CHAPTER 2

The History of Energy

As you sit in a climate-controlled room, light available at the flip of the switch, eyes roaming the page, lungs breathing in and breathing out, heart beating, and electrical pulses of your brain contemplating the words on this page, it is easy to take the *energy* that powers your world for granted. Without energy there would be no light, no book, no life. Mankind is surfing on a wave of energy that was initiated at the dawn of the universe.

Energy

The past one hundred years are like the blink of an eye in the life of humanity, and yet, within this blink, scientists have unraveled the history of energy. This story goes hand in hand with the history of the universe. Following energy back in time takes you to the origin of the universe.

Your body is powered by the energy stored in the chemical bonds of the food you eat. The energy in this food is readily observed by taking a match to a dried loaf of bread and watching it burn. Both your body and the fire combine oxygen and the bread to form water and carbon dioxide. While the fire merely produces heat in this reaction, your body uses the energy in a very complex way to move muscles and produce the electrical energy of your nervous system to control motion and thought.

Both your body and the fire use the chemical energy stored in the starch molecules of the bread. This energy is released as chemical bonds of starch and oxygen are converted to chemical bonds in water and carbon dioxide. Even the molecules your body retains will eventually revert back to carbon dioxide, water, and minerals.

The energy in the chemical bonds of the food came from photosynthesis, which uses the energy from the sun to combine carbon dioxide and water to produce vegetation and oxygen. While the oxygen and carbon stay on the earth and cycle back and forth between vegetation and the atmosphere, the sun's radiation has a one-way ticket into the process where it provides the energy to make life happen. Without this continuous flow of energy from the sun, our planet would be lifeless.

The radiation that powers the photosynthesis is produced by the virtually endless nuclear reaction in the sun. In this process, hydrogen atoms combine to form helium. When hydrogen atoms join to form more stable helium, the total mass is reduced. The lost mass is converted into energy according to Einstein's equation, $E = mc^2$. Enough mass was formed during the birth of the universe to keep the stars shining during the past 15 to 20 billion years.

The presence of different elements in our planet, solar system, and galaxy reveals energy's history. All forms of energy on Earth originated at the birth of the universe. Our life and the machines we use depend on energy's journey, catching a ride as the energy passes by. We are literally surrounded with energy in hydrogen, uranium, and chemical bonds with limits of our use of this energy largely determined by our choices and, in some cases, our pursuit of technology to better utilize these resources.

Nature's Methods of Storing Energy

All forms of energy, whether nuclear, chemical energy in coal, chemical energy in petroleum, wind, or solar, are part of energy's journey that started with the birth of the universe. In our corner of the universe, the energy output of the sun dwarfs all other energy sources. Nuclear fusion in the sun releases massive amounts of energy. The only way this energy can escape from the sun is in the form of radiation. Radiation output increases as temperature increases. Somewhere along the journey, the sun came into a balance where the sun's radiant energy loss tends to decrease the temperature at the same rate as the nuclear fusion tends to increase the temperature. In this process, the outward force of the constant nuclear explosions is balanced by the sun's gravitational force to form a nearly perfect sphere.

Before life evolved on Earth, the sun's energy reached Earth. If you close your eyes and look at the sun, your face receives the warmth while the top of your head receives little. The radiation causes Earth's equator to be warmer than the poles. These temperature differences cause wind and ocean currents. See the box "The Nature of Wind."

The Nature of Wind

The principal is easy to understand. At warm locations like the Texas coast, warm water rises in the oceans and warm air rises in the atmosphere. The space is filled from the flow of cooler water or air coming in from the sides. The cooler fluid is now warmed and keeps the process going.

Meanwhile, at colder locations like Greenland, the warmer air high in the sky or on the ocean surface is cooled and displaces the cooler fluid below. The cooler fluid moves outward to areas where fluids are rising.

Water tends to amplify wind patterns, since water vapor, evaporated by the sun, is even lighter than heated air at the same temperature. When water vapor cools, it can become a thousand times more dense by condensing into rain or snow. This can happen on massive scales like the Gulf Stream or on smaller scales, like the flow of air and moisture that keeps the skies clear of clouds on the Costa De Sol in southern Spain.

Before life existed on Earth, the sun's radiation formed water vapor and caused it to rise from the oceans. This water vapor caught the wind and was blown to the mountains, where it cooled to form rain. The high elevation of this water in the mountains gave it energy to flow downhill. Rocks and gravel dissipated this energy on its journey back to the oceans. The potential energy from water's height in the mountain is converted to thermal energy that is reflected by a slight increase in the temperature of the water as is progresses from the mountain to the ocean.

The first primitive organic life appeared on Earth about 3 billion years ago, with photosynthesis first occurring about 1 billion years later.[1] The vast majority of the vegetation fell to the ground and decomposed, combining with oxygen and going back to carbon dioxide and water. Some fell to the floor of swamps, where oxygen could not reach them as fast as they piled up. These deposits were buried deeper and deeper, making it even more difficult for oxygen to reach them and convert them back to carbon dioxide and water. After a sufficiently long time, the vegetation rearranged into more stable deposits that we call coal. Different types of coal developed, depending on the depth, temperature, and moisture of the deposits. This preservation process was particularly effective in swamps, where the water reduced the rate at which oxygen could reach the fallen vegetation.

In the seas, much of the surface was inhabited by bacteria called phytoplankton (small, floating, or weakly swimming animals or plantlife in water). The cells of these phytoplankton contained oils that are in some ways similar to the corn oil used to cook french fries. When these phytoplankton died, most of them were converted back to carbon dioxide and water by the oxygen dissolved in the water or by feeding animals. Some were swept to ocean depths, where there was little oxygen, and they accumulated. Some of these bacteria deposits were buried by silt. The passage of time and the pressure from the overburden of water and silt transformed these deposits into petroleum oil.

In the turmoil of erosion, volcanoes, and general continental drift, large deposits of coal and oil made it back to the surface, where, in contact with oxygen, they oxidized back to water and carbon dioxide. Other deposits persist for us to recover. Still other deposits were buried deeper, reaching higher pressures and higher temperatures, due to Earth's geothermal heat. There, the coal and petroleum converted to a combination of natural gas and high-carbon deposits of hard coal or carbon in the form of graphite.

