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THE ADVANTAGES OF LOCAL EXTREMES OF SYSTEMS WHEN CONSIDERING ENERGY SUPPLY TRENDS TOWARD SIZE AND COMPLEXITY

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Abstract

Recent discussions of new energy sources, including some debate concerning the relative merits of a number of approaches, reflect an emerging trend toward extremes in size and complexity of sources. This trend is justified as a fundamental premise for future energy development. The trend is related to similar trends in commerce, business, medical service, and transportation. The recent sharp increases in marginal energy costs, along with governmental intervention in the energy scene, are accelerating a focus on the concept of an energy park, at one extreme, and on small locally-controlled sources of energy, at the other. A key to successful energy use lies in intelligent coordination of the extremes.

1. INTRODUCTION

Energy is produced in systems of varying size and complexity. Size may be characterized by energy output; however, physical size may be just as valid a characterization. Complexity, or sophistication, is not necessarily associated with the intricacy of the physical laws involved, but rather with characteristics such as materials required, manufacturing sophistication, or operator training. An energy production system is integrated into a specific fuel cycle. Historically, accepted trends were toward larger systems to take advantage of savings through economy of scale. The principal result of these trends was a steady decline in the cost of energy at the margin, i.e., cost of an incremental amount of energy, from a given source such as natural gas, added to the present supply. Recently, however, the marginal cost associated with conventional energy systems has increased to a level well beyond the average cost paid by energy consumers (1). This stems in part from the enormous increases in cost of large-scale construction and the fact that large-scale energy production equipment, especially for electricity, has reached a practicable upper limit in size.

The course of history will produce a concentration of energy sources at the extremes of size and sophistication. This orderly progression was recently demonstrated in the world of commerce and is presently indicated in the worlds of medicine, education, housing, and transportation. The grocery business has led the way from small "Ma and Pa" corner grocery stores, through the "bigger is better" phase of larger and larger chain stores, to the present focusing of the large, diverse hypermarché (2) at one extreme and the small convenience stores at the other extreme.

For the provision of medical service, the diseconomies of scale obtained through the larger, more specialized hospitals has driven costs out of reason. Early economies of scale with increased specialization and convenience drove the small hospital from the scene and have yielded a facility of "standard" size and complexity, used by everyone. To maintain economic reason, there must be smaller, local hospitals for the many less-extreme medical problems and immediate emergency care, and a few even larger, more sophisticated medical centers for the treatment of severe or critical medical cases.

In energy production, this orderly progression toward the extremes is being accelerated by government stimulation. Current energy legislation is intended to motivate and expand the use of a wide range of small locally-controlled energy sources, such as solar and wood heating and wind power. Due to the typical lack of convenience and dependability of these small systems, wise users will overlay their system with a redundant, probably electricity based, energy source to be used only in time of need. This necessary action, which results in a large potential, though seldom used, electricity demand, will cause electric power plants each to serve a broader range and a greater number of users. The range and number must be large enough so that the power plant capacity will be sufficient to serve a statistical demand significantly lower than the total possible energy demand. The assurance of electrical energy will probably be about what it is today, and many power plants will be concentrated in energy centers to accomplish this.

To determine and secure an energy future, current trends are toward divergent energy system extremes, i.e., large electric power energy complexes and small localized energy facilities. Benefits are argued for both extremes. Greater benefits are argued for the intelligent coordination of both extremes. The projected large systems derive economic benefit primarily through plant standardization and reduce operating and maintenance costs. Small systems sometimes allow the cost of energy supplied at the margin to decrease, as well as conserving resources and allowing local control. Historical trends, governmental intervention, and marginal cost economic stimulation will force energy sources toward the extremes. In addition to a concentration of effort in energy parks, an entire progression in the small energy source area will come to pass. The observed trend toward the size and complexity extremes is proposed and justified as a fundamental premise for future energy development. The time is right in history for these trends to exist; and in light of the widely-accepted "bigger is better" philosophy of the past few decades applied in almost all walks of life, the development and interaction of smaller locally-controlled energy systems into the energy generation mix deserves attention.

