by pure hydrogen.

- **Production.** Hydrogen is currently more expensive to produce than conventional fuels, such as gasoline, and many of the more cost-effective production methods generate greenhouse gases.

- **Delivery.** The current system for delivering conventional fuels to consumers cannot be used for hydrogen. New infrastructure will have to be developed and deployed. Unfortunately, since several potential technologies are evolving at this stage of development, the exact infrastructure requirements have not been determined.

- **Storage.** Hydrogen has a low energy density in terms of volume, making it difficult to store amounts adequate for most applications in a reasonable-sized space. This is a particular problem for hydrogen-powered fuel cell vehicles, which must store hydrogen in compact tanks. High-pressure storage tanks are currently being developed, and research is being conducted into the use of other storage technologies such as metal hydrides and carbon nanostructures (materials that can absorb and retain high concentrations of hydrogen).

- **Safety.** Hydrogen, like gasoline or any other fuel, has safety risks and must be handled with due caution. While we are quite familiar with gasoline, handling hydrogen will be new to most of us. Therefore, developers must optimize new fuel storage and delivery systems for safe everyday use, and consumers must become familiar with hydrogen's properties and risks.

Public Acceptance

Finally, fuel cell technology must be embraced by consumers before its benefits can be realized. This is especially true for transportation, stationary residential, and portable applications, where consumers will interact with fuel cell technology directly. Consumers may have concerns about the dependability and safety of fuel-cell-powered equipment, just as they have about other modern devices when they were introduced.

A Fuel Cell In Your Phone

SOURCE: http://www.technologyreview.com

Tired of short-lived batteries? Methanol-powered micro fuel cells are racing toward market, promising up to 20 hours of cell-phone talk time.

By David Voss

November 2001

In a Los Alamos, NM, industrial park not far from the laboratory birthplace of the atomic bomb, Robert Hockaday sits in the cluttered lab of his startup company Manhattan Scientifics, holding a business-card-sized patch of clear plastic. Closer inspection shows a circuit-board-like pattern of black platinum and ruthenium printed on either side. The contraption is the innards of a five-centimeter-by-13-centimeter power plant that generates its own electricity using methanol as fuel. It may not look like much at first glance, but it's one member of a new class of tiny power packs that is ready to explode onto the market—and that just might annihilate one of the world's most ubiquitous technologies, the battery.

These miniature power plants, called micro fuel cells, promise a huge power boost for portable electronics ranging from cell phones to laptop computers to future generations of power-hungry, Web-enabled handheld devices. Today's best lithium-ion cell-phone batteries provide an average of only four hours of talk time; micro fuel cells could provide up to 20 hours of talk time. And after that, instead of plugging in the cell phone overnight, or swapping batteries, you'd just snap in a new methanol cartridge.

Fuel cells are, of course, already bursting onto the market in other forms—and in far bigger sizes. Buses powered by fuel cells are making their first appearances, and cars are next (**see "Fill 'er Up with Hydrogen," TR November/December 2000**). Fuel cells that provide backup power for homes and offices are becoming available, too (**see "Power to the People," TR May 2001**). Electrolux has even prototyped a cordless fuel-cell vacuum cleaner. Among other advantages, fuel cells use readily available sources of energy—namely, hydrogen or methanol—and produce only water, carbon dioxide and heat as waste products.

Now, industry is gearing up to make fuel cells small enough for consumer electronics. Building practical fuel cells this small—devices that produce one-tenth of a watt to 50 watts—presents huge engineering and materials challenges, but the market opportunity is enormous. "Portable fuel cells have the real potential of being profitable in a shorter time span than either stationary or automotive fuel-cell applications," says Atakan Ozbek, vice president for energy research at Allied Business Intelligence, a technology research firm in Oyster Bay, NY. "In five years this could be potentially a billion-dollar-a-year market. This industry is going to kick."

Not surprisingly, a race to commercialize the technology is in full swing and includes everyone from Motorola and Korean electronics giant Samsung to startup companies like Hockaday's. The competitors are betting on different designs—and even slightly different chemistries—but they share a common goal: taking a bite out of the $6 billion world market for rechargeable batteries.

The first successful application is likely to be methanol fuel cells that produce approximately one-tenth of a watt and can recharge conventional batteries, liberating consumers from the dashboard lighter or the wall socket. Next will be fuel cells small enough to actually fit in the battery compartments of existing phones and yet powerful enough—one watt for cell phones, 50 watts for laptop computers—to be used for direct power.

Even farther on the horizon, microchips will be directly powered by built-in fuel cells. These fuel cells will provide a boon to miniaturization by removing the need for separate power sources. They'll be custom designed to provide precise power needs. And production costs should drop when both chip and power source are fabricated as one unit. Self-powered chips, in turn, could enable a future generation of self-sufficient gadgets, like tiny networked sensors that can operate in remote areas, detecting pollutants, biowarfare toxins or anything else that needs detecting, and sending out the data for months.

Getting Small

The problem with conventional batteries is that they rely on electrochemistry that dates to the late 18th century, and they have some severe limitations. Most notably, once the supply of chemicals inside the battery has finished reacting, the battery goes dead. You must either connect it to a charger plugged into the wall socket or throw it away—preferably in the recycle bin because of toxic ingredients like cadmium and mercury. And batteries aren't likely to get much better; virtually every chemical combination has been tried, says Shimshon Gottesfeld, chief technology officer at Albany, NY-based Mechanical Technology, a company developing micro fuel cells. "Even the best batteries have little chance to go very much higher" in the power they can produce by weight, he says.

Fuel cells are more complex, but they carry fundamental advantages. As long as there's a supply of hydrogen or methanol, the fuel cell will produce electricity. Moreover, thanks to the high-energy fuels they use, fuel cells produce more energy for their weight than batteries ever will.

But fuel cells are tough to engineer, and the smaller ones are toughest of all. The design challenges for micro fuel cells start with the choice of fuel. Hydrogen is impractical; it's a gas and must be compressed at very high pressures, and even then it requires tanks too large for portable electronics. Methanol/water mixtures are more easily stored in a small fuel cell, but using them creates new engineering hurdles. To manage a liquid fuel, tiny pumps and pipes are required. Then there's the waste water. Not even the most ardent cell-phone users would tolerate power supplies that drip on their shoulders, so fuel cells must evaporate the water. All fuel cells create heat; the small versions operate at anywhere from 15 degrees C to a scalding 60 degrees C. While this provides a means to evaporate waste water, it also requires the right balance of insulation and venting.

Cramming all of this into a nifty package the size of a couple of AA cells presents a real challenge. And given the fierce competition to commercialize a micro fuel cell, most corporate players are cagey about how they've begun solving these problems. "There is a lot of posturing among the companies, but that is what you'd expect in the early stages as they try to maintain their positions," says fuel cell watcher Chris Dyer, editor of the Journal of Power Sources. But, he adds, "This isn't smoke and mirrors. It's a real technology and just requires some clever engineering to make it work."

Most observers predict that the first micro fuel cell on store shelves will be a charging device using methanol. A half-dozen companies are working on variations on this theme, including Manhattan Scientifics. In Hockaday's design, the fuel cell components aren't arranged in a stack, like traditional automotive fuel cells. Rather, they're laid out side by side, like components on a microprocessor, making them amenable to semiconductor-manufacturing techniques.

Mechanical Technology has already cofounded a company that sells refrigerator-sized commercial and residential fuel-cell power plants. Now, Mechanical Technology is setting its sights on smaller things, starting with charging devices. "We are very optimistic about the prospects for commercializing this," says Mechanical Technology's Gottesfeld, former director of the Los Alamos lab's fuel cell research program. "We are not only looking at chargers but a complete system for cell phones. We're also looking at other possibilities like laptops, the toy market and power tools."

Motorola and Korea's Samsung are also actively developing prototypes. Hyuk Chang, a principal researcher at the Samsung Advanced Institute of Technology outside of Seoul, says the company's goal is to demonstrate working models in a year, again with charging devices leading the way. "I think it will take another two years to get from the lab into customers' hands," says Chang. "The hard question is what will be the first application."

At Motorola, fuel-cell project leader Jerry Hallmark is pursuing a strategy that promises smaller fuel cartridges. He says the company has developed tiny fluid systems that would continually recycle the water in the methanol-water fuel mixture. Replacement cartridges could just carry undiluted methanol. "The fuel cell can't run on concentrated methanol; it needs a dilute solution. But you don't want to carry a dilute fuel," he says. Hallmark adds it will likely take three to five years for any company—including Motorola—to begin selling a product.

Packing a Punch

What Motorola and the other companies want most of all, though, are battery-like fuel cells that snap right onto phones and other electronics, to power them directly. "The cell phone is one of the hardest, because people would like to replace their battery with a fuel cell the same size. I'd love to be able to give it to them, but we're a long way from having something like that," Hallmark says.

To realize this vision, the companies are pursuing varied strategies. New York City-based Medis Technologies believes it can make a fuel cell that could replace the cell-phone battery, providing 20 hours of cell-phone talk time and hundreds of hours of standby on a single fuel cartridge. Robert K. Lifton, Medis's chief executive officer, says the company is using a proprietary liquid electrolyte that can operate with higher concentrations of fuel—and provide correspondingly more power—than conventional alternatives. But Medis is not saying exactly how it works. "We have around 17 patents filed, and we're waiting to get them before we discuss the details," says Lifton. The business strategy, though, couldn't be plainer: it's the razor blade approach. "The payoff for us would be the refills," at about $1 per refill, explains Lifton. He says Medis will have a prototype by the end of this year.

Another strategy involves carrying methanol as the fuel and then converting it when needed into hydrogen. Because hydrogen packs more power by weight than methanol, the scheme could produce more powerful and efficient fuel cells. Robert Savinell, a chemical engineering professor at Case Western Reserve University, is trying to build just such a small fuel cell; so far his group has built a 25-square-centimeter prototype.

The chemical conversion of methanol to hydrogen—often called "reforming" by engineers—is simple enough technologically, except when you try to do it on a thumbnail-sized device. "People have built reformers on a large scale for kilowatt applications, so the question is not whether it works. The question is whether you can make it small enough to fit in a cell phone or laptop," says Motorola's Hallmark.

Chip Power

Beyond the day when electronics come with built-in fuel cells instead of batteries, another technology frontier looms: building fuel cells directly on chips. Already, Savinell's group at Case Western has built a prototype only 1.5 centimeters by two centimeters. His group used microfabrication techniques to "print" five to six layers of fuel cell components—the membrane, electrode and catalyst—on ceramic and silicon wafers, and more recently on a flexible polymer material. At this scale, he's using hydrogen as a fuel, stored as sodium borohydride and released with a platinum catalyst. "The hope is to provide power on a chip with a sensor and a transmitter—a totally self-sufficient device," Savinell says.

Researchers at the Georgia Institute of Technology, MIT, Stanford University and Sandia National Laboratories in Livermore, CA, are also working on building chip-scale fuel cells. To make these devices run on easily stored methanol, Paul A. Kohl, a professor of chemical engineering at Georgia Tech, is fabricating tiny channels on silicon through which methanol and water can pass. These channels could be created on a conventional silicon-chip assembly line. "You could design the fuel cell to supply exactly the power you want and be the size you want," says Kohl.

Beyond shrinking fuel cells to the chip scale, another long-term goal is enabling fuel cells to directly tap the power of hydrogen but avoid high-pressure tanks. One ambitious approach would make use of carbon nanotubes: pipelike carbon molecules that have the ability to store and release hydrogen. Researchers envision nano canisters full of hydrogen that could keep fuel cells humming, but this will require breakthroughs in materials and manufacturing methods, says Michael Heben, leader of a nanostructured-materials group at the U.S. Department of Energy's National Renewable Energy

Laboratory in Golden, CO. “It could be that someone puts their finger on this in the next week, or it could take 20 years,” he says.

The most credible, reproducible results to date, says David Tomanek, professor of physics at Michigan State University, were achieved by Mildred Dresselhaus, a physicist at MIT, and colleagues at the Chinese Academy of Sciences who reported finding a way for carbon nanotubes to store 4.2 percent of their weight in hydrogen. That may be enough for micro fuel cells, Tomanek says. “It will be lighter, smaller and safer than a tank, even at four percent, and this could be done in a couple of years. But I am an optimist,” he says. Dresselhaus herself is more guarded: “At the moment, we don’t have the magic wand. We have an opening that says, ‘This is something to look for.’ The next step is still missing.” That next step could come within this decade, she adds, but “we need to have a major breakthrough.”

Other electronics giants are also experimenting with carbon molecules to improve micro fuel cells. NEC has reported using horn-shaped molecules known as carbon nanohorns as a substrate for platinum catalysts, providing more surface area for stronger chemical reactions and more power. And Sony says it is using soccer-ball-shaped carbon molecules known as fullerenes—the base components of carbon nanotubes—to construct better electrolytes.

Meanwhile, the first micro fuel cells are rapidly nearing the market. Of course, the prototypes need continual fine-tuning to make sure fuel can’t leak and to increase their efficiency. But these hurdles are relatively minor, industry watchers say. After all, batteries had their share of development troubles, too. The first high-energy lithium batteries tended to catch fire and even explode. As any cell-phone owner knows, those problems were solved.

There are plenty of reasons—about $6 billion worth, in fact—to suggest the same will happen with micro fuel cells, putting these remarkable tiny power packs in millions of consumers’ pockets. Indeed, as micro fuel cells emerge from cluttered labs like the Los Alamos outpost of Manhattan Scientifics, they may put batteries, with their limited power and heavy-metal waste disposal headaches, into technology’s recycle bin.

Fuel-cell car hopes played down

David Voss is a freelance writer and former senior editor of *Science* magazine.

SOURCE: http://news.bbc.co.uk/2/hi/science/nature/2840191.stm

Hydrogen fuel-cell cars will still not be the greenest option for drivers - even after two decades of well-funded development, says a report.

The research, from the Massachusetts Institute of Technology (MIT), US, says that diesel and petrol hybrid vehicles will still be the best option at this point, despite the prospect of "aggressive research" on hydrogen fuel.

The report undermines the prospects of early success for President George W Bush's recently announced $1.2bn drive to develop commercially viable fuel cell "freedom cars" by 2020.

Children born now, he said, might take their first drive in such vehicles.

However, it seems likely that even the most advanced hydrogen fuel cell vehicle on the road in 2020 would still not be the most environmentally-friendly option.

Clean hope

Hydrogen fuel-cell vehicles are seen as one possible way to dramatically cut the quantity of greenhouse gas emissions at some point in the future.

The hydrogen used in the cells is extracted from natural gas, or petrol, and a simple chemical reaction between this and oxygen produces energy. The only by-product of this is water.