Over tens of millions of years, the sun's energy, working with the life on Earth, formed energy deposits of coal, petroleum, and natural gas. Currently, yesterday's radiation is available as vegetation such as wood, corn, and palm oil. Today's radiation is available as sunlight, wind, ocean currents, and the hydroenergy of water in high-altitude rivers and lakes.

The legacy of the universe is all around us. Compared to our consumption of energy, the fusion energy available in the hydrogen of the waters of the ocean is almost endless. Uranium available in the soil and dissolved in the ocean can produce energy by fission. All atoms smaller than iron could be fused to form iron, while all atoms larger than iron could undergo fission (splitting) to form iron. Both processes involve the nucleus of atoms releasing vast amounts of energy.

The geothermal heat of the Earth originated at the birth of the universe. The cosmic forces at the beginning formed the atoms that collected, formed rocks, and became Earth with a molten center. If the heat were left unreplenished, the core of the Earth would have long since cooled. Adding to the heat of colliding masses, uranium and other larger molecules are constantly undergoing nuclear rearrangements (including fission) from Earth's surface to its core. The fission energy release occurs one atom at a time, but the energy adds up. The released heat maintains molten magma from Earth's core to near the surface. On the surface we see this energy released as volcanic eruptions and geysers.

It is important to recognize that nuclear conversions have played a vital role in the evolution of life on Earth and continue to maintain Earth's molten core. A natural nuclear reactor actually formed in Oklo, Gabon (Africa), about 2 billion years ago. This occurred due to the concentration of U-235 in ore at Oklo: The high concentrations caused a fission chain reaction of the U-235, leading to lower than normal U-235 concentrations and trace plutonium found in those deposits today.

We did not introduce nuclear processes (or even nuclear reactors) to Earth. We merely learned to control nuclear processes and harness the energy. We have options on where we can tap into energy's journey to power our modern machines, and halfway through the 20th century, nuclear power became one of the options to meet rapidly increasing energy demands.

Man's Interaction with Nature's Stockpiles and Renewable Energies

Primitive man was successful in tapping into the easily available and easily usable forms of energy. He lived in warmer climates where the solar warmth protected him from the cold. Even the most primitive animals, including early man, recognized the need to nourish their bodies with food.

As the use of fire developed, man was able to move into colder climates, where the energy in wood was released by burning campfires. Animal fat and olive oil were soon discovered to be useful sources of fuel to feed the fire for heat and light. These fats and oils were observed to burn longer and could be placed in containers or wrapped on the end of a stick to create a torch—hence, they are early endeavors into fuel processing. Whale blubber was added to animal fat and olive oil for food and fuel.

The wheel and axle were another early step in developing energy technology. The wheel and axle assisted man to use his physical energy to move heavier loads. The cart was made more effective by using domesticated animals. For stationary applications, water wheels and windmills converted the hydraulic and wind energies into shaft work for many applications including pumping water and grinding grain. Wind energy powered ships to explore new lands, establish trade, and expand the fishing industry.

Machines using wind and hydraulic energy made it possible for one person to do the work of many—freeing time for them to do other tasks. A most important task was educating the young. Time was also available for the important tasks of inventing newer and better machines. Each generation of new machines enhanced man's ability to educate, invent, discover, and add to leisure time.

Societies prospered when they used the freedom created by machines to educate their youth and to create new and better machines. Inventions and discoveries extended to medicines that conquered measles and polio. The benefits of modern society are available because of the effective use of energy and the way energy-consuming machines enhanced man's ability to perform routine tasks, freeing time for education, discovery, and innovation. Civilization emerged and prospered.

History shows that civilization evolves based on technology. For man, the "survival of the fittest" is largely the survival of the culture most able to advance technology. In modern history, while Hitler's technology dominated the World War II battlefields, Germany was winning the war. As the Allies' technology surpassed Germany's technology, the Allies began to dominate the battlefields, leading to victory.

If you drive through the Appalachian Mountains, you will observe how coal seams (varying from an inch to over a foot thick) once buried a few hundred feet in the Earth are now exposed on cliffs. The upheaval that created mountains also brought up deposits of coal and oil. At cliffs like these, man first discovered coal. Coal was considerably easier to gather at these locations than firewood, and eventually coal replaced firewood. Marco Polo observed "black rocks" being burned for heat in China during his 1275 travels.[2] Coal's utility caught on quickly. Between 1650 and 1700, the number of ships taking coal from Newcastle to London increased from 2 to about 600.[3] In 1709 British coal production was estimated to be 3 million tons per year. Benjamin Franklin noted in 1784 that the use of coal rather than wood had saved the remaining English forests, and he urged other countries to follow suit.

When oil was found seeping from the ground, it could be collected and used to replace an alcohol-turpentine blend called camphene (camphene being less expensive than whale oil).[4] Eventually, mining and drilling techniques were developed to produce larger deposits of coal and oil found underground.

From an historic perspective, energy technology has tended to feed upon itself and make its utility increase at ever-faster rates. Large deposits of coal made it possible for just a few people to collect the same amount of fuel that it took an entire community to gather a few centuries earlier. Easy and efficient gathering of fuel freed up more time and resources to develop new and better machines that used the dependable fuel supply.

Prior to the 19th century the decisions to proceed with newly demonstrated technology were easy because the benefits were obvious. The vast amounts of virgin wilderness dwarfed the small tracts of land that had been devastated by poor mining practices, and an energetic entrepreneur could simply go to the next town to build the next generation of machines as local markets were dominated by local businesses.

At the end of the 19th century, vast tracts of land or oceans were no longer barriers to the ambitions of the people managing corporations. The telegraph allowed instant communication and steam engines on ships and locomotives helped them reach their destinations in a matter of days. Suddenly, budding entrepreneurs could no longer travel to the next town to get outside the influence of existing corporations. In energy technology, companies became monopolistic energy empires.

The growth of local businesses into corporations with expanding ranges of influence made their products quickly available to more people. The benefits were real, but the problems were real, as well. One problem was that innovation was being displaced with business strategy and influence, determining which technologies would be developed.

For energy options to be commercialized today, both technical and nontechnical barriers must be overcome. The nontechnical barriers generated by corporations and their far-reaching political influence can be even greater than the technical barriers. These nontechnical barriers must be understood and addressed.