2. THE RELATIONSHIP OF ENERGY SOURCES WITHIN A SIZE-COMPLEXITY DOMAIN

An energy conversion stage is operated within a supporting fuel cycle which includes fuel and waste management. Size and technological complexity of the conversion stage and the associated fuel cycle affect the energy production as a function of time and the unit cost of that energy. To distinguish between energy conversion stages and energy production systems, the energy conversion stage is the mechanism that delivers useful energy, either by converting energy form or by reducing fuel to energy. The electric baseboard heater and the oil furnace are examples. The energy production system includes, with the energy conversion stage, the pre-conversion-stage and post-conversion-stage portions of the fuel cycle. The number of energy production systems can be large since various energy conversion stages can be integrated into any given fuel cycle. These conversion stages may require different inputs and different waste and energy outputs. Indeed, many conversion stages may be integrated into different fuel cycles.

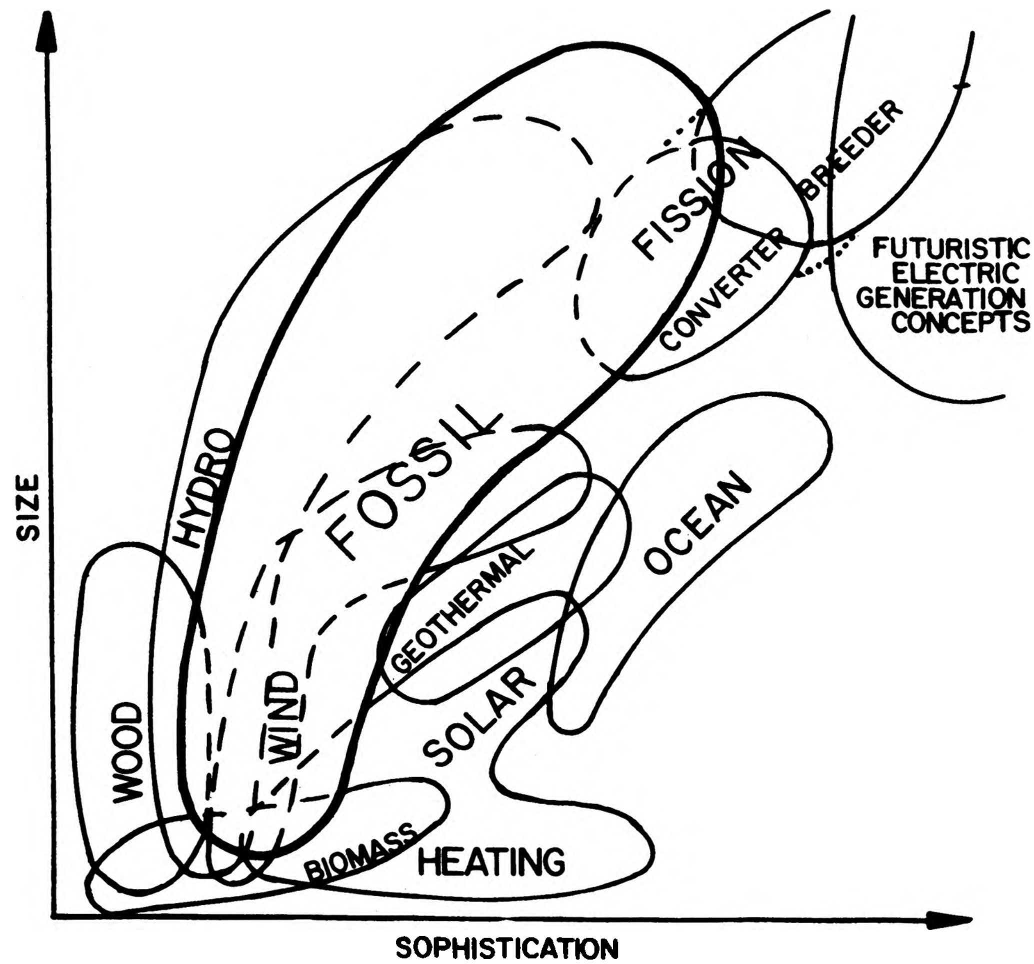
As our society has developed, both thermal and mechanical based energy production systems have continually increased in size and complexity. The use of small (5,000 - 25,000 BTU/hr) wood stoves and (500 Kwh per month) home windmills each based on simple locally-controlled fuel cycles was largely abandoned in favor of either larger (75,000 - 125,000 BTU/hr) furnace home heating arrangements and a power-plant-based electric supply for typical appliances such as 7,000 watt electric double ovens, 6,000 watt countertop stoves, and 6,000 watt hot water heaters.

