THE ESSENTIALS OF ESSENTIAL ENERGY CONSUMPTION

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CONTEXT

Most energy professionals must focus on a specific activity. For example, you the attendees at this Southwestern Petroleum Short Course focus on petroleum production in this region of Texas. Energy professionals also have a both personal and professional responsibility to objectively share information regarding the broad aspects of energy utilization — "The Essentials of Essential Energy Utilization" the title of this paper. This information should be provided our legislative representatives, although many local representatives have a realistic understanding regarding energy matters. A more difficult task is to provide factual energy related information to misinformed persons. A combination of wishful thinking, and false information makes these persons very difficult to approach regarding energy matters. A major purpose of this paper is to provide you a context in which energy matters may be discussed.

ENERGY AND CIVILIZATION

HISTORIC CONTEXT

"Energy and Society" is the title of a rather old book, 1955, which describes how energy availability greatly facilitated the rise of civilization. Interestingly, the author, Fred Cottrell, was not an energy professional, but a Professor of Government and Sociology at Miami University, Oxford, Ohio. He sensed the true significance abundant energy for society as a whole, and then he wrote skillfully about his observation almost fifty years ago. This landmark book supplied some of the ideas contained in this portion of my paper. Many of the specific dates prior to 1900 are from a five-volume history of technology publication.

Some of the major turning points of civilization and energy utilization are itemized below:

- Large sailing ships
- Replacement of wood with coal as a fuel
- Watt's steam engine
- Commercial petroleum production
- Electric power generation and distribution
- Small internal combustion engines
- Petrochemicals

Large sailing ships Sails were used on ships from the beginning of human culture, and were of great importance in ancient civilizations of Egypt, Greece, and Rome, even having a Biblical citations. Sailing ship technology improved consistently both on the Atlantic and the Mediterranean, but for many European nations the armies and internal wars consumed the goods brought to them by sailing ships. England being an island was different as clearly stated by Fred Cottrell in his book "Energy and Society":

> "What we want to point out is that as the exploitation of the ship reached its limits in terms of the existing internal economy of England, those who favored change were able to change the economy so make possible further exploitation. More and more English-men were thus enabled to multiply their own power a hundredfold up on the sea, while the great mass of other men continued within the same limits that had characterized Egypt under the Pharaohs."

Low cost transportation via wind-powered ships completely changed the world of commerce in the 17th? century with its center in England. A current parallel can be drawn to globalization in the 21st century, again facilitated by changing business practices, economical transportation, and now instant electronic communications.

Replacement of wood with coal as a fuel Increased production of iron, other metals, glass and ceramics resulted in a vastly increase in the utilization of wood for fuel, and so resulted the consumption of many forests. Developing the technologies to use coal solved this problem, and so saved the remaining forests. A particular date for this development was 1709 when in England, A. Darby first converted coal to coke so it could be utilized in his blast furnace for cast iron production. Wood ashes were still need as an alkali in many processes. For this reason, the invention and application in 1787 of the Leblanc process for production of caustic (lye, sodium hydroxide) from sulphuric acid, sodium chloride and carbon was a necessary step to eliminate dependence on wood and other biomass materials for alkaline industrial materials.

Watt's steam engine Wind and water have been employed as sources of stationary sources of mechanical energy from the beginnings of civilization. These technologies were continually improved, but still they were very constrained by location and intermittent availability. Watt's steam engine, patented in 1769, removed these constraints. Now mechanized manufacturing facilities could be built at "any location" with "any capacity" a great impetus to the industrial revolution. Steam power displaced the sailing ship, providing greater flexibility and speed. This advancement started commercially with Fulton's boat the Clermont running on the Hudson river between Albany and New York in 1807. Subsequently land transportation was revolutionized by steam-powered railroads replacing cannels and horse drawn vehicles. A specific date is the Liverpool – Manchester Railroad carrying both passengers and freight, 1830. Steam power was far less successful for what we now call automobiles and trucks, but another 19th century invention became very successful in that application, the internal combustion engines.

Commercial petroleum production It is frequently considered that modern commercial petroleum began in E. I. Drake's well in Pennsylvania, August 27, 1859, although there were some earlier examples. Petroleum provided a convenient liquid fuel, kerosene, for lamps which was far less costly than whale oil. Petroleum availability and the development of the IC engine, discussed later in this section, resulted in very rapid commercial development of both technologies in the early 1900's. The oil "boom" that is most remembered for its relative size is Spindletop, near Beaumont Texas, January 10, 1901. A date of local interest is 1921, the first commercial well in the Permian Basin, the T.P. Abrahn Number 1 near Westbrook, in Mitchell County.