There are things that the US government could be doing now to reduce this problem, not waiting 20 years for hydrogen fuel-cell vehicles
Dr Peter Wells, Cardiff University

However, producing the fuel itself would involve substantial carbon dioxide emissions, and the MIT report concludes that these, coupled with the extra "green" costs of fuel distribution, would cancel out these advantages.

The MIT team believes that improvements to the efficiency of existing diesel and petrol cars, perhaps by supplementing them with electric motors to form "hybrid engines" would yield the best performance over the next two decades.

Aggressive research on a hybrid with a diesel engine could yield a 2020 vehicle with double the efficiency and half the emissions of diesel technology left to evolve naturally, says the report.

Dr Malcolm Weiss, from MIT's Laboratory for Energy and the Environment, said: "Ignoring the emissions and energy use involved in making and delivering the fuel and manufacturing the vehicle gives a misleading impression."

Drop in the ocean

Dr Peter Wells, a senior research fellow at the Centre for Automotive Industry Research at Cardiff University, UK, said that there was a consensus that hydrogen fuel-cell vehicles would not be viable quickly.

He said that the "titanic problem" facing the US was that even if one million fuel-cell vehicles were on the road in 2020, their benefits would be dwarfed by 200 million conventional cars.
Manufacturers showed no signs of moving away from polluting vehicles such as "light trucks", he said.

He added: "There are things that the US Government could be doing now to reduce this problem, not waiting 20 years for hydrogen fuel-cell vehicles."

The MIT report, however, does say that in the longer term, there is no alternative to hydrogen so far.

Professor John Heywood, one of the authors, said: "If auto systems with significantly lower greenhouse gas emissions are required in say 30 to 50 years, hydrogen is the only major fuel option identified to date."

Fuel Cell Markets Quantified

SOURCE:
http://www.fuelcelltoday.com/FuelCellToday/IndustryInformation/IndustryInformationExternal/NewsDisplayArticle/0,1471,2113,00.html

Fuel Cell Markets Quantified: New free report is the first to measure the number of fuel cell systems already operating

20 November 2002

Author: David Jollie and Mark Cropper

Provider: Fuel Cell Today

More than 3,800 fuel cell systems have been installed and operated worldwide, according to a new report by online resource, Fuel Cell Today. The first such systems were introduced in the 1950s and the improvement in performance and increase in the number of units since then has been impressive.
"The 58 per cent annual growth rate shown by last year's figures is significant, following high growth rates in the preceding years", commented Fuel Cell Today's deputy editor and co-author of the new report, Mark Cropper. "For example, there has been significant growth in the automotive sector, with over 300 prototype vehicles built around the world since the mid-1990s."

This growth is expected to continue as companies such as Toyota and Honda lease their first fuel cell automobiles towards the end of 2002. However, other uses for this technology are beginning to emerge, for instance powering laptop computers. Toshiba plans to sell a fuel cell powered laptop from 2004.

David Jollie, the website's editor and the report's second author, noted the mix of applications revealed by this research. "Fuel cell technology has already shown its flexibility. Several hundred units have been used for stationary power generation and even a few submarines and motor scooters boast fuel cell power sources. However, in the longer term, fuel cells could become more important. For instance, we can easily envisage ten per cent and more of the car market using this technology."

Cropper continued this theme. "We have seen prototypes and early commercial units in many of these markets. Interestingly, phosphoric acid fuel cells were almost the only type being sold until two years ago but they are already being overtaken by proton exchange membrane fuel cells, as the pace of development heats up."

Fuel Cell FAQs

SOURCE: http://www.fuelcells.org/

Where did fuel cells come from?

The first fuel cell was built in 1839 by Sir William Grove, a Welsh judge and gentleman scientist. Serious interest in the fuel cell as a practical generator did not begin until the 1960's, when the U.S. space program chose fuel cells over riskier nuclear power and more expensive solar energy. Fuel cells furnished power for the Gemini and Apollo spacecraft, and still provide electricity and water for the space shuttle.

What sort of fuels can be used in a fuel cell?

Fuel cells can promote energy diversity and a transition to renewable energy sources. Hydrogen -- the most abundant element on Earth -- can be used directly. Fuel cells can also utilize fuel containing hydrogen, including methanol, ethanol, natural gas, and even gasoline or diesel fuel. Fuels containing hydrogen generally require a "fuel reformer" that extracts the hydrogen. Energy also could be supplied by biomass, wind, solar power or other renewable sources. Fuel cells today are running on many different fuels, even gas from landfills and wastewater treatment plants.

When using a fuel other than pure hydrogen, a *reformer* or *fuel processor* is required. A *reformer* a device that produces hydrogen from fuels such as gasoline, methanol, ethanol or naphtha. Three basic reformer designs are being evaluated for fuel cells for use in vehicles: steam reforming, partial oxidation and auto-thermal reforming. **Steam reformers** combine fuel with steam and heat to produce hydrogen. The heat required to operate the system is obtained by burning fuel or excess hydrogen from the outlet of the fuel cell stack. **Partial oxidation reformers** combine fuel with oxygen to produce hydrogen and carbon monoxide. The carbon monoxide then reacts with steam to produce more hydrogen. Partial oxidation releases heat, which is captured and used elsewhere in the system. **Auto-thermal reformers** combine the fuel with both steam and oxygen so that the reaction is in heat balance. Auto-thermal reforming, while not as fully developed as the others, offers the most flexibility in heat management. In general, both methanol and gasoline can be used in any of the three reformer designs. Differences in the chemical nature of the fuels, however, can favor one design over another.

To see a listing of all FCVs complete with fuel choice, see our Fuel Cell Car Chart

Can landfill or biogas be used to fuel a fuel cell?

Fuel cells currently are in operation at landfills and wastewater treatment plants across the country, proving themselves as a valid technology for generating power from the methane gas they produce, and reducing emissions. UTC Fuel Cells is a leading supplier of fuel cells for use in these areas. Currently, companies have tapped 140 U.S. landfills and are considering collecting CH_4 at another 750, according to the EPA's Landfill Methane Outreach Program.

A demonstration test at the Penrose Landfill, in Sun Valley, CA, proved successful in 1992, and fuel cells are now operating at landfills and wastewater treatment facilities in Connecticut, New York, Boston, Oregon, and Japan. Connecticut's Groton Landfill, operating since 1996, produces 600,000 kWh of electricity a year, with a continuous net fuel cell output of 140 kW. In 1997, ONSI implemented a system at the Yonkers waste water treatment plant (WWTP) that produces over 1.6 million kWh of electricity per year, while releasing only 72 pounds of emissions into the environment. ONSI has also sold its PC25C fuel cells to two districts in California. The city of Portland, Oregon, installed a fuel cell to produce power using anaerobic digester gas from a wastewater facility. It expects to generate 1.5 million kWh of electricity per year, reducing the treatment plant's electricity bills by $102,000 annually.

Companies around the world are recognizing the fuel cell's potential to reduce methane emissions. Toshiba has installed fuel cells that run on waste gases at the Asahi and Sapparo breweries and plans to expand its efforts to sell fuel cell systems that run on gas from sewage sludge. Toshiba is beginning this operation in Yokohama City, targeting the systems to local governments. Using fuel cells to recover energy from landfill and other waste gases is proving to be a viable method and is potentially one of the cleanest and most cost-effective energy conversion technologies.

How would a fuel cell-powered car compare to one powered by a battery?

Fuel cell automobiles are an attractive advance from battery-powered cars. They offer the advantages of battery-powered vehicles but can also be refueled quickly and could go longer between refuelings.

Fuel cells utilizing hydrogen as a fuel would be zero emission vehicles, and those using other fuels would produce near-zero emissions. They are also more efficient than "grid"-powered battery vehicles. In addition, fuel cell cars could produce fewer "system-wide" releases of greenhouse gases -- taking into account all emissions associated with resource recovery, fuel processing and use.

Studies by General Motors and Ford noted that fuel cell car engines could be built for about the same price as an internal combustion engine.

How efficient will a fuel cell car be, and how many miles per gallon will it get?

Many automotive manufacturers are racing to be the first to bring a fuel cell vehicle to the marketplace. Automakers and component suppliers are spending billions of dollars to drive fuel cell technology toward commercialization. Some are concentrating on using pure hydrogen, while others are trying to find ways to use gasoline-like hydrocarbons.

The energy efficiency of fuel cells also makes them an attractive alternative for automakers. Several studies have modeled the potential energy efficiency of fuel cell vehicles (FCVs). The Argonne National Laboratory estimates that methanol fuel cell vehicles (MFCVs) will achieve a fuel economy 2.1 to 2.6 times greater than an internal combustion engine (ICE) car. The Pembina Institute for Appropriate Technology assumes that MFCVs will achieve efficiencies of 1.76 times that of a gasoline ICE. For this purpose, we will rely on the fuel economy estimate of 1.74 times that of a gasoline ICE prepared by $(S+T)^2$ for the Methanex Corporation .

The U.S. Environmental Protection Agency's (EPA) 1999 assessment of automobile fuel efficiency shows that overall fuel economy for passenger vehicles (the average for cars and light-duty trucks combined) was 23.8 mpg, the lowest since 1980 and six-tenths of a mile-per-gallon lower than in 1998. The fuel economy for the entire U.S. fleet of new vehicles has been declining in recent years as light trucks and SUVs gain a greater market share. In its Reference Case, the U.S. Energy Information Administration's (EIA) Annual Energy Outlook 2000 projects that new fuel economy will grow to 31.4 mpg by 2010. We can therefore assume that the fuel economy of the gasoline ICE will improve to 32 mpg by 2010. Assuming a MFCV fuel economy of 1.74 times that of a gasoline ICE in 2010, the MFCV will achieve over 55 mpg gasoline gallon equivalent.

Innovative changes in vehicle design and materials to reduce vehicle weight and improve aerodynamics will benefit FCVs as well as conventional vehicles. For this reason the public/private Partnership for a New Generation of Vehicles (PNGV) anticipates that a fuel cell vehicle comparable to today's Ford Taurus or Chevrolet Lumina will achieve nearly 80 miles per gasoline-equivalent gallon.

For more information on the benefits of fuel cells in automobiles, please go to our Transportation Mini-site.

How much do fuel cells cost?

One company commercially offers fuel cell power plants for about $3,000 per kilowatt. At that price, the units are competitive in high value, "niche" markets, and in areas where electricity prices are high and natural gas prices low.

A study by Arthur D. Little, Inc., predicted that when fuel cell costs drop below $1,500 per kilowatt, they will achieve market penetration nationwide. Several Companies are selling small units for research purposes. Prices vary.

Fuel cells will have to be much cheaper to become commercial in vehicles. Conventional car engines cost about $3,000 to manufacture and more research is needed to bring the cost of fuel cells down to that level.

Can I use a fuel cell to power my home?

Fuel cells are ideal for power generation, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water or space heating.

There are three main components in a residential fuel cell system - the hydrogen fuel reformer, the fuel cell stack and the power conditioner. Many of the prototypes being tested and demonstrated extract hydrogen from propane or natural gas. The fuel cell stack converts the hydrogen and oxygen from the air into electricity, water vapor and heat. The power conditioner then converts the electric DC current from the stack into AC current that many household appliances operate on. Fuel Cell Technologies Ltd. (FCT) estimates the expected pay back period on a residential fuel cell for a typical homeowner to be four years. The initial price per unit in low volume production will be approximately $1,500 per kW. Once high volume production begins, the price is expected to drop to $1,000 per kW, with the ultimate goal of getting costs below $500 per kW. Fuel cell developers are racing to reach these cost targets.

H Power is joining forces with energy companies all over the world, and has signed an $81 million contract with Energy Co-Opportunity (ECO), a consortium of rural electric cooperatives, to market its fuel cells exclusively through more than 900 cooperatives. ECO has agreed to buy 12,300 of H Power's 10kW fuel cells for $10,000 each. The two companies are working to manufacture and ship units to power-starved California within the next several months, for about $8,000 per unit. Prices are expected to drop to between $3,000 and $4,000 in seven years.

Plug Power and GE MicroGen have joined to form GE Fuel Cell Systems, LLC, and are building a network of qualified regional distributors to market, install, and service their residential fuel cell. A public utility has already agreed to purchase 75 of Plug Power's first fuel cell systems, a $7 million agreement, commencing this summer. The HomeGen 7000 is capable of serving an entire household's energy needs. Several different commercial models are going to be introduced that can operate on natural gas, propane, or methanol and are expected to achieve 40% electrical efficiency. Excess heat generated by the fuel cell can be captured and used for hot water or heating, increasing overall efficiency to over 80%. GE has signed an exclusive distribution agreement with New Jersey Resources for deployment of the fuel cells in New Jersey and DTE Energy Technologies will distribute these units in Michigan, Illinois, Ohio and Indiana. KeySpan Technologies has signed on as well to purchase and test 30 fuel cells at selected locations in New York City and Long Island.

Global Thermoelectric Inc., a solid oxide fuel cell (SOFC) manufacturer, has developed a 2.3 kW residential fuel cell system that is designed to cover the base load of an average North American home. The first prototype, running on natural gas, has been delivered to Enbridge Inc., who will be testing the system to evaluate performance characteristics including heat recovery to meet residential hot water needs. The results of the testing will be incorporated into subsequent prototype designs.

IdaTech has demonstrated a 3 kW residential fuel cell system and has begun producing demo units for Bonneville Power. The methanol-powered system is about the size of a chest freezer and is expected to hit the commercial market in 2003.

UTC Fuel Cells (formerly International Fuel Cells) is developing PEM power plants running on propane and natural gas for homes and light commercial applications with a target date of 2003. UTC's stacks are modular and scalable, so when independent of the grid, multiple fuel cells can provide a high level of power reliability.

Many other companies are developing and testing fuel cells for residential applications, working together with utilities and distributors to bring them to market. Even automakers such as GM and Toyota are branching beyond vehicles and spending money on research and development for stationary applications.

To promote the commercialization of residential fuel cells, a bill proposing a stationary fuel cell tax credit has been introduced in both the House (H.R. 1275) and the Senate (S. 828), and referred to the Ways and Means Committee and the Finance Committees respectively. The bills would allow U.S. business and residential taxpayers that purchase fuel cell systems for stationary commercial and residential applications to be eligible for a $1000 per kW credit. It would be available for five years, starting on January 1, 2002 until December 31, 2006, after which fuel cell manufacturers would be expected to produce a product at market entry cost. On top of that, many states have net metering laws in place today, which allow qualified customers to sell surplus electricity back to the grid, and heat produced from a fuel cell qualifies.

Where can I buy a fuel cell?

The following companies offer a variety of fuel cell products, including prototype demonstration systems, low-wattage systems, beta-testing systems, and fuel cell-powered products. You will need to check with the individual companies to see if their systems/products are suited to your needs. You can also check out our Interactive map and listing of fuel cell developers or purchase our Fuel Cell Directory.