At this time in history there are signs that there is to be a significant and continued growth of the existing situation of increasing numbers and types of smaller energy production systems. More and more families, businesses, and small towns will increase their independence in regard to energy supplies. One cause is the dependence of larger energy production systems on more and more extensive fuel cycles. The fuel cycles supporting the larger furnace home heating arrangements and the electric appliances have extensive fuel cycles operated, controlled, and influenced by forces very foreign to the locality of energy use.

Through consolidation of financial and fuel resources, accepted trends have been toward larger and larger systems to take advantage of savings through economies of scale. The principal result of these trends was a steady decline in the cost of energy at the margin. Assisted by technological advancement, obviously the economies associated with increased size, and oftentimes related complexity, outweighed the typical diseconomies associated with components such as transportation. A most important concept is this decline in marginal energy cost. That is, whenever a new energy supply of a given type was brought to the market, the unit cost of the new incremental supply was lower than the average unit cost existing for that type of energy source. The result was that in fixed dollars energy became cheaper and cheaper. The events that have brought about changes in this very basic economic tenant may affect society more than did the fall of Constantinople.

Placing various energy sources in a size-sophistication domain yields some interesting results. Figure 1 shows qualitatively the relative placement of the ranges of energy conversion stages of the different energy sources on the size-sophistication domain. Most wood energy conversion stages are small simple devices. However, wood energy is used to fire large furnaces of 170,000 BTU (3) and boilers in certain types of industry closely associated with forest locations and products. Also, 1000 Mwe wood fired electric generation stations have been seriously considered (4). Modern air-tight wood stoves are more sophisticated than those of some years ago. The larger wood energy conversion stages are no more sophisticated than these modern small appliances.

Note from Figure 1 that large sophisticated hydro and fossil units exist, equal in size and close to the

