CHAPTER I.
INTRODUCTION

A. Energy in Today's World

The remarkable improvement in the standard of living in the USA during the 20th century is unprecedented in world history. An almost total transformation from an agrarian to an urban society occurred during this period. Work once done by people and animals is now performed by machines powered by petroleum or electricity. Both the quality and duration of life have improved.

Petroleum fuels altered the way we grow and distribute food, where we live, the location and configuration of manufacturing, and even the way we entertain ourselves. Air travel makes it possible to reach any point in the world in less than a day.

An abundant, reliable source of electricity revolutionized the factory and multiplied worker productivity. Electricity in the home allowed for refrigeration, lighting, indoor climate control and quality home entertainment centers.

The creative and inventive use of energy form the foundation of modern society. With the emergence of the 21^{st} century we are challenged to improve this foundation while faced with challenges like global warming, importing over $100 billion in crude oil each year, over-reliance on natural gas resources, and mega energy corporations that resist needed changes. How we respond to these challenges will dramatically impact our future.

Historically, it is not the lack of energy technology that limits options, but the way technology is applied. The application of available technology is too often determined by politics. In our democratic bureaucracy there is a contest between the power of money and altruistic duties to serve the public's best interest; both able to influence public opinion, the ominous electoral process and ultimate government policy. Technology also has a role in influencing government policy, but first, the technology must be understood by those who can influence policy. Only then is the technology able to empower altruistic entities over monetary interests.

Within the political arena, technology is a unique beast. Technology can be discovered, used, or hidden. But, most importantly, technology can be evaluated to determine if it is corrupt. If identified as corrupt, it can be discarded. This conclusive test for corruption is fairly unique and is known as experimental reproducibility. The ability of a scientist to experiment and to document the experimental results combined with the subsequent ability of other scientists to repeat the experiment is the foundation of modern science. Such is the power of knowledge on energy technology.

Technology wins wars, saves lives, and transforms society because it is real; it is an unquestioning servant to mankind that in the end cannot be successfully influenced by politics or money. Unfortunately, technology's greatest strength is also its greatest weakness. In politics, the power of technology is rarely called upon in lieu of other factors that can be more easily influenced.

How do we empower technology to realize its full potential to do good? Certainly, technology won wars, saved lives, and took mankind out of the caves only because man not only discovered the technology, but used it.

The money of mega energy corporations fund the facilities to supply energy, and they hire well-known technologists to advise them. In contrast, with rare exception, altruistic leaders and their constituents do not understand energy science and technology. The political system is easy prey to mega corporations that use selective dissemination of information, liberal political campaign contributions, and influential lobbyists (often *insiders* from government or industry). Inevitably, policies that lead to the greatest prosperity for energy corporations may not be the best policies for the country as a whole. The mega corporations are not evil; they are simply looking after their equity and shareholder interests. This focus on their vested interests makes it impossible for them to be objective.

Historically, few groups have been able to challenge the political influence of mega corporations. Farm lobby groups have been able to influence federal policy; however, their vested interests are in the well-being of farmers and not true national altruism.

Environmental groups are typically motivated by altruistic intentions. Membership in these organizations is based on personal motivation to show up for meetings and participate in activities. The propensity for these groups to be led astray on technology issues is immense due to their general lack of relevant technical education. The endorsement of the wrong technology due to a few good features often only "muddies the waters" for other, better technologies. For environmental groups, good intensions do not always translate to sound policy endorsements.

Ultimately, nothing replaces an understanding of the technologies that impact our lives. Hand in hand with freedom of speech and press, knowledge of technology can empower a people to keep a nation *by the people and for the people*. So long as you are of good physical and mental health, knowledge and the ability to share that knowledge cannot be taken away.

History shows that even against the most formidable rivals, knowledge is power. In the area of energy technology, the knowledge to understand energy options and participate in policy changes can be attained. The consequences of having a political hierarchy that does not attain this knowledge go far beyond higher prices at the gas pump. The consequences include potential compromises on national security, the American standard of living, and world peace.

B. Clash of Public Good versus Corporate Status Quo

Only a small fraction of new technologies make it through the scrutiny of large corporations to become commercial. This clash of new versus established technology is an artifact of a larger societal clash. It is not the clash of public good versus corporate wealth, because corporations could become wealthier. It is not the clash of public good versus the environment, because the environment could be greener. It is not the clash of public good versus crooked politicians because all could gain with change.

It is the clash of public good versus the status quo. Those who benefit from the status quo (i.e., profitable corporations) resist change; unfortunately, as the world changes and progresses, those who go with the status quo are inevitably left behind.

Understanding what the technology has to offer is at the core of this clash. The corporations are not aware that they could be wealthier. The environmentalists do not recognize it could be greener. Crooked politicians are fewer and outnumbered by politicians who simply do not know technology.