Avista Laboratories - PEM fuel cells for backup and remote applications

Ball Aerospace & Technologies Corp. - portable PEM fuel cell power systems

BCS Technology, Inc. - small PEM fuel cell systems

DAIS-Analytic Corporation - small PEM fuel cell systems

DCH Technology, Inc. - small PEM fuel cell systems

EcoSoul, Inc - small, educational regenerative fuel cell kits

ElectroChem, Inc. - small PEM fuel cell systems

Electro-Chem-Technic - educational fuel cell kits

Element 1 Power Systems, Inc. - fuel cell systems in a variety of sizes

GreenVolt Power Corporation - portable and emergency fuel cells

H Power Corporation - a variety of PEM fuel cell powered products, including backup power systems

H-TEK, Inc. - educational fuel cell kits - Japanese site

Heliocentris Energiesysteme - educational fuel cell kits

IdaTech - fuel cell systems with up to 10 kW in generating power

Plug Power, LLC - PEM fuel cells for residential applications

UTC Fuel Cells - 200kW PAFC power plants

Let us know if your company sells fuel cells and should be added to this list. Note: only sellers of fuel cell products, stacks or systems will be added to this list.

How can I invest in fuel cell companies?

Since Fuel Cells 2000 tries to be an independent voice on the subject of fuel cell technology, we do not recommend stocks of one company over another company. There are, however, places on the web where you can go for information on fuel cell companies that are publicly traded, and can track investment info on these companies. Listing these sites is not an implicit endorsement by Fuel Cells 2000 of the information contained on the sites:

Hydrogen & Fuel Cell Investor - follows news of companies that are publicly traded
Green Money - for information on investment companies that focus on investing in companies that sell or manufacture products that are energy efficient or environmentally beneficial.

What's holding back use of fuel cells?

Many technical and engineering challenges remain; scientists and developers are hard at work on them. The biggest problem is that fuel cells are still too expensive. One key reason is that not enough are being made to allow economies of scale. When the Model T Ford was introduced, it, too, was very expensive. Eventually, mass production made the Model T affordable.

Where does the hydrogen come from?

Hydrogen made from renewable energy resources provides a clean and abundant energy source, capable of meeting most of the future's high energy needs. When hydrogen is used as an energy source in a fuel cell, the only emission that is created is water, which can then be electrolyzed to make more hydrogen – the waste product supplies more fuel. This continuous cycle of energy production has potential to replace traditional energy sources in every capacity – no more dead batteries piling up in landfills or pollution-causing, gas-guzzling combustion engines. The only drawback is that hydrogen is still more expensive than other energy sources such as coal, oil and natural gas. Researchers are helping to develop technologies to tap into this natural resource and generate hydrogen in mass quantities and cheaper prices in order to compete with the traditional energy sources. There are three main methods that scientists are researching for inexpensive hydrogen generation. All three separate the hydrogen from a 'feedstock', such as fossil fuel or water - but by very different means.

Reformers - Fuel cells generally run on hydrogen, but any hydrogen-rich material can serve as a possible fuel source. This includes fossil fuels – methanol, ethanol, natural gas, petroleum distillates, liquid propane and gasified coal. The hydrogen is produced from these materials by a process known as reforming. This is extremely useful where stored hydrogen is not available but must be used for power, for example, on a fuel cell powered vehicle. One method is endothermic steam reforming. This type of reforming combines the fuels with steam by vaporizing them together at high temperatures. Hydrogen is then separated out using membranes. One drawback of steam reforming is that is an endothermic process – meaning energy is consumed. Another type of reformer is the partial oxidation (POX) reformer. CO2 is emitted in the reforming process, which makes it not emission-free, but the emissions of NOX, SOX, Particulates, and other smog producing agents are probably more distasteful than the CO2. And fuel cells cut them to zero.

Enzymes - Another method to generate hydrogen is with bacteria and algae. The cyanobacteria, an abundant single-celled organism, produces hydrogen through its normal metabolic function,. Cyanobacteria can grow in the air or water, and contain enzymes that absorb sunlight for energy and split the molecules of water, thus producing hydrogen. Since cyanobacteria take water and synthesize it to hydrogen, the waste emitted is more water, which becomes food for the next metabolism.

Solar- and Wind- powered generation - By harnessing the renewable energy of the sun and wind, researchers are able to generate hydrogen by using power from photovoltaics (PVs), solar cells, or wind turbines to electrolyze water into hydrogen and oxygen. In this manner, hydrogen becomes an energy carrier – able to transport the power from the generation site to another location for use in a fuel cell. This would be a truly zero-emissions way of producing hydrogen for a fuel cell.

What about hydrogen safety?

There are many myths about hydrogen which have recently been dispelled. Two years ago, a study of the Hindenburg incident found that it was not the hydrogen that was the cause of the accident. Safety tests performed by Ford Motor Company for the U.S. Department of Energy have found that the technologies being tested for storing hydrogen in a fuel cell vehicle are actually SAFER than storage of gasoline.

The following quotes are taken from "Direct-Hydrogen-Fueled Proton-Exchange-Membrane Fuel Cell System for Transportation Applications: Hydrogen Vehicle Safety Report" by Ford Motor Company, May 1997: Pg 17-18: "Addison Bain, a retired NASA safety expert, has conducted a comprehensive investigation of the Hindenburg incident, searching through archives in both the U.S. and in Germany, interviewing the few remaining witnesses including surviving crew members, and even securing the services of NASA scientists to analyze fragments of the Hindenburg saved as souvenirs. . . Bain's most startling hypothesis is that hydrogen may not have played a major role in the fire. He cites several witnesses that saw what could have been 'St. Elmos fire," -- lightning bolts attracted to the surface of the giant airship. His thorough analysis of the mechanical structure of the dirigible shows that any hydrogen leaking from the inner bags would have been vented to the outside. He shows from historical records and actual analysis of remaining fragments of the ship's gas bags that the construction was either cellulose acetate or cellulose nitrate. Both are flammable. . . In addition, aluminum flakes were added to the covering material to help reflect sunlight to keep the gas bags cool. But Bain points out that cellulose nitrate and metal chips are also the ingredients of rocket fuel, politely suggesting that it might not be wise to paint airships with rocket fuel! His final slide shows a photograph of another burning airship, engulfed in flames much like the Hindenburg. But with one major difference: this airship was filled with inert helium, not hydrogen, suggesting that the Hindenburg fire could very well have been started by lightning igniting highly flammable fabric on the airship. While hydrogen clearly added to the conflagration, the Hindenburg might have burned even if it had been filled with helium. In retrospect, the Hindenburg was a high risk venture, since the 190,000 standard cubic meters (6.7 million SCF) of hydrogen was carried in a set of rubberized cloth bags, with little protection from outside disturbances. The energy content of the hydrogen was equivalent to about 1,900 gigajoules (GJ), or 19 GJ per passenger. A modern hydrogen-powered vehicle would be much safer, with energy stored in crash-tested tanks instead of flimsy cloth bags. A fuel cell electric vehicle would carry about 0.8 GJ of hydrogen energy for a four-passenger car, or 0.2 GJ per passenger. The hydrogen would be stored in one or more fiber wrapped composite tanks that could survive 50-mph head-on collisions, engulfment by a diesel fuel fire, and pressures at least 2.25 times design pressure without rupture. The message is clear: a modern fuel cell electric vehicle would have 2300 times less hydrogen energy content than the Hindenburg, or 100 times less per passenger, and the hydrogen container would be immeasurably stronger. In effect, there is no comparison between the safety aspects of the Hindenburg and those of a fuel cell vehicle."

With regards to the probability of a rupture of the hydrogen storage tank, Pg 30: "Each tank is tested at 1.5 times its rated operating pressure, and samples from each lot are pressure tested to failure. Each tank design must be qualified at 2.25 times normal operating pressure. Each class of tank is also subjected to gunfire and must not explode but leak only through the bullet-hole." (Try doing that to a gasoline tank!)

Pg xi: "In a collision in open spaces, a safety-engineered hydrogen FCV should have less potential hazard than either a natural gas vehicle or a gasoline vehicle due to four factors. First, carbon fiber wrapped composite storage tanks (the leading high pressure storage tank material due to its low weight) are able to withstand greater impacts than the vehicle itself without rupture, thereby minimizing the risks of a large release of hydrogen as a result of a collision. Second, hydrogen, if released, disperses much faster than gasoline due to much greater buoyancy, reducing the risks of a post-collision fire. Third, the FCV will carry 60% less total energy than a gasoline or natural gas vehicle, resulting in less potential hazard should it ignite. Finally, the design recommended here includes an inertially activated switch in each FCV that, in the event of a collision, will simultaneously shut off the flow of hydrogen via a slenoid valve or valves, and will cut electrical power from the battery."

Pg. xii: "Hydrogen has 52 times greater buoyancy and 12.2 times greater diffusion coefficient than gasoline. Thus hydrogen will disperse much more quickly than gasoline or natural gas. Similarly, hydrogen's lower flammability limit is four times greater than that of gasoline.

You can read more about hydrogen at our Fuel Cell Library.

Can a fuel cell vehicle use other fuels besides hydrogen?

Fuel cells run on hydrogen, the most abundant element on Earth. The simplest and most efficient vehicle designs store hydrogen on board, either as compressed gas, liquid, or in metal hydride. Due to its low energy density, however, hydrogen is harder to transport and store than other liquid fuels. In addition, a limited infrastructure is currently available for distributing hydrogen to the motoring public. Many automotive manufacturers have opted to use a ‘transition’ fuel to use in their first non-fleet commercial fuel cell vehicles, with the long-term vision of establishing a pure hydrogen infrastructure. Daimler Chrysler is looking into methanol and hydrogen as options to power its first FCVs while looking at other alternatives including sodium borohydride; Ford has announced its looking into methanol for a transition fuel to hydrogen; GM is looking into methanol, hydrogen, and low sulfur, clean gasoline (CHF); and Toyota has announced that its first non-fleet FCVs will probably use CHF as a transition fuel to pure hydrogen. The very first FCVs will, however, be fleet vehicles powered on hydrogen. This is feasible since the vehicles will be able to refuel at a centrally located fuel station.

If all those fuel cell cars are emitting water, won't that create other problems?

According to calculations by Jason Mark of the Union of Concerned Scientists:

Assuming all hydrogen input turns into water, and that all water is released (either as liquid or vapor), "If the entire U.S. passenger vehicle fleet were powered by hydrogen FCVs, the amount of water emitted annually (assuming no losses) would be 0.005% the rate of natural evapotranspiration (water that evaporates or is transpired by plants) in the continental U.S."

Many people are concerned about the amount of water produced by a fuel cell vehicle. They worry "where will the water go?" "Will it cause fog or ice?" and what we can do with it to make it useful. Some discussion of what we have now (the internal combustion engine) and what we will have in a few years (the fuel cell vehicle) can help to put this into perspective.

It is important to remember that gasoline engines also produce water. The hydrogen in gasoline (and the hydrogen in diesel fuel and the hydrogen in natural gas) all combine with oxygen in the flame to produce water. The production of water is one of the big reasons combustion happens since forming water releases heat that makes the reaction possible. It is not a new thing to produce water while making power and energy. Burning or chemically oxidizing any hydrogen bearing fuel produces water. The only fuel that may be an exception to this rule is pure-carbon (coal). For the sake of comparison sake we will use a C_6H_{18} (octane) baseline for gasoline. We will base our calculations of the current situation on an internal combustion engine burning octane.

The classical hydrogen fuel cell uses hydrogen as its fuel. Where does the hydrogen come from? Natural gas! Yes, the vast majority of hydrogen sold in the world today is made from natural gas, (natural gas is mostly methane, CH_4). The conversion is done by combining the CH_4 with H_2O (water!) to make H_2 and CO_2, so the manufacturing of hydrogen actually USES water! But we will account for this by using the energy units for comparison, just to make it simpler.

So we are comparing the energy from a fuel cell using Hydrogen derived from natural gas to the energy from a gasoline engine using gasoline (octane). What is the difference? The heat of formation of water is - 69 kcal/mole and that of carbon dioxide is - 94 kcal/mole. The heat of combustion of octane in air at perfect stoichiometry with no unburned hydrocarbon is 1806 kcal/mole and the potential chemical energy contained in the same amount of methane is 370 kcal/mole. We must reduce the methane energy by 15% to account for an 85% efficient (energy basis) reformer. The reduction leaves us with 315 kcal/mole in the methane. Comparing the energy content to the hydrogen content allows us to get at the difference in water production between the two fuels.

The ratio of heat produced by chemically oxidizing each one is 1806/315 = 5.7. That means one mole of octane will produce almost six times the energy of one mole of methane (converted to hydrogen and) used in a fuel cell, and it weighs more too.

The ratio of water formed is the same as the ratio of hydrogen atoms or 18/4 = 4.5. That means the octane makes 4.5 times the amount of water as the methane does to make 5.7 times the energy. Computing a relative ratio of water production for a common unit of energy (cal or btu) gives 4.5/5.7 = 0.78. So the octane makes less water (22% less) than the methane does, on a per unit of energy basis. But energy doesn't take into account the energy conversion device (the fuel cell versus the internal combustion engine). We have to take the energy conversion efficiency into account. Fuel cells are typically 30%-40% efficient in automotive sizes.

They are even higher in efficiency in some instances running on pure hydrogen. Some automotive applications running on pure hydrogen have achieved 50% efficiency using fuel cells. Gasoline internal combustion engines are lucky to get 15%-20%. This means that for the same energy in the fuel, the fuel cell car will do twice the work, and the car will travel twice as far, or conversely that the fuel cell car will need only half the energy to do the same work (move the same miles). So divide the 5.7 in half to get 5.7/2 = 2.85 (you only need half the energy to do the same work!) and now you have the FINAL ANSWER. 4.5/2.85 = 1.6. So the internal combustion engine actually makes 1.6 times MORE water than the fuel cell for the same miles traveled in the same car with the same passenger and luggage load. On a "miles traveled" basis, the fuel cell produces LESS water than an internal combustion engine running on gasoline. This is mostly due to the much higher efficiency of the fuel cell compared to the internal combustion engine.

While it is true that the internal combustion engine will make more water, it does so at a higher temperature and this might tend to keep the water in the vapor phase longer than the low temperature fuel cell exhaust. It remains to be seen how the now fuel cell cars will fare in use, but the California Fuel Cell Partnership will certainly find out. But keep in mind that on cold days, the relative humidity is usually VERY low, even if it is snowing, so the chances of condensation on the road are reduced. In Chicago and Vancouver, when they tested the Ballard buses, they put the exhaust up at the top of the bus to help make sure the water vapor didn't cause a problem, and it didn't! It made a "plume" of water vapor on cold days, but no condensation problems at all.

