# CHAPTER III.
# ENERGY RESERVES AND RENEWABLE ENERGY SOURCES

In our industrial expansion, we can rapidly deplete available resources. This has occurred for petroleum on U.S. soil. Proven, recoverable oil reserves in the U.S. would only power our thirst for oil for 3 years if cut off from oil imports. Technology can meet the challenges of dwindling U.S. oil reserves, but only by switching to the abundance of other energy forms and reserves. This energy is available in three forms: fossilized solar energy, nuclear energy, and recent solar energy.

## A. Fossil Fuel Reserves

The "fossil" designation of certain fuels implies that the fuels' energy content originates from prehistoric vegetation or organisms. Fossil fuels are the most commonly used energy source to drive our machines. Unlike wind and sunlight which are dispersed in low concentration across the surface, commonly used fossil fuels tend to be concentrated at locations near earth's surface. Where these are easily accessible, we are able to collect them with great efficiency. Fossil fuels include such things as:

- Coal
- Petroleum
- Heavy Oil
- Tar Sands
- Oil Shale
- Methane Hydrates
- Natural Gas

In Wyoming, some coal seams are 40 feet thick and less than a hundred feet underground. In the Middle East, hundreds of barrels per day of crude can flow from a single well under its own pressure. Each source provides abundant energy.

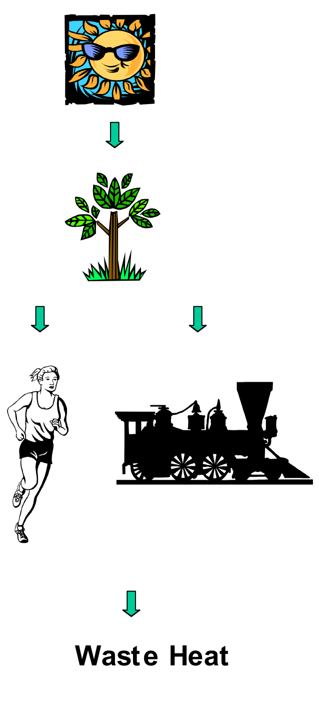
Coal[22], petroleum[23], and natural gas[24] are accessible fossil fuels and easy to use. By far, they are today's most popular fuels. Figure 1 summarizes the known accessible reserves of these fuels in the world and in the U.S. World recoverable reserves for coal, natural gas, and petroleum are 2.5E+19 (25 billion billion), 6.9E+19, and 5.3E+18 Btus[25]. For coal, the total estimated reserves are about a factor of ten higher than the estimate for recoverable reserves[26].

In the year 2000, the U.S. consumed 19.7 million barrels per day[27] or 3.8E+16 Btus per year. This consumption would deplete **known** U.S. petroleum reserves in about 3 years and **estimated** U.S. petroleum reserves in about 7.6 years.

# CHAPTER IV.
# HISTORY OF CONVERSION OF THERMAL ENERGY TO WORK

The story of energy conversion is the story of life. It is the story of people coming out of the caves to harness the environment. It is the story of conquest. And it is the story of the rise and fall of empires. The many forms of energy surround us every day including the energy that fuels life itself.

As illustrated by Figure 1, the human body and the steam engine are both parts of the marvelous conversion process that propagates life and drives machines. Starting with the nuclear fusion of hydrogen atoms in the sun, energy is transferred and converted, ultimately being dispersed to uselessness in the form of waste heat. The industrial revolution came of age when we began to understand how all these forms of energy are related.




Sun converts mass to energy through fusion.

Energy in transit, by radiation.

Photosynthesis converts radiation (energy in transit) to chemical energy in form of wood or fruit.

Energy is stored for various lengths of time, including transformation to coal or petroleum over hundreds of thousands of years.

PATH 1: The human body (all animals) converts chemical energy to muscle movement (force acting through a distance).

PATH 2: A locomotive burns wood to power a steam engine—the engine produces movement (force acting through a distance).

