PETROLEUM—ITS FUTURE AMONG ALTERNATIVE ENERGY SOURCES

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"ONCE UPON A TIME"

Once upon a time there was a land where petroleum and natural gas were abundant. In this land, petroleum and natural gas were both the most convenient fuels and at the same time the least expensive fuels. The people were reasonably happy and the economy prospered because of the abundance of economical fuel and other reasons. The fuel demand grew and grew for this prosperous economy, until the reserves of domestic petroleum and natural gas were inadequate to supply the needs of the economy. For a while, oil was imported without great financial or political difficulty, and few people worried about the future. Then imported oil was denied the people temporarily, its price increased rapidly, and many people became very concerned.

The people liked having economic and abundant fuels because some aspects of their lifestyle depended upon it. So the people decided to find an alternative energy source to replace oil and gas which would also be convenient, economic and abundant. In their enthusiasm the people also added another criterion for their desired alternative source of energy—it should not harm the environment, even a little bit. The leaders of the people, being politicians, told the people what they wanted to hear, that alternative energy sources were all around them in the wind, the sun, the plants, and the sea. They also implied that these sources of energy could become very economical if great faith were shown in "scientific breakthrough" and "economies of mass production."

The politicians were assisted in telling the people what the people wanted to hear by technologists, who said that with their particular skill the era of abundant, cheap, and non-polluting alternative energy will come. Then the technologists' laboratories and budgets grew rapidly. More technologists were hired, and more were trained. Even technologists who had never considered energy as a part of their responsibilities adapted their skills to alternative energy techniques so their budgets and laboratories grew also.

With tremendous faith and enthusiasm for the coming era of cheap and abundant alternative energy sources, the people increased questioning the desirability of their existing energy sources. At the very least, they did not want the source of energy near them, although they delighted in using the energy which came from the source. Some energy sources were declared totally unacceptable and to be banished. Politicians participated in banishing the source of energy which has the potential of lasting almost indefinitely: breeder nuclear reactors. Where unacceptable energy sources were being built, great rituals, both fair and unfair, were performed hoping to cause the energy source to disappear.

During all this time, the energy needs of the nation were still being met by the old energy sources. The people who operated these old energy sources felt continued harrassment by the politicians. The organizations who were responsible for these old sources of energy were increasingly constrained by bureaucratic agencies in their flexibility to provide energy. In the view of some people, the managers of the old energy sources had only selfish short-term motives in the decisions which they made.

Several different endings could be written for this "once upon a time story." Many of us hope to be around until the year 2000 to actually see what

happens. The remainder of this paper will suggest that energy sources of the future may not be very different from past energy sources in spite of "the great crusade for alternative energy sources."

SUSTENANCE ENERGY FOR SOCIETY

Our western civilization is one of reasonable comfort, security, and opportunity for most persons. This situation, which most of us think is very desirable, is sustained by high energy consumption. In fact, our civilization has been termed a high energy society. The history of energy in civilization and the necessity for continued high energy usage has been effectively described many years before our present energy concerns (Cottrell, 1955). Another observation correlates empirically the gross national product and the energy consumption per capita in various countries. This empirical correlation has been discussed in many ways, but the general positive correlation between standard of living and energy consumption remains (Linden, 1975).

Fortunately, these societal energy demands can be satisfied from domestic energy sources which are available and demonstrated—coal and nuclear power. Coal supplies are adequate for 100 to 200 years depending on how energy demand, reserves, and technology are projected. The breeder nuclear reactor has the potential of and an essentially infinite supply of energy. There is considerable consensus that coal and nuclear energy should become the predominate energy sources in the future. These two sources can be designated sources of bulk energy for society. This energy is necessary to sustain our complex, high technology society.

Empirically, the cost of bulk energy and construction costs are closely correlated, as shown in Figure 1. To have a consistent set of data, Nelson's refinery construction and refinery fuel cost indexes are plotted (Nelson, 1978). The fuel cost is that of natural gas and oil as used in refineries, but if coal could have been used at a significantly lower cost it would have been employed as a refinery fuel and included in the fuel cost index. The construction cost index also applies to petroleum refineries, but this index parallels other construction cost indexes. The plotted data extend back to 1926 and show an approximate one-to-one correlation between fuel cost and construction cost, except for the period of 1957 to 1969 of constant fuel prices. The cost of fuel has now increased to restore the one-to-one correlation. The author expects a continuation of the one-to-one correlation. Discussion of reasons for this extrapolation has been given in a previous paper (Parker, 1977b). The tight correlation between bulk energy cost and construction costs has been recently cited by other authors as reviewed by Malcolm Slesser (1978).