Engine Type	Water Vapor/mile	Carbon Dioxide/mile
Gasoline Combustion	0.39 lb.	0.85 lb.
Fuel Cell Running on Hydrogen from Gasoline	0.32 lb.	0.70 lb.
Fuel Cell Running on Hydrogen from Methane	0.25 lb.	0.15 lb.
Fuel Cell Running on Renewable Hydrogen	0.25 lb.	0.00 lb.

Courtesy of Jeremy Snyder, Desert Research Institute

What is the U.S. government doing now?

Government support can provide lasting momentum toward developing new technologies. Government agencies around the world are doing their part for fuel cell research & development (R&D). In January 2002, U.S. Secretary of Energy Spencer Abraham announced a new cooperative automotive research partnership called FreedomCAR with the U.S. Council for Automotive Research (USCAR) and the “Big Three” automakers: Ford, General Motors and DaimlerChrysler. This program replaces the Partnership for a New Generation of Vehicles (PNGV) and will advance fuel cell vehicles and address issues related to creating a hydrogen infrastructure.

“Under this new program … the government and the private sector will fund research into advanced, efficient fuel cell technology which uses hydrogen to power automobiles without creating any pollution,” Abraham said. “The long-term results of this cooperative effort will be cars and trucks that are more efficient, cheaper to operate, pollution-free and competitive in the showroom. This plan is rooted in President Bush’s call, issued last May in our National Energy Plan, to reduce American reliance on foreign oil through a balance of new domestic energy production and new technology to promote greater energy efficiency."

This is perhaps the biggest step the U.S. government has taken to support fuel cell technology, but it isn't the first. In 2000, the U.S. Department of Energy (DOE) committed $135 million in research funding, including projects in advanced fuel cell, hydrogen and gasoline engines with extremely low oxides of nitrogen (NOx) emissions. The DOE also awarded $17.9 million in cost-shared financial assistance to fund new research in advanced fuel cells at three Massachusetts companies: Nuvera Fuel Cells, Mechanology LLC, and Arthur D. Little Inc.

In 2000, DOE formed the Solid State Energy Conversion Alliance (SECA), made up of commercial developers, universities, national laboratories, and government agencies, to develop low-cost, high power density, solid-state fuel cells for a broad range of applications.

The U.S. Government also owns and operates 30 fuel cell cogeneration units, the world's largest fleet of fuel cells, in conjunction with the U.S. Army Engineer Research and Development Center/Construction Engineering Research Laboratory testing programs.

The Department of Transportation maintains a fuel cell bus research program. The Environmental Protection Agency has a program to facilitate the use of fuel cells at landfills and wastewater treatment plants, with several fuel cells already been installed across the United States.

Launched in 1996, the Department of Defense's (DOD) Climate Change Fuel Cell Program provides grants of $1,000/kilowatt to purchasers of fuel cell power plants. The 'buydown' program has awarded more than $18.8 million toward the purchase of 94 fuel cell units. DOD also has a residential fuel cell demonstration program involving over 21 units at 12 different military locations.

For most of the 1970s and early 1980s, a federal program involving DOE's Office of Fossil Energy and several fuel cell developers collaborated on the development of the phosphoric acid fuel cell (PAFC) system. Today, largely because of these efforts, UTC Fuel Cells is manufacturing and selling PAFCs around the world.

In the late 1980s, this program shifted its emphasis to molten carbonate and solid oxide fuel cell systems. At the FY2003 Budget briefing, the Office of Fossil Energy suggested these programs have progressed past the developmental stage, saying "molten carbonate and solid oxide fuel cells are ready to move to commercial readiness and early deployments".

The recent Freedom CAR announcement has created a new public awareness about fuel cell technology, but the U.S. government's interest in fuel cells has been around a long time. Lately, fuel cells have been getting a lot of media attention and exposure, and people are learning about their benefits and applications. With the government's support, the United States can keep up in the fuel cell race, and quite possibly, come out ahead.

Why should the government support fuel cell development?

Fuel cells can provide major environmental, energy and economic benefits that advance critical national goals. Development and optimization of energy technologies has always been a partnership between government and the private sector.

Other power technologies have enjoyed considerable support in the past, including tax credits for natural gas drilling, military support for gas turbine technology, support for solar power research, nuclear power research and coal cleanup technologies, among many other programs.

What are other countries doing?

The U.S. faces fierce competition from other countries. Canada, Japan and Germany are aggressively promoting fuel cell development with tax credits, low-interest loans and grants to support early purchases and drive down costs The following is just the tip of the iceberg of the fuel cell activity going on overseas.

In Canada, the National Fuel Cell Research and Innovation Initiative, set up by the Federal Ministry has invested CAN$30 million (US$ 20,255,215) to further strengthen the industry's research and development. As part of the Initiative, the Ministers inaugurated a new National Fuel Cell Research Facility at the National Research Council's (NRC) Innovation Center on the University of British Columbia campus. Federal spending of CAN$100 million (US$67,604,093) will stimulate new environmental technologies that reduce greenhouse gases such as wind turbines, fuel cells, and advanced materials, with the Sustainable Development Technology Fund. NETL estimates that total Canadian government and corporate spending in government programs is at least $116 million.

Also in Canada, Ballard Power Systems received $30 million from the Canadian Government. Ballard has teamed up with the subsidiary of a New Jersey electric company to commercialize stationary fuel cell cogeneration units. DaimlerChrysler recently invested CAN$450 million in cash into Ballard for development of fuel cell vehicles. DaimlerChrysler has already unveiled five fuel cell vehicles, the latest being NECAR 5, a methanol fuel cell passenger vehicle based on the Mercedes A-class car.

In Europe, Germany's federal government increased the funding for research on non-nuclear technologies in 2000, to make it equivalent to the 1995 figure, which had fallen by 30% until 1999. The 2000 budget for fuel cells increased from 6.5 million EURO to 8.5 million EURO (US$7,355,900).

In 1998, Italy spent $6.1 million (11.2 billion lire) on fuel cell R&D. The PEM program for 2000-2004 involves close cooperation between government, fuel cell, automobile and oil industries with the objective of developing a fuel cell vehicle by 2004. Several fuel options will be considered, including traditional fuels as well as hydrogen and methanol. The budget request for 2000-2004 was approximately $108.5 million (200 billion lire).

The MCFC budget request ranges from $5.4 to 24.4 million (10 to 45 billion lire) per year for the next five years, with the main goal being to develop MCFC stacks with capacities up to 500 kW.

In Japan, the budget for fuel cells at the Ministry of International Trade and Industry (MITI) for FY2000 was 8,510 million yen (US$79,514,132), nearly double of the 1999 budget. Many Japanese companies are working on fuel cells, including Toyota, Toshiba, Suzuki and Sanyo.

BP and the Economic Development Board (EDB) have signed a letter of intent to build hydrogen refueling stations for future Singapore motorists driving hydrogen-powered vehicles. BP plans to install the hydrogen refueling facilities, which cost between US$500,000 to US$1.5 million each, in 2003.

In Korea, as part of a cooperative program with the Korean government, Hyundai Motor Company has ordered $391,000 worth of fuel cells stacks from Ballard Automotive. The cells will be used in a program for evaluation and development of fuel cell technology.

China plans to invest 1 billion yuan (US$120 million) in research of electric automobiles driven by fuel cells. China now has more than 20 institutes and enterprises specializing in fuel cells. A plan is also in development where the Shanghai municipal government will invest 100 million yuan (US$12 million) per year in supporting the research and development of fuel cells.

In the United Kingdom, electricity consumption from new or renewable energy sources accounted for 2% ($20 million [£ 15 million]) in 1998. The government aims to increase renewables' share to 5% by 2003 and 10% by 2010. The government will also use market stimulation measures such as the provision of guaranteed markets for non-fossil fuel generators (via the Non-Fossil Fuel Obligation), and direct support for renewable energy technology R&D. Technologies that are being considered both for their export potential and for their potential contributions to the UK's 2010 target of 10% renewables include fuel cells, photovoltaics, offshore wind, and energy crops. Research supported by this program aims to make cost-reducing improvements that will enable the commercial deployment of renewable energy systems on a significant scale. The government funds renewable energy R&D on a cost-share basis with UK companies and seeks to leverage its resources with those of EU energy R&D programs such as SAVE and THERMIE. In addition, Britain's Engineering and Physical Sciences Research Council has launched an expanded $5 million/year fundamental R&D program focusing on renewable energy.

Iceland is leading the way in the race to the first hydrogen economy. Icelandic New Energy (INE) Ltd. Is a joint-venture company owned by: VistOrku hf (EcoEnergy), DaimlerChrysler AG, Norsk Hydro ASA, and Shell Hydrogen BV. The purpose of this company, headed by Jon Bjorn Skulason, is to investigate the potential for eventually replacing the use of fossil fuels in Iceland with hydrogen-based fuels and to create the world's first hydrogen economy. The company will lead several projects including the Ecological City Transport System (ECTOS) project involving three Mercedes-Benz Citaro hydrogen fuel cell buses in Reykjavik. This project is expected to start in 2002.

Another project with DCH Technology Inc will focus on commercial fuel cell use in Iceland.

What more should be done to spur development of fuel cells?

The U.S. government should take three steps to help commercialize fuel cells:

1. Major increases are needed in research and development budgets of the Departments of Energy and Transportation, and elsewhere.

2. The federal government should also take the lead to purchase early power units and vehicles.

3. The government should continue and expand the program to help "buy down" the cost of early units installed around the country.

To put costs into perspective, we pay more than $5 billion for imported oil each month. A small fraction of that amount could fully commercialize fuel cells within five years and create tens of thousands of jobs.

How can I build my own fuel cell?

There is an article from Home Power magazine available on the internet that provides step-by-step instructions on how to build a fuel cell from scratch: http://www.homepower.com/download2.htm - click on "Hydrogen" . The article is copyrighted in the authors' names. If you do not have Adobe Acrobat for reading PDF files and would like to see an HTML version, click HERE, instead.

Is there a school science project I could do involving fuel cells?

There are many resources out there focusing on fuel cells and many websites offer science projects and lesson plans for students and teachers interested in learning more about this technology.

Dr. Martin Schmidt has written a paper that provides an excellent school science project written for all interested persons, even for those having little prior knowledge of fuel cells. You can find his paper at http://www.fuelcells.org/career/scienceproject.pdf

If you are interested in building your own fuel cell, there is an article from Home Power magazine that provides step-by-step instructions on how to build a fuel cell from scratch: http://www.homepower.com/download2.htm - click on "Hydrogen". The article is copyrighted in the authors' names.

And as always, for the latest fuel cell news and information, our online bibliography includes links to numerous books, articles, and market studies about the entire fuel cell industry - different fuel cell types, fuels and applications. You can also go to our Links page to access information from government agencies, fuel cell newsletters and organizations involved in renewable energy or subscribe to our free Monthly Fuel Cell Technology Updates.

Where can I find more information on fuel cells, including articles, research and market studies?

Our online bibliography includes links to numerous books, articles, and market studies about the entire fuel cell industry - different fuel cell types, fuels and applications. Our Bookstore has links to free fuel cell newsletters and informational brochures. You can also go to our Links page to access information from government agencies, fuel cell newsletters and organizations involved in renewable energy or subscribe to our free Monthly Fuel Cell Technology Updates.

Group: Hydrogen Fuel Cells May Hurt Ozone

SOURCE: Science – Associated Press

Thu Jun 12, 6:56 PM ET

By H. JOSEF HEBERT, Associated Press Writer

WASHINGTON - Widespread use of the hydrogen fuel cells that President Bush (news - web sites) has made a centerpiece of his energy plan might not be as environmentally friendly as many believe.

Scientists say the new technology could lead to greater destruction of the ozone layer that protects Earth from cancer-causing ultraviolet rays.

Researchers said in a report Thursday saying that if hydrogen replaced fossil fuels to run everything from cars to power plants, large amounts of hydrogen would drift into the stratosphere as a result of leakage and indirectly cause increased depletion of the ozone.

They acknowledged that much is still unknown about the hydrogen cycle and that technologies could be developed to curtail hydrogen releases, mitigating the problem. But they say hydrogen's impact on ozone destruction should be considered when gauging the potential environmental downside of a hydrogen-fuel economy.

Ever since Bush this year singled out hydrogen development as an energy priority, the fuel has been the buzzword in energy debates. Congress plans to pump more than $3 billion into hydrogen research over the next five years in hopes of putting fuel-cell-powered cars into showrooms by 2020. Industry is spending billions more to develop fuel cells, although their widespread use is probably still decades away.

Fossil fuels — coal, oil or natural gas — produce chemicals that pollute the air as well as the greenhouse gas carbon dioxide. A hydrogen fuel cell, when making energy, releases only water as a byproduct.

In an article in this week's edition of Science magazine, researchers at the California Institute of Technology raised the possibility that if hydrogen fuel replaced fossil fuels entirely, it could be expected that 10 percent to 20 percent of the hydrogen would leak from pipelines, storage facilities, processing plants and fuel cells in cars and at power plants.

Because hydrogen readily travels skyward, the researchers estimated that its increased use could lead to as much as a tripling of hydrogen molecules — both manmade and from natural sources — going into the stratosphere, where it would oxidize and form water.

"This would result in cooling of the lower stratosphere and the disturbance of ozone chemistry," the researchers wrote. It would mean bigger and longer-lasting ozone holes in both the Arctic and Antarctic regions, where drops in ozone levels have been recorded over the past 20 years. They estimated that ozone depletion could be as much as 8 percent.

Nejat Veziroglu, president of the International Association for Hydrogen Energy and director of the Clean Energy Research Institute at the University of Miami, expressed skepticism about the Cal Tech findings.

"Leakage will be much less than what they are considering," he said.

An Energy Department spokeswoman, Jeanne Lopatto, said the Cal Tech study will influence some of the government's fuel cell research, especially in areas of hydrogen transport and storage. She said the administration "welcomes new scientific knowledge on the potential effects of hydrogen production, storage and use."

The loss of some of the Earth's ozone layer is of concern because ozone blocks much of the sun's ultraviolet light, which over time can lead to skin cancer, cataracts and other problems in humans.

Ozone depletion has been contained with international treaties banning and phasing out ozone-killing chlorofluorocarbons, or CFCs. But the Cal Tech researchers said huge increases in the concentration of hydrogen in the stratosphere "could substantially delay the recovery of the ozone layer," even if a hydrogen economy is still decades away.

John Eiler, an assistant professor of geochemistry at Cal Tech and one of the article's authors, acknowledged that the concerns raised in the study might eventually be resolved when more is learned about the hydrogen fuel cycle.

For example, much of the leaking hydrogen might become absorbed in the soil instead of drifting into the sky, he said. "If soils dominate, a hydrogen economy might have little effect on the environment. But if the atmosphere is the big player, the stratospheric cooling and destruction of the ozone ... are more likely to occur."