Radiation and molecular motion transfer waste heat to surroundings. In the end, and all through the process, essentially all of the energy is converted to waste heat that is of no value. The energy used by the muscles is ultimately expended overcoming frictional resistances as is the energy driving the locomotive.

**Figure 1.** On Earth, most energy comes from the sun and ultimately becomes heat.

# CHAPTER V.
# TRANSPORTATION

In the competition during the industrial revolution, steam turbines and internal combustion engines emerged as they provided the best combination of usefulness, engine cost, and fuel cost. Each met market demands. The less expensive engines tended to require more expensive fuels while the more expensive engines could use less costly fuels.

Burning solid trash to produce electricity is an example of an application with a high engine/system cost and a low fuel cost. A gasoline auto engine uses a relatively expensive fuel. The automobile engines may seem expensive, but to build to a coal-fired power plant for an automobile with the same horsepower makes the gasoline engine look like a real bargain.

There are novel transportation power systems like the nuclear power plants in navy ships and submarines. Civilian transportation power is dominated by petroleum derived fuels: gasoline engines, diesel engines, jet engines, and electric-powered trains/streetcars. Petroleum is the only source for transportation fuels.

## A. Transportation Before Petroleum Fuels

We entered the 19$^{th}$ century on horseback, in wagons, and on sailing ships. We traveled through the 19$^{th}$ century with horses and oxen and began to use steam engines. We emerged from the 19$^{th}$ century trying to use steam engines, batteries, and the new gasoline engine technology to drive the developing horseless carriage. This was the beginning of building the infrastructure that would be necessary to supply fuel for the internal combustion engines that power transportation vehicles.

As cities approached populations in the millions, the use of horses as the sole source of transit was not an option. Feeding and caring for millions of horses plus disposal of manure and animal carcasses occupied much of the population. The gruesome toll taken by the steep hills of San Francisco on the horses that pulled streetcars motivated Andrew Hallidie to develop the San Francisco cable car in 1873 (see insert).[89] In New York City, street congestion led to groundbreaking for the New York subway at Borough Hall in Manhattan, in March, 1900.

Streetcars and subways met the challenge of city transit and were used in metropolitan U.S. In many cities effective public transit ended suddenly when auto makers and oil companies purchased public transit systems and shut them down and replaced them with buses.[90] Through the 20$^{th}$ century the automobile achieved domination of the transit industry with increasing infrastructure (highways and fueling stations) and a regulatory base that now makes any significant change difficult.

# CHAPTER VI.
# PRODUCTION OF ELECTRICITY

## A. History of Production

**Discovery of Electricity and Electrical Theory -** Electricity is the highest form of energy available. It can be used to produce heat, light, turn motors, power a radio, television, computer—the tasks it serves seem endless. It is impossible to imagine our modern society or a modern home without electricity. Essentially every business, factory or home in the U. S. is connected to an electric utility just like water and sewerage. Producing all electrical power needs on-site is only a last resort at remote locations. While municipal water supply and sewage systems date to ancient Rome, distribution of electricity occurred in the century. Indexes that determine the standard of living in a nation show a high average use of electricity per citizen is a measure of a high standard of living. Electricity use and modern life style are closely coupled.

The written history of electricity probably starts with the description of an experiment recorded by the Greek philosopher Thales (640-546 BC). He wrote that when amber (a fossilized resin then used to make jewelry) is rubbed with fur it is able to attract light objects (a piece of feather or pith) placed close to it. Many substances can be charged in this way: Rub a glass rod with silk, or a hard rubber rod with fur and the surface of the rods become highly charged. We now call this a *charge of electricity* and the attraction is an electric or *electrostatic attraction*. The Greek word for amber is elektron and thus, the source of our word electricity and later the electron.