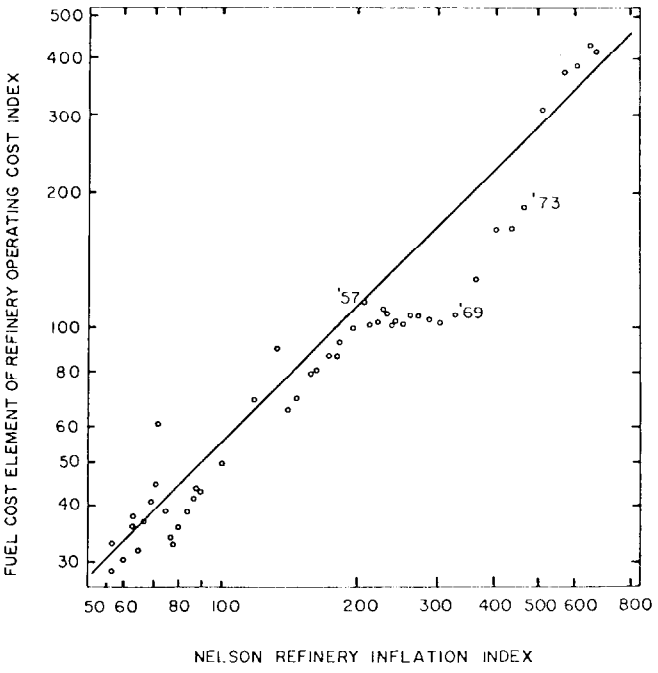

FIGURE 1 CORRELATION OF CONSTRUCTION COST (NELSON REFINERY INFLATION INDEX) AND BULK ENERGY COST (FUEL COST ELEMENT . . .) (PARKER, 1977a)

For minimized inflation and the corresponding decreases in our standard of living, it is obviously desirable to minimize increases in bulk energy costs and the related increases in construction costs. Increased productivity and reduced regulations are the frequently proposed answers. It is difficult to implement these approaches in a society which is rather hostile to the organizations supplying the conventional sources of bulk energy.

CONVENIENCE ENERGY FOR SOCIETY

In the days of "once upon a time" there was no need to distinguish between bulk fuel and convenience fuels. Petroleum and natural gas were both the most economical and the most convenient fuels available. The federal government unsuccessfully tried to extend this "garden of Eden"

situation indefinitely by regulation of gas prices, and it thereby contributed greatly to our present energy problems. Today it is essential to distinguish between bulk energy and convenience energy if we are to effectively utilize our energy resources. The term "convenience" implies that we are willing to pay some price for the convenience. For example, we pay the equivalent of $10,000 per barrel of oil for the energy in a flashlight battery to have the convenience of a portable light (Parker, 1977b). In contrast, bulk energy must be supplied society at a minimal price so the remainder of our GNP will be available for personal and societal necessities and even luxuries.

The obvious source of convenience energy is continued use of petroleum and natural gas for tasks, where the convenience can be justified by the price required for long-term production of these fuels. When the price for these convenience fuels increases significantly above inflation rates, many users will find it desirable to use less convenience energy, or to use less convenient bulk energy sources. Changes in society which minimize utilization of petroleum or natural gas will not come rapidly. Our energy problems grew over a period of many years, and we cannot solve them in only two or three years. Systems which avoid use of petroleum or natural gas (such as electric railroads and district heating) require significant savings relative to continued use of convenience fuel plus considerable planning and investment. If leaders in all walks of life are convinced about the increased cost and scarcity of oil and natural gas and they communicate this attitude to the public, our usage of convenience fuels will more rapidly adapted to the reality of their availability.