Cal Tech scientist Tracey Tromp, another of the authors, said that with advanced warnings of a problem, a hydrogen energy infrastructure could be fashioned to allow more control of leaks and reduce the adverse environmental impact.

Test driving the future in fuel cell Honda

SOURCE: http://www.bostonglobe.com/

By Royal Ford, 6/8/2003 "Hydrogen is a promissory note for humanity's future on Earth." - Jeremy Rifkin, "The Hydrogen Economy"TORRANCE, Calif. - I am driving a car with millions of dollars of research and development under its skin and a supply of just-pumped hydrogen in two tanks beneath the rear seat. I am driving the future, but I am thinking about the past.

I remember watching the old television series, "The Lone Ranger," and thinking just how cool it would be to roll into one of those old Wild West towns in a modern-day car, the only Corvette in Dodge. The fantasy, of course, was always short-circuited by one unanswerable question: "Yeah, but where are you gonna get gas when the tank is empty?"

But then another cinematic moment comes to mind. The character, Doc, from the 1985 movie "Back to the Future," is explaining why he can build a car that travels through time: "I was standing on the edge of my toilet hanging a clock, the porcelain was wet, I slipped, hit my head on the edge of the sink, and when I came to, I had a revelation, a vision. This is what makes time travel possible, the FLUX CAPACITOR." You see, while I am driving the future, I have not only those bottles of hydrogen beneath the rear seat, not only a fuel cell stack in the floor to power the car, but I also have, behind that seat, an ULTRA-CAPACITOR.

Doc, I'm coming home.

OK, maybe we won't be cashing in Rifkin's promissory note any time real soon, but Honda, with its fuel cell-powered FCX car, is demonstrating that, with certain key challenges yet to overcome, the fuel cell is probably the replacement for the internal combustion engine.

"There remains a number of significant barriers to the introduction of fuel cell technology to the mass market, and we believe that any large societal gains from this technology are still more than a decade away," Ben Knight, vice president of Honda Research and Development of the Americas, told a group of journalists who had come here last week to test drive three of the fuel cell cars.

The challenges to fuel cell cars include cost. The Honda I drove, if sold to the general public, would cost hundreds of thousands of dollars, Knight said. Second, there is a question of durability. Industry estimates are that current cells are good for only about 1,000 hours of operation before they begin to fail. And finally, there's that question from the Wild West: Where are you going to fuel it?

Honda's answer is a futuristic refueling station it has built near its headquarters in Torrance. A solar panel feeds electricity to a unit that produces hydrogen. The hydrogen is then compressed in a second unit and sent for storage to a third. Each unit looks like a black, squat, unmarked gas pump. Refueling - with a tight-fitting connector and a ground wire to prevent sparks - looks the same as any pump filling your standard tank.

A fuel cell car is basically an electric motor vehicle with its power provided by the fuel cells. The electricity for the fuel cells is produced through what is, in essence, a "reverse" process of electrolysis, a reaction in which electricity is used to break water into its components, hydrogen and oxygen. The hydrogen fuel cell process combines hydrogen - either stored in or produced in the car - with the available air. That combination yields electricity for the fuel cells and emits clean water as "exhaust."

Other manufacturers of fuel cell autos - and virtually all the big ones are working on the systems in varied versions - use batteries to store excess fuel cell energy and to recapture the energy of deceleration or braking, just as it's done in hybrid gasoline/electric cars.

But battery function is based on a chemical reaction, which means constant depletion and recharging. Honda's ultra-capacitor instead uses a physical reaction - the transfer of ions back and forth between positive and negative polls depending on energy input or demand. The ion transfer generates electricity and supplements the fuel cell by adding extra power during acceleration.

The result?

Driving in downtown Los Angeles, through high coastal hills, and along the California coast, the FCX felt much like any automobile.

There was no rumble of a combustion engine, no plume of exhaust ... just water dripping from the tailpipe. Other than a slight whir of the electric motor and the occasional whine of a compressor, the car was amazingly quiet.

In addition, because the car has an electric motor, there is no shifting from gear to gear. Torque is present from r.p.m. one (80 horsepower and a whopping 201 lb.-ft. of torque).

The car was surprisingly quick off the line and its powerful torque band carried it effortlessly up to high commuter speed on the highway into Los Angeles. Only when trying to pull out to accelerate from an already high speed was there any sense of the torque band flattening out. The car will supposedly go faster than 100 miles per hour, though we didn't test it.

And because the extra weight of the fuel cell system is stored low in the car, it felt amazingly stable. The weight was evident in hard cornering where a car that might look a bit top heavy sat flat as a brick with little sense of body roll.

This is not a technology that will be sitting in your garage soon, although the city of Los Angeles will soon have five of them in its official fleet at the bargain lease rate of $500 a month each. But it is still a technology you should keep your eye on.

Not only will hydrogen power the fleets of tomorrow, it will likely power our homes.

The time travel part? That will have to wait.

Visit boston.com/cars/ Royal Ford can be reached at ford@globe.com.

This story ran on page K1 of the Boston Globe on 6/8/2003.

New Fuel Cell Car Concept

SOURCE: http://www.sciam.com/print_version.cfm?articleID=00034FE5-BA99-1D80-90FB809EC5880000

September 16, 2002

Designing AUTOnomy

One of the designers of a radical new fuel-cell-car concept explains what was done
By Christopher E. Borroni-Bird

It had to have four wheels, but pretty much everything else was open for consideration. When General Motors decided to develop an all-new fuel-cell vehicle with electronic (rather than mechanical), drive-by-wire controls, our team started with a clean sheet. Because we did not seek to shoehorn these new technologies into existing vehicle architectures, we avoided design trade-offs that had to be made in the past. We also opened up new opportunities to improve ride and handling, interior spaciousness and flexibility and exterior styling. The early result was our first concept vehicle, AUTOnomy. The working demonstration model, named Hy-wire, is being introduced officially to the world on September 26, 2002, during the Paris Auto Show.

Fuel cells cleave hydrogen atoms into protons and electrons that drive electric motors. Instead of polluting hydrocarbon emissions, fuel cell vehicles emit only water vapor from the tailpipe. Their widespread adoption could make personal transportation--a freedom already cherished by many cultures and sought with growing frequency by emerging markets--environmentally sustainable for the foreseeable future. (For more about the potential of fuel cells in automobiles, see "Vehicle of Change," by Lawrence D. Burns, J. Byron McCormick and Christopher Borroni-Bird; Scientific American, October 2002.)

Chock-full Chassis

Starting from the ground up, we placed all the "running gear"--the fuel-cell stack, drive-by-wire electronics controls and electric motors--inside the chassis. It is nicknamed for what it resembles: a skateboard. This design lowers the center of gravity compared with a conventional internal-combustion-engine-driven vehicle of similar proportions, which improves ride, handling and stability. Future advances in communication among the various by-wire systems (more on those momentarily) could supplement these advantages further, providing superior chassis performance than is possible today.

Hy-wire is a front-wheel-drive vehicle. But the AUTOnomy program goal is to place an electric motor at each of the four wheels, to improve acceleration and maneuverability. The wheel motors might allow a vehicle to almost literally turn on a dime, making parking much easier. Since wheel motors make each wheel independently variable, vehicle stability also could be improved beyond what is possible today.

The combination of wheel motors and drive-by-wire might enable the vehicle's corners to become interchangeable electronic modules, with packaging and software-tuning flexibility adaptable to multiple vehicle types. In addition, by-wire technology may make it feasible to provide remote-control operation, which could facilitate parallel parking or even let an owner back the car out of the garage in the morning when getting ready to leave for work.

Sleek, Switchable Exteriors

Beyond the functionality advances, the coupling of fuel cells with by-wire technology provides new design flexibility. There is no need to work around the awkward center cabin hump from the internal-combustion engine's driveshaft, or its conventional steering column. Planar fuel cells provide a flat foundation that offers more of a clean sheet for exterior styling--a wider variety of shapes above the plane of the skateboard chassis is possible. Moreover, eliminating the engine compartment lifts architectural constraints, enabling designers to create new vehicle profiles to tempt customers.

On the manufacturing side, by-wire technology allows automakers to reinvent the standard business model, to one centering around the use of interchangeable bodies on top of a common chassis. A limited version of this idea exists today, in the form of a type of vehicle architecture called body-on-frame, which is typically found in pickup trucks and sport-utility vehicles (SUVs). Body-on-frame design makes it easier and less costly to create new body styles (such as crossover vehicles and extended pickup trucks) than is possible with the unibody construction commonly used for passenger cars. AUTOnomy's skateboard-like chassis takes the idea a step further, by enabling greater front-end design variation, more freedom with interior arrangements and more flexible chassis tuning.

A manufacturing advantage is that large plants could eventually mass-produce a small number of skateboard types--for example, compact, mid-size and large--saving costs. Local suppliers could then sell "snap on" bodies designed to appeal to regional tastes. The bodies could even be replaced over time, and the by-wire controls could be upgraded with software.

Inner Beauty

The flexibility of a drive-by-wire-enabled interior matches that of the fuel-cell-enabled exterior. With all but the absolutely essential hardware moved into the chassis, the design liberates space inside the vehicle.

Consider, for example, that all of today's passenger vehicles have the same human-vehicle interface: a steering wheel and foot pedals. Drive-by-wire systems provide much greater opportunity for blending this interface with the vehicle. A sports-car driver might want a different way to steer, brake and accelerate the vehicle than the conventional approach preferred by the owner of a conservative luxury vehicle.

By eliminating mechanical connections between driver and vehicle, drive-by-wire systems also let the driver relocate within the cabin. For example, while commuting to work alone, a driver might prefer to sit more toward the center front-seat position. On weekends, he or she might move back to the conventional position to accommodate family members or friends. In Europe, traveling between the Continent and the United Kingdom would become easier, since the driver could control the vehicle from either the right or left seats. This flexibility is also of value to automakers in saved manufacturing costs.

All of this newly created open space gives the interior a much more living-room-like atmosphere. Thus, the occupant compartment could be reconfigured for office work, socializing or to accommodate special needs. As just one example, a battery-powered wheelchair could be docked into the floor and recharged from the fuel-cell chassis. The human-vehicle interface (steering and braking controls) might remain with the wheelchair at all times, or even be located outside the vehicle. This could give a disabled driver continuous access to driving controls and other useful features, such as a navigation system or Internet display. The vehicle's flat floor also facilitates sleeping--ideal for a camper-body option.

The driver isn't the only one who benefits: rear passengers get to stretch their legs, too. Even in today's luxury vehicles, rear-seat passengers have modest amounts of legroom. But elimination of the engine compartment increases the usable length of the interior, stretching the distance between front and rear seats.

Finally, the unique AUTOnomy concept not only is an exciting new vehicle design with great functionality: it also offers the chance to decouple body and chassis development, which can have advantages for design, engineering, manufacturing and marketing. These benefits could lead to more affordable vehicles and greater penetration of fuel cell technology, with subsequent benefits for energy security, global warming and air quality.

Christopher Borroni-Bird joined General Motors in June 2000 as director of design and technology fusion, a group that applies emerging technology to improve vehicle design. He is also director of the AUTOnomy program, which includes the Hy-wire prototype vehicle. Previously, Borroni-Bird managed Chrysler's Jeep Commander fuel-cell-vehicle program.

XXII. Appendix K - Hybrid Vehicle References

Toyota Unveils Improved Prius; Ford Previews Hybrid Escape

SOURCE: http://www.toyota.com, www.ford.com/

Toyota Unveils Improved Prius; Ford Previews Hybrid Escape

Toyota introduced a new, larger, more powerful Prius last week at the 2003 New York International Auto Show (NYIAS). The 2004 Prius is about 15 percent more fuel efficient than the current model; according to Toyota, the new model will achieve a combined city/highway fuel efficiency of more than 50 miles per gallon. At the same time, a new lift-back rear end (somewhat reminiscent of the Honda Insight) and a longer wheelbase moves the Prius up to the midsize category of vehicles. The new Prius also accelerates faster than the current model and meets the California Air Resources Board (CARB) certifications as a Super Ultra Low Emissions Vehicle (SULEV) and a Partial Zero Emissions Vehicle (PZEV).

One key to the performance of the Prius is its new Hybrid Synergy Drive, which feeds the battery power through a new high-voltage power converter, supplying 500 volts of electricity to a 50-kilowatt motor. The new high-voltage motor is about 50 percent more powerful than the motor in the current model, and allows the vehicle to operate in all-electric mode for a greater percentage of time. The new Prius is expected to go on sale in fall. See the Toyota press release and the Toyota "Future Vehicle" Web site at:
<http://www.toyota.com/about/news/product/2003/04/16-1-prius.html>
and <http://www.toyota.com/newprius

Also debuting at the NYIAS was the new Escape Hybrid SUV (sport utility vehicle) from Ford Motor Company. Like the Prius, the Escape Hybrid is a "full hybrid" -- able to run on electric power only -- and will achieve about 35 to 40 miles per gallon. It will also meet the SULEV and PZEV standards. Ford will begin low-volume fleet production of the Escape Hybrid by year-end, and plans to begin retail sales in late 2004. In addition, Ford announced plans to launch a new midsize sedan, the Futura, in late 2005, and plans to eventually offer a hybrid-electric version of that vehicle as well. See the Ford press releases at:
<http://media.ford.com/article_display.cfm?article_id=15136>and
<http://media.ford.com/article_display.cfm?article_id=15096>.

While luxury vehicles, sport cars, and SUVs continue to dominate most auto shows, advanced-technology vehicles are a growing presence. At this year's NYIAS, which runs through April 27th, automakers are displaying four gasoline-electric hybrids, three fuel-cell vehicles, and one hydrogen-fueled internal-combustion vehicle -- enough to earn a separate category on the NYIAS Web site. See the "Alternative Fuel" category in the NYIAS "New Vehicle Gallery" at:
<http://www.autoshowny.com/html/body_new_vehicle_template_.html>.

Toyota Stages World Premiere Of All-New Prius With "Hybrid Synergy Drive"

SOURCE: http://www.toyota.com/

Toyota Stages World Premiere Of All-New Prius With "Hybrid Synergy Drive" At 2003 New York Auto Show

April 16, 2003 -- New York, NY -- The all-new second-generation Toyota Prius electric-gas hybrid vehicle made its world premiere at a press conference today at the 2003 New York Auto Show.

"When the 2004 Prius arrives in dealerships this fall it will exceed all expectations, marking the arrival of hybrid technology into the mainstream consumer mindset," said Don Esmond, senior vice president and general manager, Toyota Division. "Furthermore, the debut of the Toyota Hybrid Synergy Drive system will represent a major breakthrough in global-friendly powertrain technology."