The Industrial Revolution and Establishment of Energy Empires

The Standard Oil Monopoly

The Standard Oil monopoly of the early 20th century demonstrated what happens when a corporation loses sight of providing consumers a product and becomes overwhelmed with the greed for profit.

After the civil war, men swarmed to western Pennsylvania to lay their claims in a "black gold rush." John D. Rockefeller was among these pioneers. Within one year of discovering the potential for drilling for petroleum, the price went from $20 per barrel to 10 cents per barrel. Rockefeller realized that the key to making money in oil was not getting the oil out of the ground but rather refining and distributing the oil.[5] Standard Oil crossed the line when it changed its corporate philosophy to one of profiting by stifling the competition through monopolistic control of refining and distribution of all petroleum products.

The Atlantic and Great Western Railway controlled the cheap rail transit in the western Pennsylvania region, and this controlled the oil market. Rockefeller prevented his competition from using this railroad to sell their oil.

This was a change in paradigm for the energy industry. A company controlled the market by controlling access to the commodity. While nations and shipping fleet owners had done this in the past, this was different. This was a company operating in a free country aggressively moving to eliminate all competition.

Artificially inflated oil prices were just like taxes without representation. When previously faced with a similar situation, the people united in the American Revolutionary War. Here, the adverse impacts of the oil monopoly were difficult to quantify, unlike a tax on tea, and there was no precedent to show the way to reasonable remedies.

Competitors of Standard Oil were stifled. Some of the competition sold out. High consumer prices—higher than the free market would bear—were the result of this monopoly. Technology and innovation were also stifled. Corporate success was determined by controlling access to the products, not by the best technology.

In the past, improving technology benefited both the consumer and the company. When business savvy replaced innovation, the actions of the company were at odds with what was good for the consumer. The creative innovation and technology were now forced off the highway of ideas onto the back roads where progress was slow.

For 32 years Standard Oil profited from its monopoly on oil refining. In May 1911, U.S. Supreme Court Chief Justice White wrote the decision that mandated that Standard Oil must divest itself of all its subsidiaries within six months. In 1974 assets of the descendants of John D. Rockefeller were estimated to have the largest family fortune in the world, estimated at $2 billion.[5]

During the 20th century, pioneers had reached the end of habitable frontier. The steam engine and telegraph provided the means by which companies could extend their influence across the globe. One can argue that the international nature of today's mega corporations elevates them to a status as great as the nations they claim to serve. One can further argue that a mega corporation can be a friend or an enemy to a society in the same sense that a neighboring country can be a friend or an enemy.

In 1942 Senator Harry S. Truman led an investigating committee on treasonous prewar relationships between General Motors, Ethyl Corporation, Standard Oil, and DuPont in collaboration with the German company I. G. Farben. Company memos document corporate agreements designed to preserve the corporations no matter which side won World War II. Corporate technology exchanges compromised the competitive edge held by the United States as it entering World War II, including leaded gasoline technology (critical for high-octane aircraft fuels) and noncompetitive stances on synthetic rubber technology. At the same time, British intelligence called Standard Oil a "hostile and dangerous element of the enemy."[6,7,8] Continuation of this behavior led to anticompetitive-related antitrust hearings on leaded gasoline technology against these American companies in 1952.

With technology and innovation taking a backseat to business interests, politics and energy technology became perpetually intertwined. The larger companies were formally pursuing their agendas, even when these agendas were in conflict with public interest and involved collaboration with the enemies of our nation's closest allies.

A corporation that profits by providing consumer products more efficiently and at a lower cost is significantly different than a corporation that makes profit by controlling the supply or price of a consumer commodity or product. The Rockefeller Oil monopoly demonstrated that the profits were greater for the business strategy that is in conflict with national benefit. In the end, the only punishment was the mandated divestment of the Rockefeller Oil subsidiaries. The Rockefeller family emerged as the wealthiest family in the world.

What was the real precedent set by the Standard Oil monopoly? Was it that monopolies will not be allowed, or was it that great fortunes can be made and kept even if you are caught? The consequences are that business practices and not technical merit tend to have more and more impact on which technologies become commercial and ultimately benefit the public. With the introduction of the corporate lobbyist, technical merit is debatably in at least third place in this hierarchy.

Innovation in a World of Corporate Giants

There is little doubt that obstructed commercialization of technology stifles technology innovation. Companies and individuals have little incentive to build a nuclear-powered automobile, since the government would not allow this vehicle to be used on the highways (for good reason). Restricted commercialization can be good by redirecting efforts away from projects that endanger society. Restricted commercialization can be bad when the motivation is to maintain a business monopoly and to stifle competition.

History has shown little evidence of the impact of unrestricted entrepreneurism because modern history has been dominated by business rather than technical innovation. The true potential of unrestricted entrepreneurism is rarely seen. World War II is the best example in recent history illustrating what happens when we focus on developing the best technology available and the machines to get a job done. Within a ten-year period, the following technologies were developed:

- Nuclear bomb
- Jet aircraft
- Radar
- Transistors
- Intercontinental rockets
- Guided missiles
- Synthetic oil produced from coal
- Mass production of aircraft and tanks
- Swept wing and flying wing aircraft
- Stealth submarine technology
- Plastics industry, including synthetic rubber, nylon, and synthetic fiber

Many of the commercial advances between 1946 and 2000 occurred because decisive technology was developed during World War II. Some 20th-century accomplishments that fall into this category are nuclear power, jet air travel, landing a man on the moon, guided missile technology, transistor-based electronics and communication, stealth aircraft, including the B1 bomber, and the modern plastics industry.

The technological developments of World War II illustrate what can be achieved when technology and commercialization become a national goal. If technology has inherent limits on the good it can provide; we are far from reaching these limits. We are limited by mankind's pursuit, by the willingness of environmental groups to allow new technologies to become part of our societal infrastructure, and by the willingness of corporations or governments to invest in development and commercialization.

At the beginning of the 21st century, politics and energy technology are hopelessly entangled. Nine out of the top ten of the Global 500 companies are in energy or energy technology (e.g., the automotive industry), and business savvy trumps innovation in these companies.

The United States rose to superpower status in the 1940s when the national focus was on developing and commercializing strategic technologies. History has shown powerful countries fall when the national focus switches from advancing technology to maintaining the steady flow of cash to corporations and well-connected individuals (maintaining corporate status quo). The czars of Russia or aristocrats of Rome are two of many examples where common people were driven to revolt against a system dominated by who you were rather than what you had contributed.