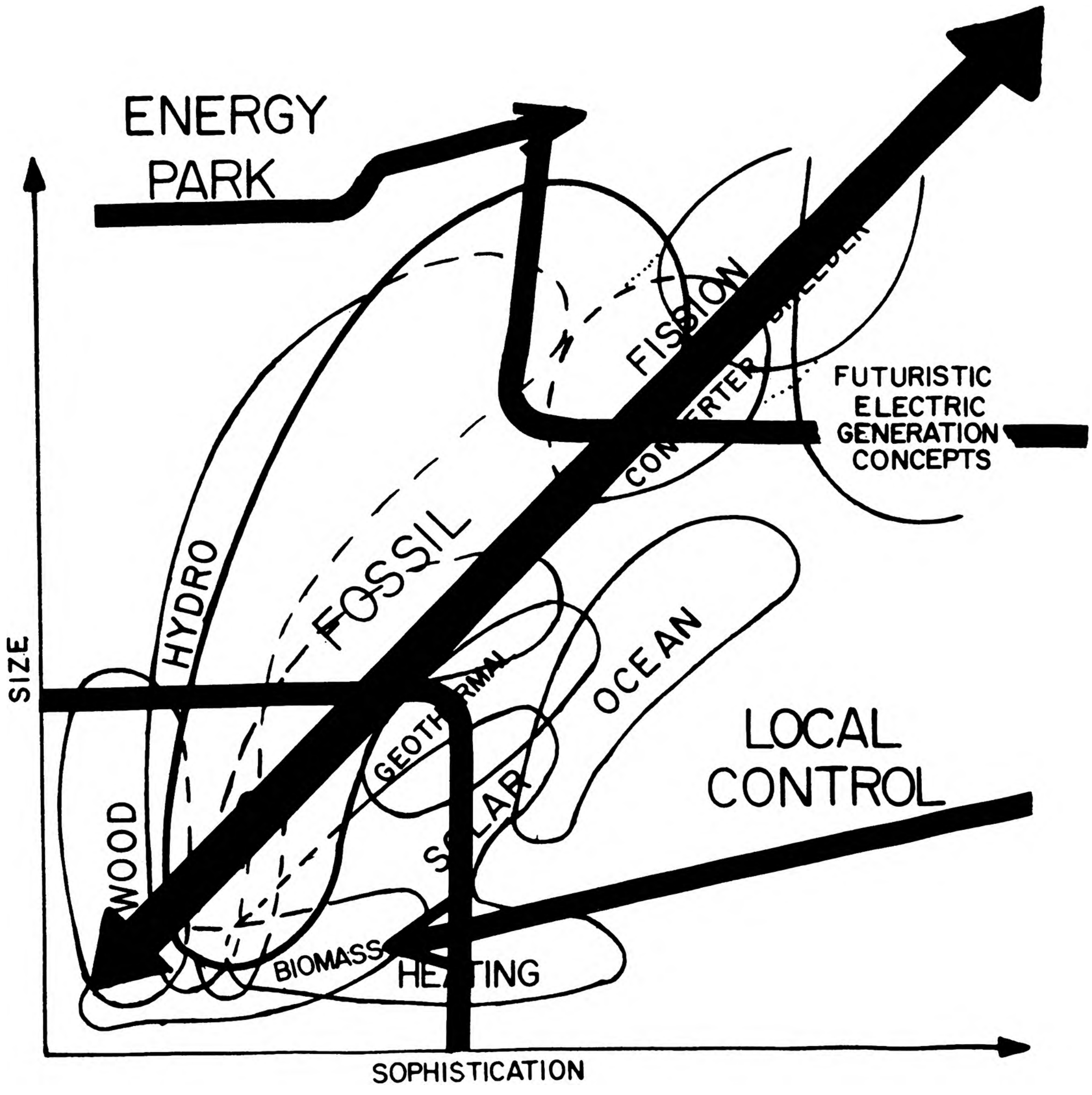


COMPARATIVE SIZE AND SOPHISTICATION RANGES OF ENERGY CONVERSION STAGES

FIGURE 1

futuristic electric generation concepts such as fusion and "mirror-in-the-sky" solar power plants. An attempt has been made to include most energy sources in Figure 1. Note that the area included within a pattern labeled with an energy source name has no relation to importance. Fossil energy, for example, happens to be a very versatile energy source and applications range from simple energy conversion stages such as a small heating or cooking unit to a complex stage such as a very large electric power plant.

In the Twentieth Century, the emphasis in the world of energy has been toward the upper right portion of Figure 1. Novel and useful advances in the energy supply scene have carried us, boosted by cheaper marginal energy costs, away from the small, simple, locally-controlled energy supplies toward larger more centralized energy supplies. The demand of and the examples set by the population centers have dictated