Electric power generation and distribution Another major transition in society and civilization began with the invention of a practical electric light bulb by Thomas Edison. A date to remember is the October 21, 1879 demonstration of light bulbs and their manufacturing process for the press at his research facility in Menlo Park. Another important date is September 4, 1882, when electricity was first distributed by underground wiring to customers in the financial district of New York. From this point on use of electricity in homes grew at an exponential rate, until essentially all homes in the US above the poverty level have access to utility-provided electric power. Another milestone in the generation of electric power is the first commercial nuclear power plant in 1957 located at Shippingport, Pennsylvania. Uses for electric power expanded rapidly with the invention of motors beginning 1873. The AC induction motor invented by Nicola Tesla in 1888 was a major turning point in the utilization of electric motors. Electric motors made manufacturing facilities more flexible, and eventually became a part of everyday life, now even electric pencil sharpeners. Electric motors made practical urban rail transportation which revolutionized the structure of our cities and suburbs, by allowing many workers to live a considerable distance from their jobs. A major milestone was the construction of the City and South London Railway, 1887-1890.

Internal combustion engines An additional invention was required to supply mechanical energy in a convenient portable form. This invention was the internal combustion, IC, engine, both spark ignited and compression ignited (diesel). The four-stroke cycle was crucial for the practical IC engines and this "Otto" cycle was made commercial by N. A. Otto in 1878. Otto engines soon came to dominate IC engine production. The diesel engine was invented in 1892. Initially these two engines were very low speed heavy engines. In 1889 Daimler patented and then marketed a high-speed 2-cylinder "gasoline" engine, which permitted the development of practical and convenient automobiles and trucks. Mass production of economical cars began with Ford's Model T on October 1, 1908 and his moving assembly line soon became essential to it economic production.

Another outcome of IC engine availability was their application in agriculture: Steam engines were already used in threshing grain, to a very limited extent as tractors, but they and not significantly displaced draft animals. The IC engine powered tractor transformed agriculture by the ultimate elimination of draft animals in commercial agriculture. The first successful tractor was the Hart-Parr tractor in 1900-02. They even coined the term "tractor" for their machine. Availability of practical tractors had two major results. First, more land became available for growth of marketable crops, since the land was not needed to main draft animals. Second, the labor requirements for farms were vastly decreased, to where now less than 1% of our population is needed to produce an excess of crops. Small IC engines have also made possible forklift trucks, front-end loaders, etc. that have all but eliminated the manual labor of digging, lifting, and carrying, so decreasing the numbers of persons needed for transportation and construction activities.

Petrochemicals Petrochemicals are made from “petroenergy”, petroleum and natural gas, and so they are a part of this paper, “The Essentials of Essential Energy Production”. Petrochemicals supply now lubricants, paints, solvents, detergents, etc. that formerly were supplied by agriculture, in addition to plastics, which were scarcely used prior to petrochemicals. Commercial synthetic organic chemistry began with “coal tar” derivatives and with rather high valued materials dyes. A pioneer in this field was William Perkin who as a teenager produced the dye now known as Mauve from coal tar derivatives (Coal tar came from pyrolysis of coal to produce metallurgical coke) More mundane uses for coal tar products included solvents, wood preservatives, etc. The first petrochemical, isopropyl alcohol, dates from 1919. The almost instantaneous growth of petrochemicals occurred just prior to and during World War II — synthetic rubber, high-octane aviation fuels, plastics and ammonia. We now have industry supplies much of our needs for various organic materials, but which has not significantly displaced the bulk the bulk construction materials — wood, concrete and steel. I have provided more details about the relationship of petrochemicals and agricultural materials in another paper.

ENERGY USAGE TODAY

“The Third Wave” was a book that made waves in the early ‘80’s, leaving an erroneous picture in the minds of many people. Toffler’s analogy for changes in society was waves overtaking and obliterating each other in a series of world changing events:

- First primary industries – Agriculture and mining
- Next secondary industries – Manufacturing
- Finally tertiary industries – Service industries.
- (And now after Toffler’s Third Wave — the information age and the Internet.)