Germany's synthetic oil production from coal is one strategic technology that did not become commercial in the United States after World War II. This same technology is currently commercial in South Africa because there was a different philosophy toward investing in this infrastructure. Today in South Africa the industry is self-sustaining and the technology is being sold for use in other countries. These production facilities were designed and constructed by U.S. engineering firms.

Canada started developing its oil sand resources in the 1960s, even though the technology could not undercut the price of crude oil. Because of continued and dedicated development, the oil sand oil now costs $20 per barrel to produce as compared to crude oil at over $50 per barrel (year 2005) on the world market.

The Oil Economy

The 21st-century U.S. civilization as we know it would be impossible without crude oil. We get over 90% of all automotive, truck, train, and air transport fuels from crude oil, as well as the majority of our plastics. The plastics are used to make everything from trash bags and paints to children's toys. If it is a solid device that is not paper/wood, ceramic/glass, or metal, it is probably plastic.

Crude oil is a good fuel. Figure 2-1 illustrates how this natural product can be separated by boiling point range to provide gasoline, a middle fraction (kerosene, jet fuel, heating oil, and diesel fuel), and fuel oil (oil used for boilers or large diesel engines for ships and electrical power plants). The natural distribution of crude oil into these three product classifications varies with the source of the crude oil.

Modern refining processes convert the crude oil into these three product categories and also provide chemical feed stocks. The modern refining process breaks apart and rearranges molecules

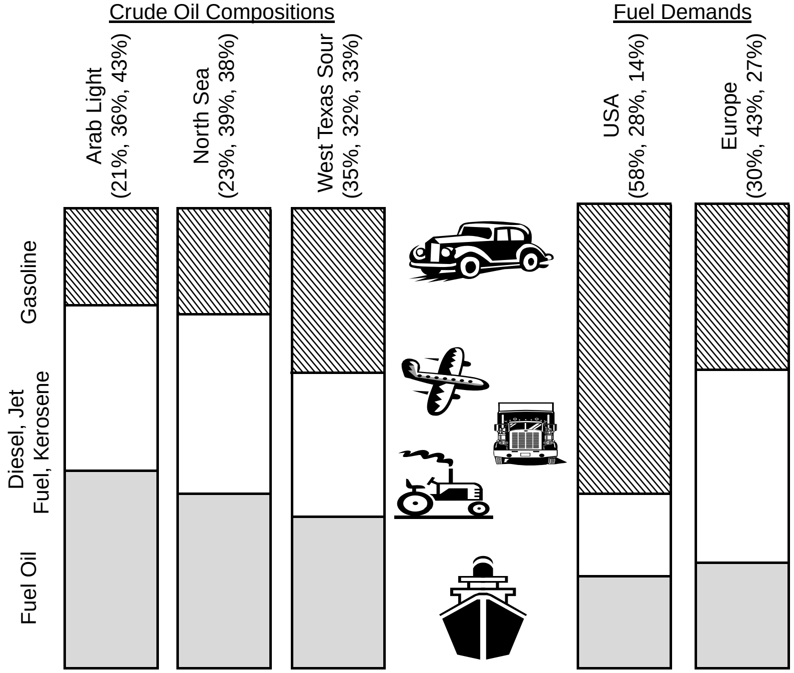

FIGURE 2-1. Typical composition of oil. (Keith Owen and Trevor Coley, *Automotive Fuels Reference Book*, 2nd ed. Warrendale, PA: Society of Automotive Engineers, 1995.)

to produce just the right amounts of gasoline, diesel, and fuel oil. In the United States, this typically means converting most of the "natural" fuel oil fraction and part of the middle fraction to increase the amount of gasoline.

Figure 2-2 is a detailed description of crude oil processing for the United States and shows import versus domestic production and other commercial applications. The figure also illustrates how complex crude oil processing is when it comes to providing commercial product demands.

Figures 2-3 and 2-4 show the extent of U.S. oil imports and how prices fluctuate. Since the year 2000, the United States has been spending over $100 billion per year to import crude oil (estimated at over $200 billon per year in 2005). Cheap oil in 1997 and 1998 brought a prosperous U.S. economy; more expensive oil in 2001 and 2002 added to the economic slump.

As illustrated in Figure 2-2, the United States imports well over half of the crude oil it processes. One can argue whether the world will have enough oil for the next 100 years or only the next 25 years. One thing is certain: The useful and significant domestic oil production in the United States would last less than ten years (about 7.6 years if there were no imports), and it will continue to decline. Over half the world's known oil reserves are in the Middle East. Figure 2-5[9] shows the breakdown, with Saudi Arabia, Iran, and Iraq with the greatest reserves.

Energy Sources

Petroleum provides more than 90% of vehicular fuels in the United States, but in addition petroleum represents 53% of all energy consumed in the United States, as shown in Figure 2-6. The energy stocks used in the United States are in sharp contrast to U.S. reserves (see Figure 2-7), and this will ultimately lead to energy crises.

If the world continues energy consumption at its present rate, it has approximately 3.6[i] years of petroleum (to supply all energy needs), 17 years of coal, 46 years of natural gas, and millions of years of uranium (assuming full use of uranium and ocean recovery).[10] If the United States were the sole consumer of world energy reserves, world petroleum would last 75 years toward meeting all the U.S. energy needs, coal 500 years, natural gas 1,000 years, and uranium tens of thousands of years.

[i] For world oil reserves of 5.3e18 Btu and world total energy consumption of 1.5e18 Btu/yr.