As compared to other technologies, energy technology is unique. People continue to die due to inadequate heating and air conditioning. Commercial productivity slows to a crawl when the flow of vehicles stop (as occurs during blizzards). Essentially all people rely on energy to the point of not being able to effectively function as a part of society without the heating, transportation, and general efficiency in daily life provided by electricity, vehicular fuels, and natural gas. While high-tech and pharmaceutical companies receive much attention in the stock markets, the energy industry stands out in terms of shear magnitude and impact.

Energy corporations have been an integral part of society for the past century with no end to their importance in sight. Of the top ten Global 500 companies in 2001, 9 are corporations doing business predominantly in energy or automobile manufacturing. Of the top ten Fortune 500, 6 are energy-related as listed in Table 1.

The smallest of these companies in the top ten list is Chevron Texaco with annual revenues of $100 billion. The total revenue of the energy and automobile companies in the top ten of the Global 500 is $1.4 trillion. Wal-Mart is the only non-energy or automotive company in the top ten of the Global 500.

In view of the monetary power of these companies, it is no surprise that any competitive technology must have their support or be mandated by government policy. When the visions of these energy corporations are shortsighted, all can suffer.

Table 1. Energy and energy-related corporations in the top ten of the Fortune 500 and Global 500 (2001).

Fortune 500 (revenue in $ billion per year)			Global 500 (revenue in $ billion per year)		
2	Exxon Mobil	$192	1	Exxon Mobil	$210
3	General Motors	$177	3	General Motors	$185
4	Ford Motor	$162	4	Ford Motor	$181
5	Enron	$139	5	DaimlerChrysler	$150
6	General Electric	$126	6	Royal Dutch/Shell Group	$149
8	ChevronTexaco	$100	7	BP	$148
			8	General Electric	$130
			9	Mitsubishi	$127
			10	Toyota Motor	$121
	TOTAL	$896		TOTAL	$1,401

This text is written to provide an introduction to energy science and technology that might help citizens/legislators make independent decisions about options available as we consider our energy future. We have chosen to focus on transportation fuels and electric power production because they are essential energy industries. The narrative describes current technologies that provide transportation fuel and electricity.

The story starts with the concept of energy and how all forms of energy have common origin. These common features include an origin in the energy of the atom. All energy on earth originated from atomic energy. Through the years energy has degraded, it has been stored, and mankind has learned to use it.

The sun's light was yesterday's atomic energy. The energy stored in wood and vegetable oils was yesterday's sunlight. Yesterday's wood and vegetable oils are today's coal and crude oil. Yesterday's coal and crude oil are today's natural gas. A description of these natural energy stockpiles and their history sets the tone for subsequent sections on technology using these energy reserves. Chapters 2 and 3 describe how energy reserves were formed and the amounts of these reserves.

Nature used time to transform the sunlight to wood, oil, coal, petroleum, and natural gas. Today, man can transform these reserves. Relatively simple processes for converting petroleum into gasoline have evolved into technologies that allow coal to be taken apart and put back together again at the molecular level. Fuel cells can convert the chemical energy of hydrogen or methane directly to electricity without combustion.

To understand the advantages and disadvantages of nature's energy reserves requires an understanding of engines and power cycles. Studying the text on gasoline engines can reveal the mystery of these machines in a matter of minutes. Likewise, processes for converting coal into electricity that took centuries to develop can be quickly learned with a joy like that of looking through a microscope for the first time.

Instruments of Change

It took man centuries to develop the metals used for today's energy machines. At the start of the 20th century with the materials (primarily steel) in place, high performance machines were developed in a matter of years. Having the right materials available was necessary for the advances, but it alone was not sufficient.

One of the biggest differences between the time period before and after the year 1900 was the role governments played in fostering technical development. Largely starting with the aircraft and motorized vehicles of WWI, federal appropriations to improve military capability have driven progress in the machines for energy conversion. Governments provided the funding and dedication to fully develop machines to help meet national objectives such as winning a war. The benefits extended far beyond the war.

The steam turbine designed to power warships in the early 1900's produced improved turbines for domestic electric power production. Gas turbines used to drive air compressors in military jets at the end of WWII were used in commercial jets after the war. The early 1940's Manhattan project produced the atomic bomb, and about ten years later the same nuclear science produced the first nuclear reactor that replaced the Diesel engine in submarines.

Taking concepts out of the laboratory and into public use typically comes with a high price tag. Today we benefit tremendously from the developments undertaken by governments in the 20th century. First-world governments recognize the need for basic research. Support for basic research is essential to maintain their leadership status.

One of the greatest challenges of capitalism in the 21st century is to continue with world-impacting technologies without the motivation of world conflict to take the technologies forward. In what could be referred to as a social experiment of the late 20th century, governments have relied more on major companies to develop technology. Major corporations seldom assume the cost of long-term research. Progress has slowed in many areas. This social experiment is failing.