In 1997 the Toyota Prius was the world's first mass-produced electric-gas hybrid vehicle. Bigger and better in every metric of comparison, the all-new 2004 Prius will usher in a new era of electric-gas hybrid technology when it launches this fall. The new Prius will feature increased interior space, moving from a compact to the midsize class. Its new Hybrid Synergy Drive system will supply significantly more power and performance, best-in-class fuel economy, and best-in-market emissions performance.

The 2004 Prius will be the first Toyota equipped with the new high-voltage/high-power Hybrid Synergy Drive powertrain. Like the original Toyota Hybrid System (THS) on the current Prius, Hybrid Synergy Drive is defined as a "full hybrid system." Unlike competitive systems currently on the market, the full hybrid system is capable of operating in either gas or electric modes, as well as a mode in which both the gas engine and electric motor are in operation.

The advantages of a full hybrid system are numerous. The most important, however, is that because the car can be run under certain conditions with electric power only, fuel consumption, and emissions, can be reduced significantly.

A major difference between the new Hybrid Synergy Drive concept, and how it is improved over the current THS system centers on the duration of electric-mode driving and the peak power delivered electrically. The Hybrid Synergy Drive has a 50 percent more powerful 50-kilowatt drive-motor operating at up to 500 volts. This increased voltage and power is enabled by a newly adopted high-voltage power converter. Additionally, the generator in the new Prius has a higher peak operating speed that increases electric-mode operation in city and freeway slow-and-go operation. With 50 percent more electric power available and improved low-end torque from the drive motor, a significant boost in acceleration performance is possible.

Hybrid Synergy Drive is expected to increase fuel efficiency in the new Prius by 15 percent with combined mpg rising from the high 40's to the mid-50's. This will enable Prius to have the best fuel efficiency rating of any midsize vehicle sold in America, delivering twice the combined mileage rating of its closest competitor. What's more, the midsize Prius will also boast a higher combined mileage rating than any compact sedan sold in America.

Hybrid Synergy Drive will significantly improve acceleration performance from the mid-12-second range to the mid- 10-second range. This acceleration level is comparable to the Toyota Camry LE four-cylinder.

Finally, Hybrid Synergy Drive will enable Prius to be nearly 30 percent lower in emissions than the current ultra-clean Prius, producing nearly 90 percent fewer tailpipe pollutants than a conventional internal combustion engine. When it arrives this fall, Prius will be certified as a SULEV, or "Super-Ultra-Low-Emission-Vehicle" for tailpipe emissions in California and those states adopting California standards. In the rest of the country, Prius will be certified as Tier 2, Bin 3. In addition, in California and those states adopting the California rules, Prius will be certified as a PZEV category vehicle. PZEV, or "Partial Zero Emissions Vehicle" is a category composed of many elements. In addition to the SULEV exhaust standard, PZEV also requires meeting a zero fuel evaporative standard, a 150,000-mile durability demonstration and offering an extended emissions system warranty.

Prius will feature dramatic and distinctive aerodynamic styling. With its triangular mono-form shape, it is a dramatic visual departure from the original Prius, and contributes greatly to one of the most aerodynamic production vehicles on the planet. At an amazing 0.26, its coefficient of drag will be a major factor in the vehicle's interior noise isolation and will contribute to its significantly increased fuel efficiency.

The new bolder design is the wrapping for a much larger package that is full of surprises. The new Prius rides on an entirely new platform. Although its wheelbase is nearly six inches longer than the current Prius it retains a relatively short overall length, casting a shadow only slightly larger than the current model. What is not so obvious from the outside is its significantly larger midsize interior.

Designers were able to achieve this tour de force in packaging by configuring Prius as a four-door lift-back. Not only does this layout work well with the vehicle's slipstream styling, its rear lift-back and fold-down rear seat combine to offer a new level of cargo hauling flexibility.

The new Prius will be electronically controlled with by-wire throttle and shift control. The new by-wire shift control allows Prius to replace the traditional gearshift lever mounted on the floor or the steering column with tap-of-the-finger shifting of a small joystick mounted on the dash.

A Smart Entry and Smart Start option allows keyless entry and keyless startup. As the driver reaches for the door handle, an on-board sensor will recognize the signal from a key in his pocket and automatically unlock the doors. Since the driver has already been security-cleared to enter the vehicle, he can leave the fob in his pocket, push a start button located on the dash, and drive away.

Smart Entry and Start is one of only a handful of options offered in the new Prius. Offered in a single, well-equipped trim level, Prius standard equipment will include ABS brakes, power windows, door locks and mirrors, and a unique electric inverter air conditioning system. Instead of running off the fan belt, the new inverter air conditioner is fully electrically operated. Not only does this improve fuel efficiency, it ensures passenger comfort, even when the gasoline engine is off and the car is being propelled only by the electric motor.

"We've learned a lot about Prius since its launch in America two-and-a-half years ago, said Esmond. "With increased interior space, increased power and performance, best-in-class fuel economy, and best-in-market performance, we are more convinced than ever that the new Prius will continue to lead electric-gas hybrid technology into the mainstream market."

Ford Points to a Strong Hybrid Future

SOURCE: http://www.ford.com/

NEW YORK, April 16, 2003 – Ford Motor Company is highlighting its commitment to hybrid vehicles at this week’s New York International Auto Show. The company is showing the Escape Hybrid SUV – which will begin low-volume fleet production at year’s end and retail production in the second half of 2004 – as well as announcing that the all-new 2006 Ford Futura mid-size car will be the company’s next hybrid vehicle.

As the first true no-compromise hybrid SUV, it combines the cargo capacity and go-anywhere capability of the Ford Escape sport-utility vehicle with the fuel economy and emissions benefits of a "full" hybrid system.

"The Escape Hybrid is just one way we’re delivering on our ‘better world’ promise," said Ford Division president Steve Lyons, referencing Ford Motor Company’s vision of great products, a stronger business and a better world. "And that’s just the beginning," Lyons said. "Adding a Ford Futura hybrid down the road will allow us to reach many more customers with this technology."

The Ford Escape Hybrid will be among the most advanced hybrid vehicles on the road when it debuts. The hybrid system has been uniquely engineered by Ford for the Escape.

Among the breakthrough technologies on the vehicle is an advanced thermal management system that will result in longer battery life.

Other benefits will include better acceleration performance when the vehicle is in pure electric mode and more efficient powertrain operation during highway driving.

"The Ford Escape Hybrid significantly improves the power density of the hybrid drive system to meet the power demands of an SUV in available space," according to Ford Hybrid Technology Chief Engineer Prabhakar Patil. "Applying hybrid technology to an SUV clearly presents a challenge. You simply have to get more out of the same type of powertrain package that to this point has only been asked to propel a smaller car."

As the first true "no-compromise" SUV, the Escape Hybrid will offer:

- A "full" hybrid system, including a 300-volt nickel-metal-hydride battery, allowing the vehicle to run on either the gasoline engine or battery power alone
- 35-40 miles per gallon fuel economy in the city driving cycle
- Extraordinarily low emissions under the California SULEV (Super Ultra Low Emission Vehicle) and PZEV (Partial Zero Emission Vehicle) standards, with 97 percent fewer hydrocarbon emissions than permitted by the national Tier 1 standard and virtually zero evaporative emissions
- Nearly a 50 percent reduction in CO_2 emissions in city driving
- Significantly extended driving range between fuel stops
- Acceleration performance comparable to the 201 horsepower Escape V-6 engine
- Cargo capacity and off-road capability equal to the base Escape, with optional 4WD

At the heart of the Escape Hybrid is a compact hybrid transaxle linking Ford's efficient 2.3-liter four-cylinder engine, 65-kW electric motor, 28-kW generator and the drive wheels.

This hybrid system, co-developed by Ford, Volvo and Aisin AW, gives "full" hybrid benefits, including:

- Engine stop/start (automatically stops engine while idling and instantly restarts as necessary)
- Electric assist (supplements the 2.3-liter gasoline engine when accelerating/passing)
- Regenerative braking (recovers energy typically lost as heat through braking friction, storing it for the next acceleration)
- Electric drive (in city driving, the gasoline engine may be off as much as 40 percent of the time)

This "full" hybrid functionality is packaged neatly in place of the standard transaxle and is powered by a 300-volt nickel-metal-hydride battery pack located beneath the rear load floor. Since the battery is charged while braking and cruising, the Escape Hybrid does not need to be "plugged in" like battery-electric vehicles.

Escape Hybrid Show Vehicle

The Escape Hybrid show vehicle is Ice Blue with silver lower body cladding. Differentiating it from production Escape models are its 18-inch, 8-spoke alloy wheels; a new front fascia with integrated stylized skid plate and circular fog lamps; quad headlamps and silver honeycomb grille insert. Hybrid graphics with Ford's road-and-leaf logo further set the Escape Hybrid apart. The rearmost window on the left side is split to accommodate an air extractor for the cooled hybrid battery pack beneath the load floor. The vehicle also has the innovative No Boundaries Rack System available on today's Escape.

Inside, this Escape Hybrid is trimmed in light ivory leather with leather-and-sisal woven inserts in the seats and door panels. The floor mats also are made from natural woven material. The leather-wrapped steering wheel frames chrome-ringed, satin-white gauges showing the state of the hybrid battery. The tachometer includes an area indicating electric-only mode when the engine is temporarily switched off to save fuel.

A new center console with a leather-wrapped floor-mounted shifter is featured. A single liquid-crystal display in the center console serves as the audio system interface, a navigation system and a real-time "power path" visual indication of the operating state of the hybrid system. It shows, for example, if the battery is being charged or discharged, if the vehicle is recovering energy during braking or if the electric drive is providing additional power. A painted ivory bezel surrounds the LCD screen.

Future Futura Hybrid

The Ford Futura – the first of 10 Ford, Lincoln and Mercury products from the same flexible architecture – will be available in 2005, punctuating Ford's "Year of the Car" strategy next year.

The Futura Hybrid, like the Escape Hybrid, mates a 2.3-liter I-4 gasoline engine with a 65-kW electric motor. The Futura Hybrid will be introduced after the 4- and 6-cylinder models enter production.

The Hybrid Principle

Hybrid vehicles use smaller engines that easily meet the cruising needs of the vehicle, while relying on an electric motor or other assistance to provide the extra power necessary for acceleration and hill climbs. The result is better overall efficiency, without a performance penalty.

Hybrids are designed to recover energy during braking. In traditional vehicles, the energy used to accelerate the car is lost as heat when the driver applies the brakes. Hybrids, on the other hand, can be engineered to recover a substantial portion of what would otherwise be "lost energy" and store it temporarily for use while accelerating again.

The Escape Hybrid is a "full" hybrid, meaning it has a relatively large storage battery and has the capability of driving on electric power alone. Mild hybrids, by contrast, are distinguished by relatively small battery capacity and the inability to propel the vehicle in an electric-only drive mode.

When the driver calls for maximum acceleration, the gasoline engine and the electric motor work in parallel, providing the launch performance of a powerful V-6 engine. In less demanding situations, the Escape Hybrid can run on its electric motor alone, its gasoline engine alone or the most efficient combination of the two.

While cruising on the highway, for example, the gasoline engine is used. But for low-speed driving, such as bumper-to-bumper traffic, the electric motor can be the sole power source and can propel the vehicle without the assistance of the gasoline engine.

An electric power steering assist system remains functional even when the engine shuts down and provides greater efficiency than traditional hydraulic systems.

Ford Escape, A Top-Selling Compact SUV

Introduced as a 2001 model, the Ford Escape provides fun and responsive ride and handling, an outstanding interior package, fuel economy and low emissions in a small, rugged SUV. Available in front-wheel drive and four-wheel drive configurations, the Escape is designed to appeal to customers who want sporty and durable transportation.

The Escape is designed for maximum comfort, convenience, passenger roominess and cargo flexibility. Escape has four doors and a rear lift gate with flip-up glass for access to the cargo area. The cargo area, with the seats down, offers a maximum cargo capacity of 69.2 cubic feet.

Escape has room to carry five adults and their cargo comfortably. Its low step-in height and wide door openings allow good access, while its unibody design provides outstanding handling and ride comfort.

For consumer information regarding the Escape Hybrid, see http://www.fordvehicles.com/

Hybrid Cars Are Attracting a Broad Range of Americans

SOURCE:
http://www.nytimes.com/2002/12/11/business/11PRIU.html?ei=5062&en=e1bfc639108f6a2f&ex=1040187600&partner=GOOGLE&pagewanted=print&position=bottom

December 11, 2002

By DANNY HAKIM

DETROIT, Dec. 10 — When drivers want to make a statement with their cars, the message typically is about status (BMW), hormones (Mustang), power (Hummer) or speed (Porsche). But the latest car-as-statement is an unornamented Japanese subcompact driven by people who want to poke a finger in the eye of Saddam Hussein, the oil sheiks and the neighbors who jump into gas-guzzling sport utility vehicles for a drive to the grocery store.

The car, the Toyota Prius, is the best seller in a small but soon-to-grow category of vehicles known as hybrids that — by running on a combination of gas and electric power — get as much as twice the mileage of conventional cars. It has attracted a bipartisan coterie of customers who say they consider it the anti-S.U.V., a car that makes both a political and environmental statement without demanding too many trade-offs.

Prius owners, predictably enough, include Hollywood celebrities who wear their environmentalist sentiments on their sleeves — actors like Cameron Diaz, Leonardo DiCaprio and Ted Danson. More surprisingly, the car is being bought by county sheriffs and bank executives intent on doing their part, as tensions escalate in the Mideast, to reduce American oil imports.

"We're, hopefully, setting an example for the community," said Robert Crowder, the sheriff of Martin County, Fla., who has bought 15 hybrids for his department.

In Marion County, Fla., Wyatt Earp, who besides being a descendant of the Wyatt Earp is a fleet manager for the sheriff's office, has bought four Priuses. "This is a technology that will take us out of our dependence on foreign oil," he said.

Ms. Diaz had her latest Prius customized, Hollywood style, with a black paint job and leather seats.

"I wanted to do my part," said the actress, who bought her first Prius a couple of months after the Sept. 11, 2001, attacks.

Driving with a heavy foot in Los Angeles traffic, she got about 18 miles per gallon in her old Mercedes, she said. But, she added, "I can milk 40 to 45 out of the Prius, if I'm driving like a good girl."

Toyota began selling the Prius in the United States, in limited numbers, two years ago, and there are now about 39,000 on American roads. Worldwide, the company hopes to sell 300,000 hybrids annually within five years. It is expected to announce at least one new hybrid model next month at the North

American International Auto Show in Detroit — possibly a version of the Highlander sport utility, people who have been told about the plans say.

Toyota's production plan means "this is going to go from being an environmental curiosity to a commercially important product," said John Casesa, an analyst at Merrill Lynch.