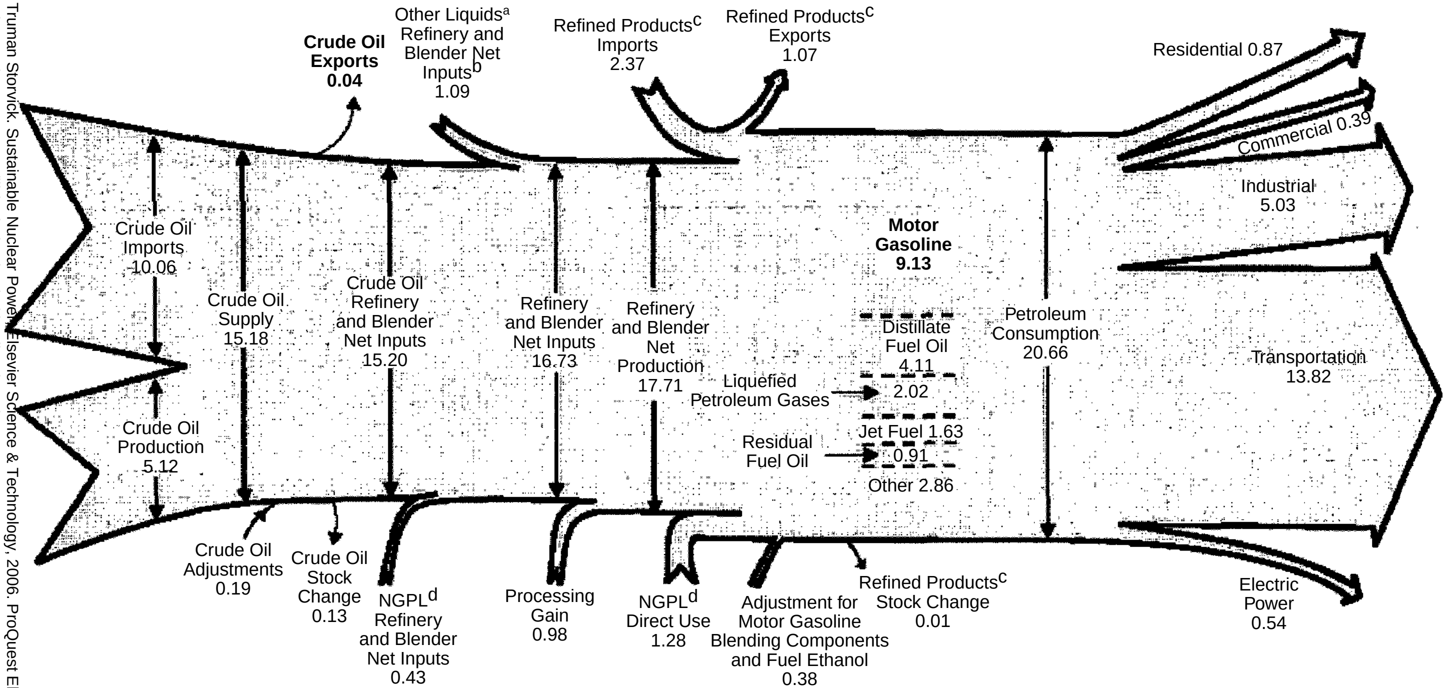

FIGURE 2-2. Year 2000 oil flow in quadrillion Btu. (U.S. DOE Public Domain Image. http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/default.htm, May 17, 2002.)

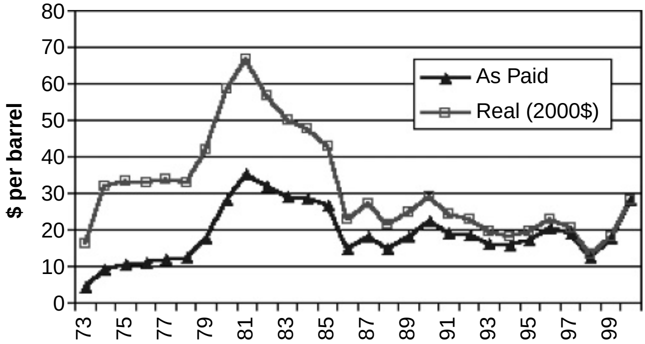

FIGURE 2-3. Recent U.S. oil prices. (U.S. DOE Public Domain Image. http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/default.htm, May 17, 2002.)

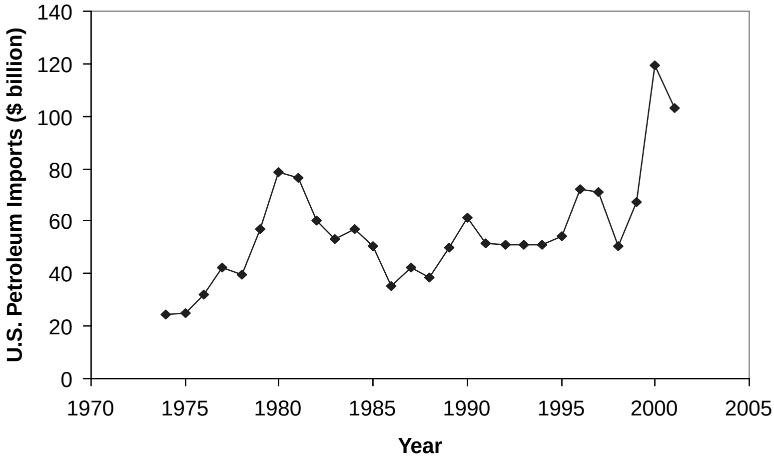

FIGURE 2-4. U.S. imports of petroleum. (http://www.eia.doe.gov/emeu/mer/txt/mer1-6, May 17, 2002.)

In the year 2000, the United States imported 53% of its petroleum to satisfy a consumption of 19.7 million barrels per day. If total U.S. demand for petroleum had to be met with known reserves in the United States, we would run out in about three years. The strategic petroleum reserve (most stored in salt caverns) would last a total of 31 days.[11]

It is where consumption exceeds availability that technology makes the difference. There is little doubt that the world's demand for petroleum is rapidly exceeding the availability of petroleum.