Petrochemical feedstocks presently make only moderate demands upon our natural gas and petroleum production capabilities. These uses will become responsive to increased prices for these materials. Some petrochemicals, methanol and ammonia, can be made from coal using existing technology. Other petrochemicals, ethylene, aromatics, and carbon black, may justify continued usage of petroleum and natural gas, even if the prices increase considerably. The choice should be the business decision of the petrochemical manufacturers.

FUTURE OF PETROLEUM AND NATURAL GAS PRODUCTION

By employing oil and natural gas as convenience fuels, instead of bulk fuels, the one-to-one correlation of construction costs and bulk fuel costs is avoided for oil and gas production. For this reason it is necessary that oil and gas be displaced from the bulk fuel market as quickly as it is economically feasible. When oil and gas are priced as convenience fuels whose price is expected to increase, consumers can reduce their consumption as indicated in the previous section and can also afford to pay the prices for oil and gas that increased production costs require.

Higher domestic prices for petroleum can justify production of reservoirs which were previously uneconomical, exploration in areas where little oil has been found, and expensive enhanced oil recovery processes. At some price for domestic petroleum, other sources will become attractive, for liquid fuels such as shale oil or hydrocarbon liquids produced by processing coal. Oil shale reserves exceed domestic petroleum reserves by a factor of 4 to 10. When shale oil becomes attractive as a convenience fuel, the nation's requirements for liquid fuel can be supplied for a long time. Note that shale oil is not being recommended as a bulk fuel, since it cannot compete with the existing bulk energy sources, coal and nuclear power.

Natural gas can be considered in a similar fashion, and its ultimate convenience usage may be in heating homes. At some point, the price individuals are willing to pay for the convenience of gas fuel may justify its synthesis from coal. Before that time, gas will be available from reserves which cannot be produced economically today. These presently uneconomical gas reserves are one to two times greater than our present gas reserves.

ALTERNATIVE ENERGY SOURCES

To be certain wise selections are made it is desirable to consider all potential sources of energy for our nation. These alternative energy sources must enter into the existing markets for either bulk energy or convenience energy, unless our whole economy is drastically altered. For this reason, it is desirable to make cost comparisons between alternative energy sources and existing energy

sources.

At present, no widely available alternative energy source can compete as a supplier of bulk energy. If it could, it would be doing so now. Many people project that when the cost of energy reaches a certain value, a particular alternative energy source will become attractive. The author does not expect this to happen, because the cost of construction and the cost of bulk energy correlate very closely as discussed previously and shown in Figure 1. Rising bulk energy costs are matched by rising construction costs, and sources of alternative energy which are not economical today will not become economical tomorrow.

Alternative energy sources are potentially available. For example, the sunlight hitting 40 acres in a good location (2200 BTU/day/ft^2), if it were collected with fifty percent efficiency, is equivalent in energy content to 300 bbl of oil per day. The problem is to build and maintain 40 acres of collector and then to profitably utilize the energy as received. The thermal energy from the sun cannot be priced as if it were oil, because it is not as convenient as oil. Assume the value of solar energy to be $1.00 per million BTU, and assume commercial quality solar collectors could be built and installed for $10 per square foot. The investment in forty acres of collectors would be 17.4 million dollars compared to an annual income of 0.7 million dollars. A 25 year pay-out with no consideration for the required investments in addition to collectors. Previously the author estimated that if solar collectors cost fifty percent more than carbon steel shell and tube heat exchanger, and the economic environment was a large industrial plant, the cost of solar energy without provision for storage would be in excess of $20 per million BTU (Parker, 1976). In some locations the intensity of wind energy approaches that of the sun. Calculations made for wind energy lead to similar high costs for energy.

The problem of collectors and storage for alternative energy sources can be circumvented by use of biomass. A forty acre field producing 10 tons per acre per year of dry matter would be equivalent to about 2.8 barrels of oil per day. Unfortunately wood is not nearly so convenient a fuel as petroleum. The technology for utilization of biomass is available. The forest products industry is increasing its utilization of residues from wood processing and preparing to intentionally gather residues from forests for use as fuel. The sugar cane industry has energized itself from the processed sugar cane, bagasse. These options for utilization of biomass as bulk energy are primarily limited by gathering and transportation costs versus the value of the energy. Biomass residues can potentially provide only a few percent of our bulk energy needs, even if economical relative to coal and nuclear power. Intentional growth of biomass for energy involves both additional investment in "energy plantations" and decisions whether land is better utilized by growing wood for conventional use and crops for food than as an energy plantation.