Not everyone is convinced. Executives at General Motors say they think that adding an electric motor to every car is unduly expensive and will divert resources from what they consider more viable new technologies, including vehicles powered by hydrogen fuel cells.

"I don't think anybody's got confidence that the economics make any sense," Rick Wagoner, G.M.'s chief executive, said in a recent interview.

Others in Detroit, though, are tiptoeing into the business. DaimlerChrysler said last month that it would start selling a hybrid version of its Dodge Ram pickup truck next year, and the Ford Motor Company plans to sell a hybrid version of its Escape sport utility, beginning late next year.

The Prius has an electric motor that takes over for the internal combustion engine at low speeds and when the car stops. Because the battery is charged by the gas engine, the car never needs to be plugged in. The gas engine kicks in at 15 to 20 miles per hour, so the Prius, unlike conventional cars, usually gets its best mileage in city driving.

Drivers say the silence of the electric motor can be disconcerting at first.

"When you're sitting at a light, you're thinking, `Did my car just die?' " Ms. Diaz said. "You have to be careful going down alleyways, because people don't see you coming."

James E. Press, the executive vice president of Toyota Motor Sales U.S.A., said the Prius is slightly profitable already — not counting an undisclosed amount in research and development costs. And if Toyota can reach its sales goals, profit margins will improve significantly.

"When you have that kind of volume to spread the investment over, and anticipated improvement in economies of scale, and improvement of efficiencies of production and design, these vehicles should be as profitable as anything else that we sell," Mr. Press said.

The Prius is not cheap. Prices start at $20,500, which is $4,500 more than a similar size Toyota Corolla, though buyers qualify for a $2,000 tax deduction intended to encourage sales of fuel-efficient vehicles. Until recently, the Prius was the only four-door hybrid sold in the United States, but Honda — which has sold its two-door Insight since 1999 — recently began offering a hybrid Civic, starting at $19,550.

Politicians who drive hybrids include Representative Constance A. Morella, a Republican from Maryland who lost her re-election campaign last month, and Senator Robert F. Bennett, a Republican from Utah. New York City has bought more than 200 Priuses for agencies like its buildings and parks departments.

The Sisters, Servants of the Immaculate Heart of Mary, a community of nuns based in Monroe, Mich., about 35 miles south of Detroit, bought several of the hybrids; recently, the nuns used them to ferry religious leaders who came here to lobby the Big Three for improvements in fuel efficiency.

"The Gospel today requires that we respond to the needs of earth," Sister Nancy Cathcart explained.

Robert Goldberg, the president of the Ohio Savings Bank, based in Cleveland, has bought five Priuses so far, and he plans to convert the company's whole fleet of a few dozen cars to hybrids.

"It's a fight against terrorism," Mr. Goldberg said. "If the United States was not so dependent on oil in the Middle East, we wouldn't have the problem we do."

Mr. Goldberg used to drive an Audi A6 and says that his gas bill has fallen from nearly $30 a week to $15 every two weeks since he bought a Prius for himself.

Ariel Emanuel, a Hollywood talent agent whose brother Rahm was elected to Congress last month as a Democrat from Chicago, traded in his Ferrari for a Prius. His gas bills of $250 a month have fallen to about $30.

"Every time I get into it, I feel like I'm demonstrating my point of view on national security," Mr. Emanuel said. "Fifteen of the 19 terrorists came from Saudi Arabia. I refuse to give them more money."

Stephen Collins, a star of the WB network's drama "Seventh Heaven," said he bought his Prius at the recommendation of the actor Ed Begley Jr., an environmental activist who also appears on the program.

"It was a personal political reaction to Sept. 11," Mr. Collins said. "It's my personal fantasy that we could turn around to a country like Saudi Arabia and say: `We love you guys, but we don't need your oil. Knock yourselves out, but we don't need it.' And it wouldn't be that hard to do."

Hybrid sales to soar, Power report says

SOURCE: http://www.sacbee.com/
By Mark Glover -- Bee Auto Editor
Published 2:15 a.m. PDT Friday, June 6, 2003

Sales of hybrid-powered vehicles are expected to exceed 500,000 units annually by 2008 and 872,000 units by 2013, a survey by J.D. Power and Associates said.

U.S. consumers purchased approximately 38,000 hybrid vehicles -- which are powered by a conventional engine-electric motor combination -- in 2002, and sales of hybrids are expected to increase to 54,000 vehicles this year.

"The biggest limiting factor on sales is that up until now, the hybrid engine option has been offered only in compact cars," said Walter McManus, executive director of global forecasting at J.D. Power. "That's about to change, and when it does, we'll see sales increase dramatically."

The hybrid electric vehicle first reached the market in 1999 with the launch of the Honda Insight. The Toyota Prius made its debut the following year, and the Honda Civic Hybrid went on sale in 2002. The first SUV hybrid, the Ford Escape, and the first full-size pickup hybrids -- a Chevrolet Silverado and GMC Sierra -- will hit commercial fleets later this year and retail dealers in early 2004.

"By 2005, trucks should account for about 39 percent of hybrid sales," McManus said. "We know, based on (our) studies, that consumers express interest in a hybrid powertrain option in the same segment as their current vehicle. Once those vehicles are available, and in most cases that will be very soon, hybrid sales could take off."

XXIII. Appendix L- Fuel Comparisons

Pros, Cons and Analysis

Ethanol

Pros	Cons	Analysis
• Bi-partisan support • When compared to conventional gasoline, ethanol yielded lower emissions of carbon monoxide than motor gasoline • Ethanol-blended fuel cuts tailpipe emissions of volatile organic compounds that form ozone in the atmosphere • **30% Reduction in Carbon Monoxide (CO) Emissions** Use of a 10% ethanol blend results in a 25-30% reduction in carbon monoxide emissions by promoting a more complete combustion of the fuel. • **6-10% Reduction in Net Carbon Dioxide (CO_2) Emissions** Use of 10% ethanol-blended fuels results in a 6-10% net reduction of CO_2. • As ethanol contains no sulphur, and because it promotes more complete fuel combustion, blending gasoline with ethanol would reduce any potential for these emissions and the	• When compared to conventional gasoline, ethanol has higher emissions of nitrogen oxide that causes smog • Fuel grade ethanol contains sulphur to distinguish it from drinking alcohol • Ethanol-blended gasoline can lead to increased emissions of acetaldehyde, a toxic pollutant • Need for more arable land to grow corn • A study by Cornell University scientist David Pimentel shows that producing ethanol from corn actually requires more energy than the fuel produces though the DOE states that "Ethanol production is extremely energy efficient, with a positive energy balance of 125%, compared to 85% for gasoline." • Currently, ethanol-blended fuels receive a 5.3 cent per gallon exemption from the excise tax • At present, the infrastructure needed to produce, store, and blend more ethanol	• Ethanol is a domestic fuel that is supported by politicians and industry alike. • Whereas the current production techniques can only use the corn grain to make ethanol, when cellulosic biomass processing is available in 2007, the fuel will be manufactured from corn husks, lignin, wood, paper mill sawdust etc. • As ethanol can be reformed to produce hydrogen, it is a fuel that can be used during the transition towards the final normative scenario

adverse effects of sulphur • Fuel ethanol is produced from biologically renewable sources, such as grain or wood products.	does not exist • Given that ethanol cannot be transmitted through petroleum pipelines, the costs of transporting ethanol to other regions of the country will be high. • Insufficiently volatile for cold-engine starts in spark ignition engines, even at moderate temperatures. Because of the low volatility, the most important performance issues for the alcohol fuels are the cold-start problem and misfiring during warm-up	

Biodiesel

Pros	Cons	Analysis
• Increased energy self-sufficiency for importing countries • Increased demand for domestic agricultural products • Biodegradability and improved air quality • Particularly lower sulphur emissions than from fossil fuels • Exhaust emission improvements include substantial reductions in carbon monoxide, hydrocarbons and particulates • Creates more employment as it is three to six times more labour intensive per unit of production than fossil fuels • Domestically produced, renewable fuel	• The production of nitrogen gases is similar to regular diesel fuel • High production costs • Studies conducted when petroleum prices were in the range of US$18 to $20 per barrel concluded that petroleum must rise to over US$40-$50 per barrel to make biodiesel production viable without a subsidy. • Biodiesel has a higher viscosity than conventional diesel and therefore becomes less useful at lower temperatures • Biodiesel can be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems	• Biodiesel is a good selection in the short run in terms of emissions and environmental impacts vis a vis hybrids • It is not cost effective due to high production costs • It does not help us in our transition towards fuel cell vehicles running on hydrogen in the future. • Investing into infrastructure, and changing the existing fleet to a fuel that will potentially have a 10yr lifecycle only is not feasible and sustainable in the long run

• Can be manufactured from vegetable oils, animal fats, or recycled restaurant greases. • Pure biodiesel or blends of biodiesel with petroleum diesel are safer to store, handle, and use than conventional diesel fuel	• Horsepower, torque, and fuel economy are similar to those for diesel fuel.	

Diesel

Pros	Cons	Analysis
• Diesel is a petroleum-based fuel with a higher energy content than gasoline. • This greater energy content -coupled with the efficiency of compression ignition - explains why diesel vehicles get better gas mileage • Clean diesel refiners are working to virtually eliminate sulfur from diesel fuel • **Safety** - Diesel is a safer fuel than gasoline or other alternatives. It is less flammable and explosive than gasoline. • **Energy content** - Diesel fuel contains about 30% more energy per gallon as compared to gasoline. • **Efficiency** - Today's heavy duty clean diesel truck engines get 10 - 30% better fuel economy than those built in the last 10 years • **Performance** - Diesel technology has a greater power density than other fuels - it	• Mostly imported- no significant domestic reserves • Does not meet strict emission laws of the future	• Clean diesel is a good selection in the short run in terms of emissions and environmental impacts vis a vis hybrids • It does not help us in our transition towards fuel cell vehicles running on hydrogen in the future. • Importing diesel does not reduce our dependence on imports from politically unstable geographic areas.

packs more power per unit volume than other fuels. • **Durability** - Diesel engines are renowned for their durability, lasting hundreds of thousands of miles. • **Continuous improvements** - clean diesel technologies, today's trucks and buses are eight times cleaner than those built just a dozen years ago.		

Methanol

Pros	Cons	Analysis
• Low emissions • High-performance • Less flammable than gasoline. • Can be manufactured from a variety of carbon-based feedstocks such as natural gas, coal, and biomass (e.g., wood)	• Produces a high amount of formaldehyde in emissions • Insufficiently volatile for cold-engine starts in spark ignition engines, even at moderate temperatures. Because of the low volatility, the most important performance issues for the alcohol fuels are the cold-start problem and misfiring during warm-up	• Can be used directly in fuel cells • Can be reformed to make hydrogen for fuel cells • Is technologically the easiest liquid fuel to reform to make hydrogen • Is technologically easier to produce using cellulosic biomass than ethanol

P-Series Fuels

Pros	Cons	Analysis
• P-Series fuel is a unique blend of natural gas liquids (pentanes plus), ethanol, and a biomass-derived co-solvent (MTHF). • P-series could be 96% derived from domestic resources. • More than 60% of the energy content in P-series is derived from	•	• While mostly derived from domestic resources and better in terms of environmental impact than regular gasoline or diesel, it is similar to E85, clean diesel or bio-diesel • It can be used in flex fuel vehicles in the short and medium terms however it will not be

renewable sources. • P-series fuels could reduce fossil energy use by 49% to 57% and petroleum use by 80% relative to gasoline. • Greenhouse gas emissions of the P-series fuels are 45% to 50% below those of reformulated gasoline. • Emissions testing was performed on two 3.0L ethanol Ford Taurus FFV's. The emissions of air toxics from the P-series fuels were lower than those from all other test fuels, both in terms of total mass emissions and in terms of the relative severity of toxicity.		used in the long term • It does not help us in our transition towards fuel cell vehicles running on hydrogen in the future. • Investing into infrastructure, and changing the existing fleet to a fuel that will potentially have a 10yr lifecycle only is not feasible and sustainable in the long run

Natural Gas

Pros	Cons	Analysis
• Some domestically produced • Readily available to end-users through the existing utility infrastructure • Natural gas is also clean burning and produces significantly fewer harmful emissions than reformulated gasoline or diesel. • Commercially available medium- and heavy-duty natural gas engines have demonstrated over 90% reduction of CO and particulate matter and over 50% reduction in NO_x relative to	• Natural gas markets have been wrestling with tight supplies • The price of natural gas has almost tripled in the past four years. • Most natural gas is imported • Natural gas is not a viable option for internal combustion engines except in specialized situations, but can be distributed broadly in the existing NG infrastructure and reformed into H2 at filling stations. • Most of the natural gas reserves in the world are located in other	• Instability anticipated in the natural gas markets over the next decade • Reserves of our largest importer, Canada, are going down. It will eventually reach the level that Canada will need to import natural gas so they can export to the US in accordance with NAFTA treaties. It is anticipated that Canada might break the NAFTA agreement when that happens • Importing gas from the Middle East does not reduce our dependence on imports from politically unstable

commercial diesel engines. • Hydrogen can also be made directly from natural gas and is now the major source of H2.	are located in other countries,[59] so using natural gas as the major source of energy for transportation would be intrinsically vulnerable. • Furthermore, a major commitment to natural gas would provide incentives for building more liquid natural gas production facilities and ships, both of which present a significant terrorist hazard.	geographic areas.