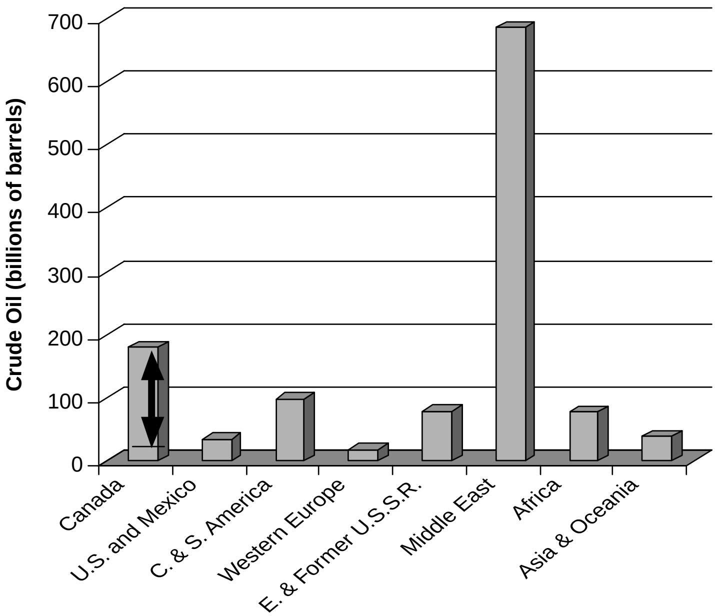

FIGURE 2-5. World oil reserves by region. Estimates of Canadian reserves by *Oil and Gas Journal* in 2003 are much higher than in previous years. Most likely they include easily recovered oil sands. (PennWell Corporation, *Oil and Gas Journal*, Vol. 100, No. 52 (December 23, 2002).)

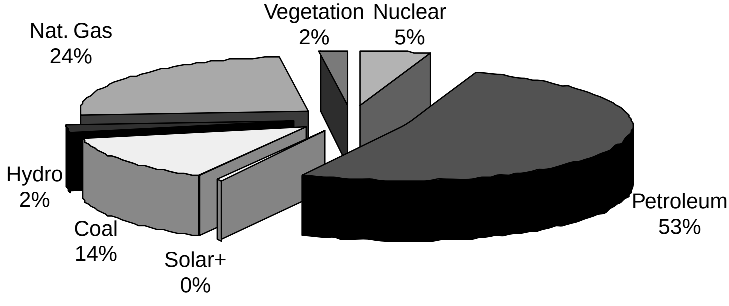

FIGURE 2-6. U.S. energy consumption by source.

The use of petroleum as currently practiced is not sustainable. From the position of available energy reserves (see Figure 2-7), coal and nuclear are the obvious choices to replace petroleum. The right combination of technologies can make the difference between security or vulnerability, between cheap energy or economic recession due to restricted oil supply.

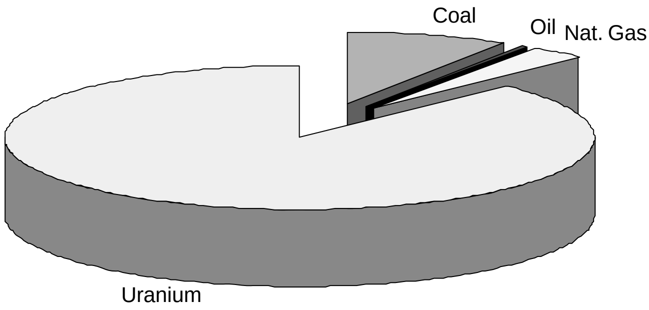

FIGURE 2-7. Estimate of U.S. energy reserves.

Environmental Impact

Environmentalism has a rich tradition of keeping industry under control. History bears witness to the devastation caused by deforestation. As early as 6000 B.C., the collapse of communities in southern Israel were attributed to deforestation.[12] In southern Iraq, deforestation, soil erosion, and salt buildup devastated agriculture by 2700 B.C.[13] The same people repeated their deforestation and unforgiving habits in 2100 B.C., a factor in the fall of Babylonia. Some of the first laws protecting timbering were written in 2700 B.C.[14]

Advances in citywide sanitation go back to at least 2500 B.C. and can be attributed to people uniting in an effort to improve their environment against the by-products of civilization. In 200 B.C. the Greek physician Galen observed the deleterious acid mists caused by copper smelting. Lead and mercury poisoning was observed among the miners of the A.D. 100 Roman Empire, and high levels of lead may have been a factor in its fall. The bones of aristocratic Romans reveal high levels of lead, likely from their lead plates, utensils, and, in some instances, food.[15]

Poor sanitation during the Dark Ages, including raw sewage and animal slaughter wastes littering the cities, contributed to both the Bubonic Plague and cholera. In these ancient cases, the factors that allowed civilization to attain its magnificence also presented new or recurring hazards. In this early history, the lives saved by the benefits of agriculture and metal tools far outweighed those lives lost or inconvenienced due to adverse environmental impacts.

The dark smoke of coal burning became evident as a significant problem in the 13th century. In 1306 King Edward I forbade coal burning in London.[16] Throughout history, the tally of deaths attributed to air pollution from heating and other energy-related technology accumulated. The better-documented of these cases are reported prior to government regulations that finally brought the problems under control.

On October 26 and 31, 1948, the deaths of 20 people along with 600 hospitalizations were attributed to the Donora, Pennsylvania, smog incident. A few of the other smog incidents in the next few years include 600 deaths in London from "killer fog" (1948); 22 dead and hundreds hospitalized in Poza Rica (Mexico) due to killer smog caused by gas fumes from an oil refinery (1950); 4,000 dead in London's worst killer fogs (December 4–8, 1952); 1,000 dead in a related incident in London in 1956; 170–260 dead from New York's smog (November 1953); and in October 1954 most of the industry and schools in Los Angeles were shut down due to heavy smog conditions (a smart, proactive measure made possible by the formation of the Los Angeles Air Pollution Control District in the 1940s, the first such bureau in the United States). In the 1952 London incident, the smoke was so thick that a guide had to walk ahead of buses, with all of London's transportation except subway traffic coming to a halt on December 8, 1952.

In 1955 the U.S. Congress passed the Air Pollution Research Act. California was the first state to impose automotive emission standards in 1959, including the use of piston blow-by recycle from the engine crankcase. The automakers united to fight the mandatory use of this modification that cost seven dollars per automobile. Subsequent federal legislation has been the dominant force on changes in U.S. energy infrastructure during the last 25 years.

The late 1960s has been characterized as an environmental awakening in the United States. Prior to 1968, newspapers rarely published stories related to environmental problems, while in 1970 these stories appeared almost daily.[17] Sweeping federal legislation was passed in 1970 with the Clean Air Act establishing pollution prevention regulations, the Environmental Policy Act (EPA) initiating requirements for federal agencies to report the environmental ramifications of their planned projects, and the establishment of the Environmental Protection Agency. The Clean Air Act was amended in 1990 specifically strengthening rules on SOx and NOx (sulfur and nitrogen oxides) emissions from electrical power plants to reduce acid rain. This legislation ultimately led to the closing of some high-sulfur coal mines.