It is far better to view these changes in society as new structures built on the old but still essential foundations developed in the past, as illustrated in Figure 1. In this more realistic context, rather large amounts of energy must be still be expended to maintain these essential foundations, and to produce the goods that they provide – food, housing, transportation. These foundations also support health services, education, complex government, etc. These energy demands are essential, in keeping with the title of this document, “The Essentials of Essential Energy Usage.” Planet wide energy consumption will be increased as less developed countries develop their infrastructure for mechanized agriculture and manufacturing, and their standards of living continue to increase. Two factors contribute to even further demands for energy. First, the recovery of mineral resources and fossil energy from less concentrated and convenient resources. Low concentration ores demand considerable more energy and effort to process them than conventional rich ores. Second, environmental concerns demand that former waste streams from manufacturing operations now be essentially pollutant free, down to parts per trillion. Reducing contaminants **to** very low levels is similar to processing low concentration ores, it takes a lot of energy and effort.

ENERGY – ITS VALUE AS FUNCTION OF TEMPERATURE

Energy is neither created **or** destroyed. It is just degraded in value or it enters or leaves a system, in our case the planet Earth. High temperature energy sources are valued since they can operate heat engines that provide mechanical power for the production of the most convenient form of energy, electricity. Energy at just above ambient temperatures has a negative value, a demonstrated by the investment in cooling towers to dissipate this low valued energy to the atmosphere. Energy available at temperatures below the ambient has to be generated by a considerable expenditure of energy for specialized purposes in addition to air conditioning and refrigeration. These concepts regarding the value of energy at various temperature are illustrated in Figure 2. The data for energy values are taken from a chemical process design manual, with the exception of the lowest temperature for liquid nitrogen as supplied to small users, a vendor quote. ($1.00/GJ = **$1.05/million** BTU) The thermodynamics of the value for energy may also be summarized in terms of the Carnot cycle efficiency for heat engines, which is superimposed on Figure 2.

$$CarnotEfficiency = \frac{Temperature_{,,,.} - Temperature_{,.,,,,}}{Temperature_{,,,.}} \qquad (1)$$

The cold temperature in the above equation is the temperature of the immediate surroundings, for this example assumed to be 25 C (77 F), but it is entered in the above equation as an absolute value, 298 K. (For temperatures below ambient the "hot" temperature is 25C.) This graph of Carnot efficiency further illustrates the fact that energy that is available at near ambient temperatures has very little value. The value of energy from flat-plate solar collectors is very limited by the relatively low temperatures at which it is available. Energy made available at low temperatures is costly because of the quantity of high-temperature energy required for its production. Energy availability at high temperature is valued because it can be used to operate heat engines, as well as to energize chemical processes. The value of energy contained in chemical fuels is high because it can provide energy at very high temperatures required for existing heat engines including engines in our own individual vehicles. Entropy represents another quantitative measure of the value of energy, which could also have been used as a theme in this section.

ENERGY – CONVENIENT FORMS

Convenience of usage is more qualitative characteristic of energy than its available temperature, but is equally important. Convenience in using various forms of energy is a function of application as indicted in the table below:

Energy used for —	**Source of energy —**
Transportation fuels	Liquid fuels – gasoline, diesel, jet fuel
Residential and light industrial uses	Natural gas, electricity
Electricity generation and heavy industrial uses	Least costly source to utilize – coal, nuclear, etc

Liquid fuels are the much preferred for transportation purposes, although the technology exists for compressed natural gas fueled vehicles. Liquid fuels are convenient to carry on-vehicle, safe, and easy to transport and store. Liquid fuels based on petroleum are economical and can be formulated to meet environmental standards. Contemporary life-styles depend heavily on transportation of both goods and people, and so the continued availability of economical liquid transportation fuels is central to our present society, and a major feature of this paper, "The Essentials of Essential Energy Consumption,"

For stationary applications in urban areas natural gas is the preferred source of energy. In urban areas, natural gas is economically and safely distributed to small users, where it can then be utilized for domestic heating purposes. In rural areas, liquefied petroleum gas, propane, offers similar user convenience, except that it must be delivered by truck. Natural gas is also the preferred energy source for many commercial and light industrial applications. Electricity offers the same convenience as natural gas to consumers. and it is more flexible providing lights, air conditioning, etc. Electricity is generally more costly than natural gas, and it utilizes only about 1/3 of the energy contained in the fuel used to generate the electricity.

For large-scale generation of electric power the cost is the prime consideration, both the direct cost of the fuel, and the investment required to utilize the fuel for electricity production in an environmentally acceptable manner. Traditionally the primary source for power for electricity production has been coal and lignite. The large-scale infrastructure exists for mining, and transportation of coal, and its subsequent conversion to electricity. Nuclear power is the other major source of energy for electric power production. Hydroelectric power is of limited availability, and many renewable sources of energy are not generally economic in the open market.