59 http://www.aneki.com/gas.html

Fuel Comparison

Fuel Comparison

	Gasoline	No. 2 Diesel	Biodiesel (B20)	Compressed Natural Gas (CNG)	Ethanol (E85)	Hydrogen	Methanol (M85)
Chemical Structure	C_4 to C_{12}	C_{10} to C_{20}	Methyl esters of C_{16} to C_{18} fatty acids	CH_4	CH_3CH_2OH	H_2	CH_3OH
Cetane Number	5 to 20	40 to 55	46 to 60	N/A	N/A	N/A	N/A
Octane Number	86 to 94	8 to 15	~25	120+	100	130+	100
Main Fuel Source	Crude Oil	Crude Oil	Soy bean oil, waste cooking oil, animal fats, and rapeseed oil	Underground reserves	Corn, Grains, or agricultural waste	Natural Gas, Methanol, and other energy sources.	Natural gas, coal, or, woody biomass
Energy Content per Gallon	109,000 - 125,000 Btu	128,000 - 130,000 Btu	117,000 - 120,000 Btu (compared to diesel #2)	33,000 - 38,000 Btu @ 3000 psi; 38,000 - 44,000 @ 3600 psi	~ 80,000 Btu	113,000 - 134,000 Btu	56,000 - 66,000 Btu
Energy Ratio Compared to Gasoline			1.1 to 1 or 90% (relative to diesel)	3.94 to 1 or 25% at 3000 psi; 3.0 to 1 @ 3600 psi	1.42 to 1 or 70%		1.75 to 1 or 57%
Physical State	Liquid	Liquid	Liquid	Compressed Gas	Liquid	Compressed Gas or Liquid	Liquid
Types of Vehicles Available todaY	All types of vehicle classes	Many types of vehicle classes.	Any vehicle that runs on diesel today-no modifications are needed for up to 5% blends. Many engines also compatible with up to 20% blends	Many types of vehicle classes.	Light-duty vehicles, medium and heavy-duty trucks and buses - these vehicles are flexible fuel vehicles that can be fueled with E85 (ethanol), gasoline, or any combination of the two fuels.	No vehicles are available for commercial sale yet, but some vehicles are being leased for demonstration purposes.	Mostly Heavy-duty buses are available.
Available Vehicles to Purchase	See your local Car/Truck dealership	See your local Car/Truck dealership	Visit the Vehicle Buyers Guide http://www.ccities.doe.gov/vbg/ to learn more about light or heavy-duty Alternative Fueled Vehicles				
Vehicle Conversion Information	N/A	N/A	Visit the AFDC conversion page http://www.afdc.doe.gov/afv.conversion.shtml to learn more				

Environmental Impacts of Burning Fuel	Produces harmful emissions; however, gasoline and gasoline vehicles are rapidly improving and emissions are being reduced.	Produces harmful emissions; however, diesel and diesel vehicles are rapidly improving and emissions are being reducedespecially with after-treatment devices.	Reduces particulate matter and global warming gas emissions compared to conventional diesel; however, NOx emissions may be increased.	CNG vehicles can demonstrate a reduction in ozone-forming emissions (CO and NOx) compared to some conventional fuels; however, HC emissions may be increased.	E-85 vehicles can demonstrate a 25% reduction in ozone-forming emissions (CO and NOx) compared to reformulated gasoline.	Zero regulated emissions for fuel cell-powered vehicles, and only NOx emissions possible for internal combustion engines operating on hydrogen.	M-85 vehicles can demonstrate a 40% reduction in ozone-forming emissions (CO and NOx) compared to reformulated gasoline.
Energy Security Impacts	Manufactured using imported oil, which is not an energy secure option.	Manufactured using imported oil, which is not an energy secure option.	Biodiesel is domestically produced and has a fossil energy ratio of 3.3 to 1, which means that its fossil energy inputs are similar to those of petroleum.	CNG is domestically produced. The United States has vast natural gas reserves.	Ethanol is produced domestically and it is renewable.	Hydrogen can help reduce U.S. dependence on foreign oil by being produced by renewable resources.	Methanol can be domestically produced from renewable resources.
Fuel Availability	Available at all fueling stations.	Available at select fueling stations.	Available in bulk from an increasing number of suppliers. There are 22 states that have some biodiesel stations available to the public.	More than 1,100 CNG stations can be found across the country. California has the highest concentration of CNG stations. Home fueling will be available in 2003.	Most of the E-85 fueling stations are located in the Midwest, but in all, approximately 150 stations are available in 23 states.	There are only a small number of hydrogen stations across the country. Most are available for private use only.	Methanol remains a qualified alternative fuel as defined by EPAct, but it is not commonly used.
AFV Fueling Station Locations	N/A	N/A	Visit the AFDC Refueling Station Locator page http://www.afdc.doe.gov/fefueling_mapsite.shtml to search for stations near you.				
Infrastructure Information	N/A	N/A	Visit the AFDC infrastructure resource page http://www.afdc.doe.gov/altfuel/infractructure.html to learn more				
Maintenance Issues			Hoses and seals may be affected with higher-percent blends, lubricity is improved over that of conventional diesel fuel.	High-pressure tanks require periodic inspection and certification.	Special lubricants may be required. Practices are very similar, if not identical, to those for conventionally fueled operations.	When hydrogen is used in fuel cell applications, maintenance should be very minimal.	Special lubricants must be used as directed by the supplier and M-85-compatible replacement parts must be used.
Safety Issues (Without exception, all alternative fuel vehicles must meet today's OEM Safety Standards)	Gasoline is a relatively safe fuel since people have learned to use it safely. Gasoline is not biodegradable though, so a spill could pollute soil and water.	Diesel is a relatively safe fuel since people have learned to use it safely. Diesel is not biodegradable though, so a spill could pollute soil and water.	Less toxic and more biodegradable than conventional fuel, can be transported, delivered, and stored using the same equipment as for diesel fuel.	Pressurized tanks have been designed to withstand severe impact, high external temperatures, and automotive environmental exposure.	Ethanol can form an explosive vapor in fuel tanks. In accidents; however, ethanol is less dangerous than gasoline because its low evaporation speed keeps alcohol concentration in the air low and non explosive.	Hydrogen has an excellent industrial safety record; codes and standards for consumer vehicle use are under development.	Methanol can form an explosive vapor in fuel tanks. In accidents; however, methanol is less dangerous than gasoline because its low evaporation speed keeps alcohol concentration in the air low and non explosive.
			You can get average costs for all types of fuels through the Alternative Fuel Price Report				

XXIV. Appendix M - Hybrid Vehicle Comparison

Source: http://www.fueleconomy.gov/feg/hybrid_sbs.shtml

Side-by-Side	2003 Honda Civic Hybrid	2003 Honda Insight	2003 Toyota Prius
	Fuel Economy		
Fuel Type	Regular	Regular	Regular
MPG (city)	48	57	52
MPG (hwy)	47	56	45
MPG (comb)	48	56	48
Annual Fuel Cost	$484	$415	$484
	Global Warming		
Annual Greenhouse Gas Emissions*	Worst Best 15.3 3.1 4.0 tons	Worst Best 15.3 3.1 3.5 tons	Worst Best 15.3 3.1 4.0 tons
	Safety		
National Highway Traffic Safety Administration	NA	Crash Test Results	Crash Test Results
	Air Pollution		
EPA Air Pollution Score 0 to 10 (best)	**EPA Air Pollution Score** / Availability 7 — ULEV 3HNXV01.34A5	**EPA Air Pollution Score** / Availability 6 — LEV 3HNXV01.0PCE 8 — BIN 5 3HNXV01.0PCE	**EPA Air Pollution Score** / Availability 7 — ULEV 3TYXV01.5LH1 10 — SULEV 3TYXV01.5LH1

	10 SULEV II 3HNXV01.0PCE	

For more infomation see EPA's Green Vehicle Guide

EPA Size Class	Compact Cars	Two Seaters	Compact Cars
Engine Size (liters)	1.3	1	1.5
Cylinders	4	3	4
Transmission	Automatic (fully variable gear ratios)	Automatic (fully variable gear ratios)	Automatic (fully variable gear ratios)
Drive	Front-wheel drive	Front-wheel drive	Front-wheel drive
Gas Guzzler	no	no	no
Turbocharger	no	no	no
Supercharger	no	no	no
Passenger Volume	91 ft^3 (4D)	NA	89 ft^3 (4D)
Luggage Volume	10 ft^3 (4D)	NA	12 ft^3 (4D)
Additional Engine Characteristics	NA	VTEC	NA

* Based on 45% highway driving, 55% city driving, 15000 annual miles and the following fuel prices:

Regular Gasoline: $1.55 per gallon

GHG-Greenhouse gas emissions expressed in CO2 equivalents. Estimates include the full fuel cycle and exclude vehicle manufacture. (U.S. Department of Energy, GREET Model, Argonne National Laboratory).

XXV. Appendix N – Flex Fuel Vehicle Comparison

2003 Flexible Fueled Vehicles

Sorted by MPG (city), Click on column headings to resort

Model		MPG		Annual Fuel Cost*	Greenhouse Gas Emissions (tons/yr)*	
Chrysler Sebring Convertible 6 cyl, 2.7 L, Auto(4), Gasoline or E85	Gas	21	28	$1011	8.1	
	E85	16	20	$1588	6.0	
Chrysler Sebring 4Door 6 cyl, 2.7 L, Auto(4), Gasoline or E85	Gas	21	28	$1011		
	E85	16	20	$1588		
Dodge Stratus 4 Door 6 cyl, 2.7 L, Auto(4), Gasoline or E85	Gas	21	28	$1011		
	E85	16	20	$1588		
Chrysler Voyager 6 cyl, 3.3 L, Auto(4), FFV (E85), Gasoline or E85	Gas	20	26	$1058	8.6	
	E85	13	17	$1928	7.2	
Mercury Sable 6 cyl, 3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	19	27	$1058	8.6	
	E85	14	20	$1688	6.5	
Ford Taurus 6 cyl, 3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	19	27	$1058	8.6	
	E85	14	20	$1688	6.5	
Dodge Caravan 2WD 6 cyl, 3.3 L, Auto(4), FFV (E85), Gasoline or E85	Gas	19	26	$1058	8.7	
	E85	13	17	$1928	7.2	
Ford Taurus Wagon 6 cyl, 3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	19	26	$1107	8.8	NA
	E85	14	19	$1688	6.7	
Mercury Sable Wagon 6 cyl, 3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	19	26	$1107	8.8	NA
	E85	14	19	$1688	6.7	
Chrysler Voyager/Town & Country 2WD 6 cyl, 3.3 L, Auto(4), Gasoline or E85	Gas	18	25	$1163	9.2	NA
	E85	13	17	$1928	7.2	
Ford Ranger FFV -	Gas	17	21	$1223	10.1	4

Ethanol 2WD 6 cyl, 3 L, Auto(5), FLEX-FUEL, Gasoline or E85	E85	13	16	$1928	7.4	4
Mazda B3000 2WD FFV 6 cyl, 3 L, Auto(5), FLEX-FUEL, Gasoline or E85	Gas	17	21	$1223	10.1	4
	E85	13	16	$1928	7.4	
Ford Explorer FFV 4WD 6 cyl, 4 L, Auto(5), FLEX-FUEL, Gasoline or E85	Gas	15	21	$1367	10.8	4
	E85	11	15	$2249	8.4	
Ford Explorer FFV 2WD 6 cyl, 4 L, Auto(5), FLEX-FUEL, Gasoline or E85	Gas	15	21	$1367	10.9	4
	E85	11	16	$2076	8.1	
Mercury Mountaineer 2WD FFV 6 cyl, 4 L, Auto(5), FLEX-FUEL, Gasoline or E85	Gas	15	21	$1367	10.9	4
	E85	11	16	$2076	8.1	
Mercury Mountaineer 4WD FFV 6 cyl, 4 L, Auto(5), Gasoline or E85	Gas	15	20	$1367	11.2	4
	E85	11	15	$2076	8.1	
Chevrolet C1500 Silverado 2WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	15	19	$1367	11.4	1
	E85	11	14	$2249	8.4	
GMC C1500 Sierra 2WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	15	19	$1367	11.4	1
	E85	11	14	$2249	8.4	
Chevrolet C1500 Tahoe 2WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	19	$1453	11.8	0
	E85	11	14	$2249	8.7	
GMC C1500 Yukon 2WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	19	$1453	11.8	0
	E85	11	14	$2249	8.7	
GMC K1500 Yukon 4WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453	12.1	0
	E85	10	13	$2249	8.9	
GMC K1500 Yukon AWD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453	12.1	0
	E85	10	13	$2249	8.9	
GMC K1500 Yukon XL 4WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453	12.1	0
	E85	10	13	$2249	8.9	
GMC K1500 Yukon XL AWD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453	12.1	0
	E85	10	13	$2249	8.9	

Chevrolet K1500 Avalanche 4WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453	12.1	0
Chevrolet K1500 Avalanche AWD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	E85 Gas	14	18	$1453 $2249	12.1 8.9	0
	E85	10	13	$2249	8.9	
Chevrolet K1500 Suburban 4WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453	12.1	0
	E85	10	13	$2249	8.9	
Chevrolet K1500 Suburban AWD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453		
	E85	10	13	$2249		
Chevrolet K1500 Tahoe 4WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453		
	E85	10	13	$2249		
Chevrolet K1500 Tahoe AWD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1453		
	E85	10	13	$2249		
Chevrolet C1500 Suburban 2WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1551		
	E85	10	13	$2249		
GMC C1500 Yukon XL 2WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1551		
	E85	10	13	$2249		
Chevrolet C1500 Avalanche 2WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	14	18	$1551		
	E85	10	13	$2249		
Chevrolet K1500 Silverado 4WD 8 cyl, 5.3 L, Auto(4), FLEX-FUEL, Gasoline or E85	Gas	13	17	$1551		
	E85	10	12	$2454		
	Gas	13	17	$1551		
	E85	10	12	$2454		

* Based on 45% highway driving, 55% city driving, 15000 annual miles and the price of fuel used by the vehicle. You may customize these values to reflect the price of fuel in your area and your own driving patterns.

GHG-Greenhouse gas emissions expressed in CO2 equivalents. Estimates include the full fuel cycle and exclude vehicle manufacture. (U.S. Department of Energy, GREET Model, Argonne National Laboratory)

XXVI. Appendix O - Diesel Vehicle Comparison

http://www.fueleconomy.gov/feg/byfueltype.htm

2003 Diesel Vehicles

Sorted by MPG (city), Click on column headings to resort

Model	MPG (city)	MPG (hwy)	Annual Fuel Cost*	Greenhouse Gas Emissions (tons/yr)*	EPA Air Pollution Score From 0 to 10 (best)
Volkswagen Jetta Wagon 4 cyl, 1.9 L, Man(5), Diesel	42	50	$466	4.7	1
Volkswagen New Beetle 4 cyl, 1.9 L, Man(5), Diesel	42	49	$466	4.7	1
Volkswagen Golf 4 cyl, 1.9 L, Man(5), Diesel	42	49	$466	4.7	1
Volkswagen Jetta 4 cyl, 1.9 L, Man(5), Diesel	42	49	$466	4.7	1
Volkswagen Golf 4 cyl, 1.9 L, Auto(4), Diesel	34	45	$552	5.5	1
Volkswagen Jetta 4 cyl, 1.9 L, Auto(4), Diesel	34	45	$552	5.5	1
Volkswagen Jetta Wagon 4 cyl, 1.9 L, Auto(4), Diesel	34	45	$552	5.5	1
Volkswagen New Beetle 4 cyl, 1.9 L, Auto(4), Diesel	34	44	$552	5.6	1

* Based on 45% highway driving, 55% city driving, 15000 annual miles and the price of fuel used by the vehicle. You may customize these values to reflect the price of fuel in your area and your own driving patterns.

GHG-Greenhouse gas emissions expressed in CO2 equivalents. Estimates include the full fuel cycle and exclude vehicle manufacture. (U.S. Department of Energy, GREET

Model, Argonne National Laboratory)