Beginning with 1968 automobiles, the Clean Air Act (CAA) required the EPA to set exhaust emission limits. Ever since, the EPA has faced the task of coordinating federal regulation with the capabilities of technology and industry to produce cleaner-running vehicles. Since the precontrol era, before 1968, automotive emissions (gasoline engines) of carbon monoxide and hydrocarbons have been reduced 96%, while nitrous oxide (NOx) emissions have been reduced 76% (through 1995, the result of 1970 CAA).[18] The phasing out of lead additives from gasoline was a key requirement that made these reductions possible.

On February 22, 1972, the EPA announced that all gas stations were required to sell unleaded gasoline with standards following in 1973. Subsequent lawsuits—especially by Ethyl Corp., the manufacturer of lead additives for gasoline—ended with the federal court confirming that the EPA had authority to regulate leaded gasoline. Leaded automotive gasoline was banned in the United States in 1996. In 2000, the European Union banned leaded gasoline as a public health hazard.

The removal of lead from gasoline was initially motivated by the desire to equip automobiles with effective catalytic converters to reduce the carbon monoxide and unburned fuel in the exhaust. The lead in gasoline caused these converters to cease to function (one tank of leaded gas would wreck these converters). The influence of energy corporations was obvious when the U.S. Chamber of Commerce director warned of the potential collapse of entire industries from pollution regulation on May 18, 1971. This has been viewed as a classic example of *industrial exaggeration*.

Corporate influence was again seen in 1981 when Vice President George Bush's Task Force on Regulatory Relief proposed to relax or eliminate U.S. leaded gas phaseout despite mounting evidence of serious health problems.

Since the banning of lead in gasoline, scientific communities are essentially in unanimous agreement that the phasing out of lead in gasoline was the right decision. In addition to paving the way for cleaner automobiles, these regulations have ended a potentially greater environmental disaster. All the lead that went into automobiles did not simply disappear—it settled in the soils next to our highways. Toxic levels of lead in the ground along highways continue to poison children and contribute to mental retardation even today. (See the box "Lead (Pb) and Its Impact.")

In perspective, the air quality in our cities is good and generally improving. While the federal government monitors emissions and works to reform emission standards, the public and media tend to follow other issues more closely. Issues such as oil spills and global warming make the news.

Lead (Pb) and Its Impact, as Summarized by the EPA

Health and Environmental Effects: Exposure to Pb occurs mainly through inhalation of air and ingestion of Pb in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues. Lead can adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to Pb may cause neurological impairments, such as seizures, mental retardation, and behavioral disorders. Even at low doses, Pb exposure is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ. Recent studies also show that Pb may be a factor in high blood pressure and subsequent heart disease. Lead can also be deposited on the leaves of plants, presenting a hazard to grazing animals.

Trends in Pb Levels: Between 1988 and 1997, ambient Pb concentrations decreased 67 percent, and total Pb emissions decreased 44 percent. Since 1988, Pb emissions from highway vehicles have decreased 99 percent due to the phaseout of leaded gasoline. The large reduction in Pb emissions from transportation sources has changed the nature of the pollution problem in the United States. While there are still violations of the Pb air quality standard, they tend to occur near large industrial sources, such as lead smelters. Between 1996 and 1997, Pb concentrations and emissions remained unchanged.

Source: http://www.epa.gov/oar/aqtrnd97/brochure/pb.html.

The *Exxon Valdez* oil tanker spill (March 1989) is one of the most onerous oil spill incidents. This oil tanker ran aground in Price William Sound, Alaska, spilling 11 million gallons of petroleum. It is all the more infamous because of the costly remediation/penalties (over $1 billion in fines, with Exxon claiming $3.5 billion in total expenditures) that Exxon was required to perform as a result of this incident. Five billion dollars in punitive damages was also awarded against Exxon, but this remains to be collected after almost a decade.[20] In 1992 the supertanker *Braer* spilled 26 million gallons of crude oil in the Hebrides islands. Both of these incidents are dwarfed by the *Amoco Cadiz* wreck off the coast of France in 1978 with a spill of 68 million gallons.

In view of the *Amoco Cadiz* incident and the cumulative tens of thousands who died in London's killer fogs, it is easy to understand the increased environmental consciousness in Europe compared to that of the United States. For example, the European governments are aggressively addressing potential global warming issues, while the U.S. government tends to withdraw from international cooperation on the issue. Neither the United States nor European governments dispute the fact that carbon dioxide levels are increasing in the atmosphere. They do have varying opinions on the implications of these increasing carbon dioxide emissions.

On June 23, 1988, NASA scientists warned Congress about possible consequences from global warming with potential effects of drought, expansion of deserts, rising sea levels, and increasing storm severity. On December 11, 1997, the Kyoto Protocol was adopted by President Clinton (a Democrat) and 121 leaders of other nations. The Republican-dominated U.S. Congress refused to ratify the protocol. More recent comments by President Bush concerning the Kyoto Protocol sound like the comments and actions of the U.S. Chamber of Commerce director and former Vice President George H. W. Bush on the phaseout of lead from motor gasoline.

What the Future Holds

The complexity of U.S. politics that forced the breakup of Standard Oil in 1911 is now dwarfed by the manner in which energy and international politics are coupled. Operation Desert Storm and the Gulf War in 1991 put all doubt aside. The U.S. government is willing to protect oil supplies with direct military action.

Our transportation systems, fuel oil and propane heating, and plastic materials have unquestionably saved more lives than have been lost in the conflicts fought to keep oil flowing. However, if alternatives like nuclear power or biomass can maintain the benefits of cheap transit, heating fuels, and plastics, these alternatives should be pursued rather than entering into military conflict. Canada and South Africa have certainly demonstrated that crude oil can be cost effectively replaced with coal and oil sands.

Today's politics and government policies inhibit technology. They can also inhibit national prosperity. Understanding this requires learning about energy science, energy conversion technology, and economic/profitability analysis. It requires evaluating the facts and resisting the temptation to look for simple answers. Vested corporate and political interests are ready to capitalize on ignorance providing their public answers.