The curious early observers noticed a difference in the charge produced by amber and by hard rubber. They used pith balls suspended from a string. As you moved the pith balls together, they would touch and separate from each other as they were moved apart. . When the pith balls were each touched with charged amber and then moved toward each other, they would push apart or repel each other. This was also true when both pith balls were touched with charged rubber. When one pith ball was touched with charged amber and the other with charged rubber, as they were brought together, they were suddenly pulled together by an attractive force.

Each of us has run a static electricity experiment. When you walk across a carpet and touch a light switch or water facet, there is snap. You can see the spark if the room is dark. This works best during the winter when the air is dry. It works with leather or rubber soled shoes but really works when you're barefoot. The explanation of these crude observations did not come until the 19$^{th}$ century.

# CHAPTER VII.
# ENERGY IN HEATING, VENTILATION, AND AIR CONDITIONING

## A. The Heating, Ventilation and Air Conditioning Industry

The energy used by American consumers for heating, ventilation, and air conditioning (HVAC) is second only to the energy used for transportation. HVAC applications consume about the same amount of energy per year as the 130 billion gallons of gasoline consumed annually in the U.S. (see Table 1). From a greenhouse gas emission perspective, about 8.8% of carbon dioxide emissions are from space heating furnaces as compared to 33.9% from electrical power production. A large fraction of the electrical power is used for HVAC.

**Table 1.** Summary of largest energy applications of energy.

| | **Energy in Quadrillion BTU** |
|---|---|
| Amount of Gasoline Consumed[15] | 15 |
| Electricity Produced[16] | 12 |
| Approximate Energy Expended on Producing Electricity[17] | 34 |
| Energy Consumed for HVAC (including hot water heaters)[18] | 14 |

Consumers use electricity, fuel oil, liquid petroleum gas, kerosene, and natural gas for heating. Table 2 shows that natural gas and fuel oil provide most of the space heating needs.

The competition created by alternative technologies and fuel choices provide relatively stable heating/cooling costs, just as with electrical power production. In the HVAC industry, energy savings result from improved building construction with better insulation and double or triple pane windows. The consumer can chose between investing in energy efficient buildings with lower yearly energy costs or buying less expensive HVAC equipment with higher annual energy expenses. Diversity in energy sources and competition among equipment manufacturers has made the HVAC

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[15] 130 billion gallons times 115,000 Btu per gallon.
[16] 11.6 rounded up.
[17] Assuming average efficiency of 35%
[18] Residential [5.2 + .55/0.35 1.29 +. 0.16+0.08 + 0.39/0.35] + Commercial [1.7 + .35/0.35 + 0.16/0.35 0.81/.5]

# CHAPTER VIII.
# CORPORATE PROFITABILITY VERSUS NATIONAL BENEFIT

Many of today's problems could be solved through the successful commercialization of known technologies. Unfortunately, the availability of technology-ready alternatives is but one piece of a complicated puzzle that must be in place for commercialization to occur in capitalistic societies. Federal and state policies often determine whether new technology can compete with foreign and domestic alternatives. These policies and new technologies impact the projected profitability, investment risks, and ultimate benefits.

Today's global economy is considerably more complex than at the start of the 20th century. Then, there were hundreds of independent shops putting together their own version of the automobile, and an entrepreneur had a realistic chance to enter that market. Today, the energy industries are dominated by giants and successful startup companies in the industry are rare. If anything, strategic investments in energy technologies has an even greater impact on national prosperity today than a century ago, and such investments are occurring less frequently.

How do we empower technology to realize its full potential to do good?

In the 20th century, capitalism prospered to the extent that Soviet-style communist governments collapsed. Trends toward socialism halted and substantially reversed. This change in the world's political environment brings with it changes in how technology is used and given the momentum needed to become commercial.

World conflicts are not longer driving technology as they did in the 20th century. The cold war and space race are no longer driving technology. First world governments are burdened with the increasing costs of health care, pensions, and welfare while faced with the baby-boom aftermath of increasing retirement and fewer people in the 18-65 year workforce. In this environment, it is too easy for the government to spend money on services and pensions rather than to invest that money into national infrastructure. It is all to easy to leave even nationally-strategic investments in the hands of corporations.