At the start of the twentieth century suitable liquid fuels were rare, and the proper match of a fuel with an engine was an art. Today, we can move vehicles or produce electricity from energy originating in petroleum, coal, natural gas, wood, corn, trash, sunlight, geothermal heat, wind, or atomic energy. Each of these can be used in different ways. Natural gas, for example, can be used directly in spark-ignition engines, converted to gasoline fuel, converted to diesel fuel, converted to hydrogen fuel, or converted directly to electricity.

With these multiple energy sources and hundreds of ways to use them, is there one homemade technology-ready alternative to replace petroleum? Is at least one alternative cost competitive with the $100 billion in crude oil we import each year? If we were able to make this one transformation, many of our international problems and fluctuations in economic prosperity would be replaced with increased national security and a more robust economy.

The process for unlocking the potential of technology starts with asking the right questions. Both history and science have a story to tell.

In 1940, Germany was converting coal into the highest quality diesel and jet fuel, and they were able to sustain this industry (aside from allied bombing) using coal that was considerably more costly than the vast, rich reserves of today's Wyoming coal. Wyoming has vast supplies of coal in 40 feet seams just feet below the surface--it can literally be harvested for a few dollars a ton as quickly as it can be loaded into trucks.

Synthetic fuel production, as an alternative to crude oil, was sustainable in Germany in 1940. Why is it not sustainable today with cheaper coal, 60 years of scientific and technological advance, and pipeline distribution that does not rely on costly petroleum tanker shipment from the other side of the world? Originally, the German synthetic fuel process was designed to produce refinery feedstock. Can the synthetic fuel industry leapfrog the competition by producing a fuel that can be directly used in engines? If the refinery could be bypassed, the cost advantages of synthetic fuels are even further advanced over petroleum alternatives.

South African synthetic fuel (known as Fischer-Tropsch) facilities were able to sustain production of synthetic oil from coal while in competition with world crude oil prices at $10 per barrel in the late 1990's. Canadian syncrude facilities are reported to be producing petroleum from tar sands at $10 to $12 per barrel. The tar sand reserves are about the same size as world reserves of petroleum. Today, Canadian tar sands are used instead of imported oil—the technology is sustainable and very profitable.

Why have South Africa and Canada been able to incubate these industries during the past few decades while the U.S. failed and, today, remains without a significant synthetic fuel industry to replace crude oil imports that exceed $100 billion per year? Lack of competitive technology is not at fault.

Repeatedly, U.S. voters have given the mandate to foster cost-competitive alternatives to imported petroleum. Do U.S. policies foster the development of replacements for petroleum, or do U.S. policies lock in competitive advantages for petroleum over proven alternatives? When you get past the hype of fuel cells, ethanol, and biodiesel, a comparison of U.S. tax policies on imported crude oil relative to domestic fuel production reveals practices that favor crude oil imports. These and similar policies are the silent killers of the technology that can eliminate the need to import fuels and can create quality U.S. jobs for millions.

Influencing tax policies is one of the mega corporations' most effective tools for dominating energy markets. These policies do not require a constant participation of corporations in national politics, but rather, a strategic political victory here or there that sets a policy lasting for decades. On the subject of commercializing new technology, the visions of energy corporations are too shortsighted. Herein is the greatest problem that capitalism and Western society will face in the 21st century.

Much has been written promoting hydrogen as the fuel for tomorrow. While it is true that thermal efficiencies up to 70% make fuel cells more efficient than any other chemical conversion engine, this is only part of the story. For fuel cells, the details are extremely important. What is the rest of the story? Chapters 4 and 5 look at conversion technologies and the source of energy that powers these cycles.

Of all the energy technologies, nuclear energy is probably the most misunderstood. Nuclear energy can be produced safely, and we understand the technology well enough to minimize the risk of even the worst-case accident. However, the handling of nuclear waste has always been a thorn in the side of that industry. From the fundamental perspective, the issue of nuclear waste is rather ironic. One question is obvious to even a first year college student first exposed to nuclear technology. Can the really nasty, fission products in spent nuclear fuel be separated from the bulk of the waste—the bulk being considerably more benign and quite valuable? The answer is surprising.

Fundamentally, the removal of the fission products is easier than concentrating the fissionable uranium isotope initially used as nuclear fuel. Pursuit of this topic answer reveals that typical once-through technology only produces about 3-4% of the energy available in the fuel. Reprocessing of the spent fuel is not only possible, but it would substantially reduce present "waste" inventories by converting essentially 100% of uranium's energy into power plant fuel. In other words, the "waste"[1] generated during thirty years from a 1,000 megawatt nuclear power plant could be used to continue to produce 1,000 megawatts of electricity for the next 1,000 to 2,000 years—without generating greenhouse gases while reducing the quantity of spent fuel stored at that facility.