ENERGY RESOURCES

Liquid fuels are the central to our society, and so their continued availability at a reasonable price is a major concern. Petroleum is the economic source of liquid fuels, so the continued availability of petroleum is the focus of much concern. Economic transportation of petroleum via large tankers and pipelines results in petroleum production, transportation and marketing being a global activity into which local energy production activities must fit by default. The focus of the debate is "how much petroleum is left on the planet Earth?" This particular question is simply stated, but it is impossible to answer with one number, X.xx billion barrels. A recent book, "Hubbert's Peak: The Impending World Oil Shortage", repeats an earlier assertion that global petroleum production will peak in 2004 to 2008, not that far into the future. I have developed an alternative analysis regarding petroleum availability, "2005 – Peak in Petroleum Production or Pinching Hubbert's Pimple." The central feature of my paper is that petroleum availability is really a function of price. and to date all petroleum has been produced at a constant, deflated price. The maximum "final" price for petroleum will be the price of petroleum-equivalent alternatives for synthetic liquid fuels. Petroleum will continue to be produced at this capped price for many years as technology continues to improve. My analysis places the peak in global petroleum production at 2040 or beyond.

The concept that the current price for a particular commodity is a predictor for future availability has been developed by Julian Simon, and demonstrated for copper. If investors and speculators truly expected petroleum shortages in the next few years they would purchase reserves now. This is not happening, as per the following quotation from Deffeyes's current book:

> "**A** company taking the 2004-8 hypothesis (for a peak in global petroleum production) seriously would be willing to pay top dollar for existing oil fields. There does not seem to be an orgy of reserve acquisitions in progress."

In addition, Deffeyes's book says we are not prepared *to* utilize alternative sources *of energy* for liquid fuel production. My recent publication has documented several alternatives to petroleum for liquid transportation fuels. Two of these are ready for commercial production, when there is a real increase petroleum prices — liquids fuels from natural gas, and coal gasification.

Energy sources for electricity production, coal and nuclear, are very abundant but their increased usage constrained by environmental activists. Many of these activists are poorly informed regarding the necessity for our society to consume rather large amounts of energy, the theme and title of this paper, "The Essential Nature of Essential Energy Usage." **As** a result natural gas has become the favored fuel for new electrical generating facilities, in spite of its more valued use in residential and light commercial applications. Development of modular high-efficiency gas turbines has also favored short-term usage of natural gas for "boiler fuel".

ENERGY CONSERVATION

Most directly energy conservation is an economic decision. Does the present value of energy conserved in the future justify the incremental investment necessary today for its conservation? These choices regarding energy conservation are among the decisions that engineers and managers make everyday, without need for special national conservation policies. These energy conservation decisions are also made every day by consumers as they choose the price they pay for special energy conserving appliances, and as they consider gas mileage when they purchase new vehicles, ranging from SUV's to bicycles. Simon suggests that consumer energy Conservation and recycling is a personal value and/or choice, and so it should not be coherced by regulations.

ENERGY POLICY

A major consideration regarding energy policy is in the perversive need for increased energy usage, both in developed countries and particularly in developing countries as their population and standard of living increase. **A** theme of this paper has been to document this essential energy usage. Energy policy should the focus on assuring that energy is available in convenient, economic, and environmentally forms for all of society. Our present infrastructure for providing energy both to industry and consumers has succeeded effectively in this task for many years, and it is now evolving to utilize alternatives to petroleum when eventually necessary. Special interest groups have attempted to take advantage of perceived energy shortages and environmental risks to further both their financial interests, including salaries, and to express their personal perceptions, which are frequently not based on facts. Consensus should be reached among energy professionals regarding alterations to our energy policies, and then they should inform the public including legislators regarding these energy matters. This activity is not unlike physicians having major national inputs regarding medical matters.

CONCLUSIONS

For 300 years fossil energy has fueled the industrial revolution. The industrial revolution has in turn greatly diminished labor requirements in both industry and agriculture, providing the opportunity for our technological society to flourish, based on new inventions and democratic forms of government. The inherent need for significant levels of energy utilization continues into the 21st century and beyond.

Technologies are available to transition from currently abundant petroleum to alternative energy sources for both liquid transportation fuels and for electric power generation in the long-term.

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