For the most part, today's investments are made by corporations and individuals. Governments only indirectly influence decisions. These investments are based on corporate profit within the bounds of government regulations, taxes, and other social costs. For technology to reach its full potential to do good, it must attract the needed investments in this environment.

# CHAPTER IX.
# Emerging Fuel Technologies and Factors Driving Technology

## A. Politics of Change in the Energy Industry

Energy conversion and utilization is a multi-trillion dollar business and vital to today's society. The magnitude of these industries present both mega opportunities and extraordinary challenges. While these industries were once predominantly driven by technology, today, politics dominates essentially every aspect. One of today's greatest challenges is to advance an industry in which technology has been displaced from the role of driving the industry to the passive role of potentially empowering the political machine that drives the industry. By definition, technology is well-defined and can be continuously improved, thus building vast infrastructures and continuously improved alternatives. On the other hand, politics is better characterized as existing in various states of chaos that make it less susceptible to the process of continuous improvement.

The politics of energy include contributions from both corporations and environmental groups. Mega corporations seek to maintain the status-quo, because these corporations control billions of dollars of revenue per year. Why ruin a good thing? Environmental groups including the U.S. Environmental Protection Agency tend to be single issue and focus on their perception of environmental impacts. Typically, true balances of benefit and risk are considerably more complicated than the portrayals of environmental groups. A quadrangle of overlapping interests and conflicts is formed by industry, environmentalists, politics, and public welfare.

**Technology Emerging to What End? -** Several fundamental issues related to defining and discussing emerging energy technologies, including:

- When the goal of proposed improvements is defined, the challenge can be substantial,
- When the goal of proposed improvements is not defined, the challenge borders on the futile,
- Just as with the chicken and the egg, that which comes first (the fuel versus the engine) in driving change in energy technology is uncertain and filled with obstacles, and
- While new technologies may be on the sidelines ready to meet the goals, the momentum of the industry is formidable and will likely dominate.

In view of these types of obstacles in the energy industry, the task of identifying the potential of an emerging technology is very difficult. Proposed objectives to be met by new technology should have a reasonable

# CHAPTER X.
# BY HAPPENSTANCE OR DESIGN

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. Machines powered by petroleum and electricity have essentially replaced work once done by people and animals. Both the quality and duration of life have improved.

How did this happen? What social and economic forces encouraged the development of energy technology to bring about these changes? Is there a way to enlist these forces for change to bring about an improved energy infrastructure as we enter the 21$^{st}$ century?

We reviewed the fuel resources available for transportation and electric power production. The supply and cost of electricity in the U. S. has remained fairly stable over time. The diversified source of energy to produce electricity (fossil fuels, nuclear, hydro, etc.) is responsible for this price stability even as restrictions on emissions have been applied. The future will require technological advances to make electric power production ever more "environmentally friendly." It will take improved old or completely new technology to meet the demand for more electric power and satisfy the projected new environmental restrictions.

Petroleum is essentially the only source of energy for transportation. Domestic production of petroleum in the U. S. has peaked and each year we are more dependent on imported oil. Imported oil represents a national economic balance of payments burden. Most of the overseas oil comes from regions that are politically unstable and strategic deployment of military forces are assigned by the U. S. to those regions. The U. S. economy and our national security are tied to this global energy economy and politics.

Transportation and electric power are two critical sectors of the U. S. economy and standard of living. It is reasonable to consider ways to assure the future supply of fuel for transportation. There will be increasing social pressure to reduce pollution and greenhouse gases that come from vehicles and electric power plants.

The advances in technology that are achieved at any time are limited by the construction materials (steel, plastics, ceramics, etc…), the infrastructure, and the skills people bring to the task. These resources limit the advances that are made in the short term. An interesting question is why technology advance at a snail's pace for years, and then suddenly takes off with the commercialization of many new devices that improve the use of available resources.

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