To convert alternative energy sources into convenient energy sources, considerable processing is necessary. For example, solar energy can be converted to hydrogen via electricity and hydrolysis. Some people project that hydrogen can be stored and transported conveniently, but the investments involved are quite large. Grain and sugar can be fermented into ethyl alcohol, but at a considerable cost. Ethyl alcohol made from petroleum is about half the cost of ethyl alcohol based on fermentation. Anarobic fermentation partially converts manure to biogas, but the large scale economics depend on refeeding the fermentation residues to cattle. Biomass can be converted to ammonia or methanol via producer gas, but coal may be a more convenient raw material for these products. Other examples could be added to the list, illustrating that convenience fuels can be produced from alternate energy sources, but in each case the cost will be rather high, and probably not competitive during this century with these same convenience fuels from fossil fuels. In an relatively open economy, investors can invest in alternative energy sources any time they perceive it is a desirable project.

Individuals may find that their economics are different from large scale economics. If they have access to woodlands, firewood for heating may be very economical. If they like to build and maintain their own residences, full or partial solar heating can be utilized and certainly minimize utility bills. These choices are certainly available, but we should not expect significant reductions in our nations energy

consumption because of them.

Proponents of alternative energy sources speak of breakthroughs making their technologies economically attractive, but there is an inherent contradiction in "predicting breakthroughs." On occassion they occur, and in other cases they have not occurred even though there has been diligent research (for example, a generally useful cure for cancer). Tasks which have few economic constraints, such as development of nuclear weapons and space exploration, have been accomplished in a matter of a few years. Development of alternative energy sources has a very strong economic constraint. For this reason, development of alternative energy technologies is a very different problem than many of our dramatic technological accomplishments.

Economies of scale and learning curves are cited as phenomena which will make alternative energy sources attractive if we push ahead. There are clear examples of these situations, but their extrapolation to alternative energy sources is a statement of faith not fact. Many large scale cost reductions of manufactured goods and foods have come from intensive utilization of economical fossil energy and very massive investments in facilities, as well as learning curves and economies of scale. The correlation of construction costs and bulk energy costs makes these opportunities much less available when applied to reducing the cost of energy from alternative sources. The dilute and itermittent nature of two major alternative energy sources, solar and wind, is a significant problem in reducing the cost of utilizing them.

It is certainly reasonable to expect continued advances in technology with regard to energy and many other needs of mankind. On the other hand, it is not prudent to commit our nation's security and economic viability to the hope that alternative energy sources will become sufficiently low in cost to energize our present high energy society. For this reason we must use our present economic resources as effectively as possible. This means coal and nuclear power for bulk energy, and petroleum and natural gas for convenience fuels.

SUMMARY AND CONCLUSIONS

Division of energy requirements into two catagories, bulk energy and convenience fuels, is an effective means to structure our energy needs. Availability of bulk energy for the minimum price which will attract investors is essential to maintaining our present standard of living. Even so, it will be difficult to maintain this standard of living unless government, industry, and labor strive to increase productivity. Sources of bulk energy which are not cost effective today will not become so in the future, since construction costs correlate very closely with bulk energy costs. It is expected that coal and nuclear power will be the dominant sources of bulk energy for our economy.

Petroleum and natural gas should be considered convenience fuels whose price can be expected to rise as their production from difficult sources becomes more expensive. This continued rise in price for convenience fuels must be communicated to all persons, so that they can make alterations in their lifestyle at a pace which is not harmful, either economically or socially.

Alternative energy sources—solar, wind, biomass, etc.—will find it difficult to compete in price with coal and nuclear power for our bulk energy requirements in an open market. Similarly, alternative energy sources will not be able to compete with convenience fuels from fossil sources on the basis of price in this century and perhaps longer. Specific tax advantages or other subsidizes for alternative energy sources, if applied on a significant scale, will divert available gross national product from socially benefical utilization and from personal luxuries.

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