The summary of energy reserves in Chapter 3 shows that there is no energy shortage. Spikes in gasoline prices, electricity prices (California), and natural gas prices (throughout the United States) that occurred during the first two years of the 21st century cannot be justified based on a shortage of energy resources. Essentially all recent historical spikes in oil prices can be attributed to a lack of competition. It appears that in some cases the consumer was a victim of corporate strategies that created the appearance of shortages.

Two mechanisms produce shortages: government regulations that effectively prevent new capacity from coming on line (or define a fuel that limits potential suppliers) and a lack of diversity in energy feed stocks. Both mechanisms prevent the free market from establishing the price. In electrical power generation, increased use of natural gas presents the opportunity for gas suppliers to limit electrical power diversity, and this increases prices. For vehicular travel, an overdependence on petroleum fuels has already created national and consumer vulnerability.

A number of technologies are available to address today's greatest energy problems, but they challenge the current status quo of the energy industry. On electrical power generation, 100% nuclear fission (reprocessing of spent nuclear fuel) can address problems with both nuclear waste and electrical power diversity.

On petroleum, U.S. tax strategies actually give foreign producers a \$7–\$15 per barrel competitive advantage (see Chapter 8). The Canadian oil sand industry and U.S. synthetic petroleum (infant) industry are capable of meeting U.S. oil consumption needs at current prices (greater than \$25 per barrel). More importantly, if given an equitable tax strategy compared to imported crude oil, these industries could create new-source competition that would tend to stabilize fuel prices at levels lower than current prices fluctuating above \$30 per barrel.

Finally, an increasing overlap of electrical power and vehicular fuel energy networks would provide additional diversity to stabilize gasoline prices. The use of electrical power for automobile transportation has an important advantage over Fischer-Tropsch fuels and Canadian oil sands. Electrical power distribution bypasses the refinery and liquid fuel distribution infrastructure that is dominated by oil corporations.

The concept of market overlap is simple. When consumers have the ability to select between powering their vehicles with electrical power or gasoline, the price of gasoline will stabilize. If the fuel cell researchers deliver what they promise, rechargeable fuel cell systems could leapfrog rechargeable batteries for electric cars in commuting applications. Rechargeable fuel cells also have distinct advantages when used in hybrid cars. This topic is covered in greater detail in Chapter 9.

Environmentally Responsible Nuclear Power

The nuclear processes that occur in nuclear fission reactors were not invented by man. These processes have been occurring on the earth since its formation. What is new (within the past century) is our understanding of nuclear processes and the controlled use of nuclear fission to produce electrical power. There is nothing to be gained by avoiding the use of nuclear power, but there is much to be gained by the responsible use of nuclear fission to provide the energy.

When compared to the thousands who have died in the smog produced from coal or the thousands who have died in military conflicts designed to control the flow of petroleum, commercial nuclear power in the United States has proven to be the safest and most environmentally friendly energy source. The statistics shown in Table 2-1 reported by Hinrichs[19] further show that the environmental impact of nuclear power is a small fraction of the impact of coal power. The lessons of history are clear.

George Santayana once said, "Those who fail to learn the lessons of history are destined to repeat them." In energy technology, history's lessons are that more people will die from coal and petroleum utilization—from occupational accidents, military confrontations, and pollution generation—than from nuclear. The environment will also suffer more with coal and petroleum—from oil spills to the buildup of carbon dioxide in the atmosphere. Responsible nuclear power (as in historical U.S. commercial nuclear power) should continue to be safer and more friendly to the environment provided engineers and scientists continue to apply the lessons they have learned in regard to safely designing and operating nuclear power facilities.

TABLE 2-1
Impacts as summarized in 1986 of coal versus nuclear for a 1 GW power plant operating for one year.

	Coal	*Nuclear*
Occupation Health Deaths	0.5–5	0.1–1
Occupational Health Injuries	50	9
Total Public and Worker Fatalities	2–100	0.1–1
Air Emissions (tons)	380,000	6,200
Radioactive Emissions (Curies)	1	28,000

On the topic of nuclear waste, history shows that waste should not be buried (as was irresponsibly done with chemical waste in the early 20th century). Rather, processes should be designed to first minimize waste, and the waste that is generated should be treated to minimize its volume and contained to prevent diffusion into the environment.

References

1. B. P. Tissot, and D. H. Welte, *Petroleum Formation and Occurrence*. New York: Springer-Verlag, 1978, p. 5.
2. http://www.runet.edu/~wkovarik/envhist/2middle.html.
3. Ibid.
4. http://www.runet.edu/~wkovarik/envhist/4industrial.html.
5. Anthony Sampson, *The Seven Sisters*. New York: Bantam Books Inc., 1981, p. 27.
6. http://www.runet.edu/~wkovarik/envhist/7forties.html, May 20, 2002.
7. Stevenson, William, 1976, A Man Called Intrepid. New York: Harcourt Brace Jovanovich.
8. Borkin, Joseph, 1978. The Crime and Punishment of I. G. Farben. New York: Free Press Source for Fig. 2-4 http://www.eia.doe.gov/emeu/mer/, May 17, 2002.
9. Also see http://www.eia.doe.gov/emeu/international/reserves.xls.
10. Consumption at 7.1e16Btu/yr in U.S. and oil, coal, and gas reserves of 5.3e18, 2.5e19, and 6.9e19. World consumption of 1.46e17, 1.18e17, and 1.4e18 for total of 1.4e18 → use 1.5e18 for world. From http://www.eia.doe.gov/pub/international/iealf/table11.xls.
11. http://www.eia.doe.gov/neic/quickfacts/quickoil.html, May 17, 2002.
12. Grove, 1995.
13. Perlin, 1991.
14. http://www.radford.edu/~wkovarik/envhist/, May 19, 2002.
15. Noel De Nevers, *Air Pollution Control Engineering*. New York: McGraw Hill, 1995, p. 2.
16. http://www.runet.edu/~wkovarik/envhist/2middle.html.
17. *Changes in Gasoline III*, published by Technician's Manual, Downstream Alternatives, Inc. P.O. Box 190, Bremen, IN 46506-0190, 1996, p. 8.
18. http://www.runet.edu/~wkovarik/envhist/10eighties.html, May 20, 2002.
19. R. A. Hinrichs, and M. Kleinbach, *Energy—Its Use and the Environment*, 3rd ed. New York: Brooks/Cole, 2002, Table 14.6.
20. http://www.sitnews.us/1004news/100604/100604_knowles_exxon.html.