New "Plug-In" approaches on hybrid vehicle designs could be used to replace essentially all imported oil without producing air pollution. They could become cost effective in a matter of months if made a priority.

If nuclear energy is deemed too risky, why not make it safer? At stake are tens of thousands of years of abundant energy that is as clean and safe as we choose to make it.

Cheap, pollution-reducing, and greenhouse-gas-free electricity would go a long way toward paving a brighter future for mankind; however, even with cheap electricity, battery-powered cars are still not cost effective relative to internal combustion engines. Effective solutions to the complex modern

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[1] Here, "waste" refers to spent fuel containing 97-98% uranium with plutonium. It also includes 3 pounds of depleted uranium generated for each pound of fuel uranium produced.

energy needs require a variety of technologies, including liquid fuels, reliable fuels for electrical power generation, and energy storage systems to maximize the use of the most efficient alternatives. Chapters 6 and 7 complete the introduction to energy technology and conversion by summarizing the history of electrical power production and how heating, ventilation and air conditioning are major drivers in the energy industry.

The final three chapters of the book bring together the technologies and profitability analyses by which investment decisions are made. The failure of the U.S. to rid itself of a dependence on imported petroleum is not due to the lack of technology. The bottom lines of the profitability analyses speak for themselves. In approximate order from the greatest to least of obstacles, the following have prevented commercialization of alternatives to crude oil in the U.S.:

1. *Expecting existing oil companies to take the lead in developing alternatives* is the greatest obstacle preventing the U.S. from becoming energy-independent. With each major oil corporation having crude oil reserves averaging more than 10 years, the price of oil could never be high enough for them to make multi-billion-dollar investments today that would make these vast reserves obsolete tomorrow.

2. *The international market is not protected by U.S. anti-trust laws*. This puts investments at risk and increases the investors' needs for quick paybacks of investments. The U.S. government must be proactive against unscrupulous foreign competition and therein protect these infant industries before the damage is done. These "intangible risks" can double the threshold petroleum prices above which investments into alternative fuels is justified.

3. When considering investments in alternative fuel technology, investment criteria of 12.5% return on investment with capital payback in 15 years are never met (even for companies without oil reserves). Ironically, when observing those things that form the essence of modern society (including highways, electrical power plants, museums, sanitation, airports, a physician's education, an engineer's education, a teacher's education …), none can be justified on investment criteria of 12.5% ROI and 15-year payback. This *demanding investment criteria* increases the price threshold at which corporations are willing to invest into alternative fuel facilities by about 50%. Alternative fuel infrastructure needs to be financed using similar investment criteria and methods used for other critical civil infrastructure such as airports, highways, and electrical power plants. $100 billion per year of oil imports, lost domestic jobs, and national security issues simply do not enter into corporate investment decisions.

4. *Inequitable taxes on domestic synthetic fuel production as compared to imported crude* oil doubles the price of domestic alternatives. Taxes on a barrel of imported crude oil are about $0.12 per barrel while the $28 price per barrel of domestic synthetic crude oil includes $14 in social costs and taxes.

5. Technology costs (the fundamental equipment and conversion costs) present the lowest barriers. Good engineering and collaboration would make a U.S. synthetic fuel industry economically viable after 1-4 above are addressed. Several different technologies would be viable. Without addressing 1-4, only costly federal subsidies can make an alternative fuel industry viable. Even then, only token production capacities can be put in place before the subsidies become too expensive and loses political support.

Today's technology will allow coal to replace imported crude oil at $14 per barrel[2]. With anticipated improvement and collaboration, this would reduce to $10 to $12 per barrel. When taxes are added, the price increases to about $28 per barrel. This increases to about $56 per barrel when 20% return on investment and 6-year payback are included in the investment threshold. When oil reserves are included in the profitability analysis, prices in excess of $100 per barrel will not justify making the needed infrastructure investment for current oil corporations. In the absence federal policies designed to replace imported crude oil, this hierarchy of increasing barriers assures continued dependence on imported crude oil. Continued dependence on imported crude oil is the U.S. government policy. It is short-term policy that will produce disastrous long-term consequences.

The good news is that our nation has managed to prosper, while importing over $100 billion in crude oil per year. The even better news is that we have the technology to simultaneously 1) become energy-independent, 2) create thousands of quality domestic jobs, 3) substantially reduce greenhouse gas emissions without additional consumer costs and 4) reduce the national trade deficit. But how do we empower technology to realize its full potential to do this?

We learn the facts, and with the further empowerment of the greatest nation in history we place our destiny back into the hands of the people.

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[2] Price has tax and social costs removed and has been adjusted to correct for improved quality of oil—the product can be directly distributed as fuel.

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