EXTREMIZING EFFECT IN THE SIZE AND SOPHISTICATION RANGES OF ENERGY CONVERSION STAGES

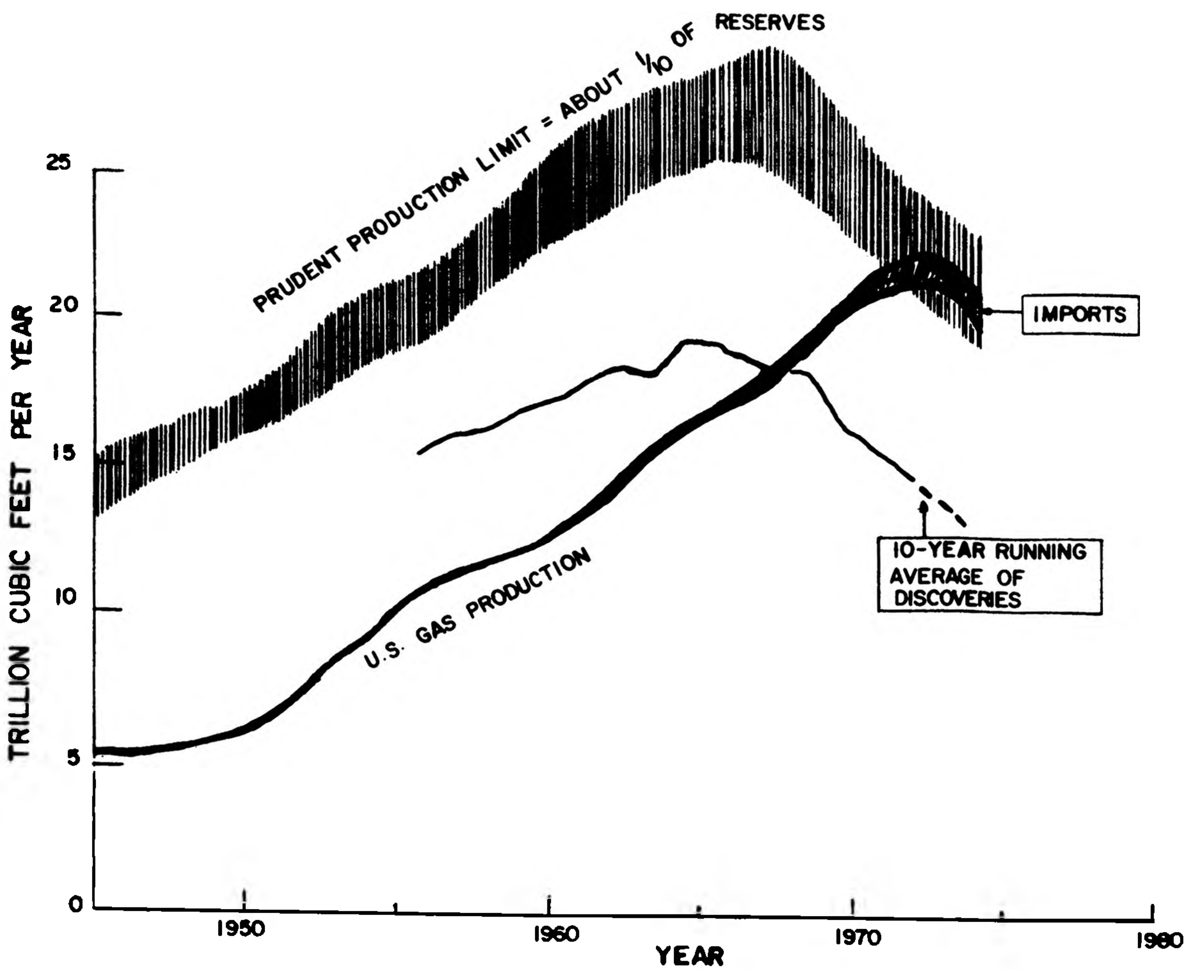
FIGURE 2

the total energy picture of a very diverse country.

Alvin Weinberg and others promote concepts of further centralization of electric supply, with associated fuel cycles, into extremely large and sophisticated energy parks. Many propose increased use of locally-controlled energy supplies such as solar heating (5), wind power (6), small hydro facilities (7), and wood stoves (8). Indeed we see both occurrences more and more frequently. In the northeastern and middle Atlantic states, the wood stove market has grown to immense proportions. In the state of Maine, as many as 75 percent of the homes use wood to heat their homes (9). More and more people are investing in solar heat, and the government is attempting to provide rewards for taking steps toward local control. Meanwhile, the utilities are building larger clusters of large power plants. An example of the extreme case is a large electric power source associated with a large fuel cycle, i.e., the energy park concept (10). These trends are overlaid onto Figure 1 and shown in Figure 2. Furthermore the arrows in Figure 2 emphasize the extremizing concept espoused here.

3. ENERGY PRODUCTION AND THE DRAMATIC CHANGE IN MARGINAL COST

The realizations gained through the dramatic events of 1972 and 1973 will affect the entire energy issue. Wise people, including M. King Hubbert (11), anticipated problems earlier. The closeness of U.S. production of natural gas to the prudent production limit suggested a potential intersection of the two curves in the early 1970's. Figure 3 (12) shows the



U.S. PRODUCTION AND CONSUMPTION OF NATURAL GAS

FIGURE 3

intersection of the U.S. gas production curve with the prudent production limit. Note that since the intersection of gas production with the 10-year running average of discoveries in 1968, the reserves have been drawing down. The production must now quickly drop down to about the 10-year running average. All the curves in Figure 3 display the characteristic Hubbert notion that the production of a nonrenewable resource of a given grade tends to follow a Gaussian distribution function plotted against time.

By April 1972, the U.S. gas industry was producing at its maximum. The valves were wide open! There was no more slack! In the winter of 1972-73 propane was short for obvious reasons. Natural gas was being used at its limit. To add a new natural gas customer, an old one had to leave the system. Gas distribution was far from perfect. Industry bought the propane, and the pressure was on. There were dislocations in the propane market.

In November 1973 there occurred, for political reasons, the Arab Oil price change. As a result of the Yom Kippur war the price was changed immediately from $3 to $11 - $12/barrel. Spot oil was as high as $18/barrel. A most important note is in order. The Arabs had tried during the six-day war in 1967. They cut Europe off from its oil supplies. At that time the U.S. merely opened wider the oil valves and provided the needed extra oil for Europe. This could not be done in 1973, however, because the U.S. valves had meanwhile been opened wide, and even the U.S. was in 1973 somewhat (although not yet heavily) dependent upon the Arab oil.

During this same critical period, which signaled a dramatic change in fossil energy resource availability, an economic blow was felt in the energy world. For the first time since the industrial revolution, the cost of energy supply at the margin increased. From the industrial revolution until the 1970's, all such events in a time period taken as an average, when an additional supply of a given energy source was brought to the marketplace, the economic effect of the additional supply was to reduce the average unit cost of that energy source to the customer.

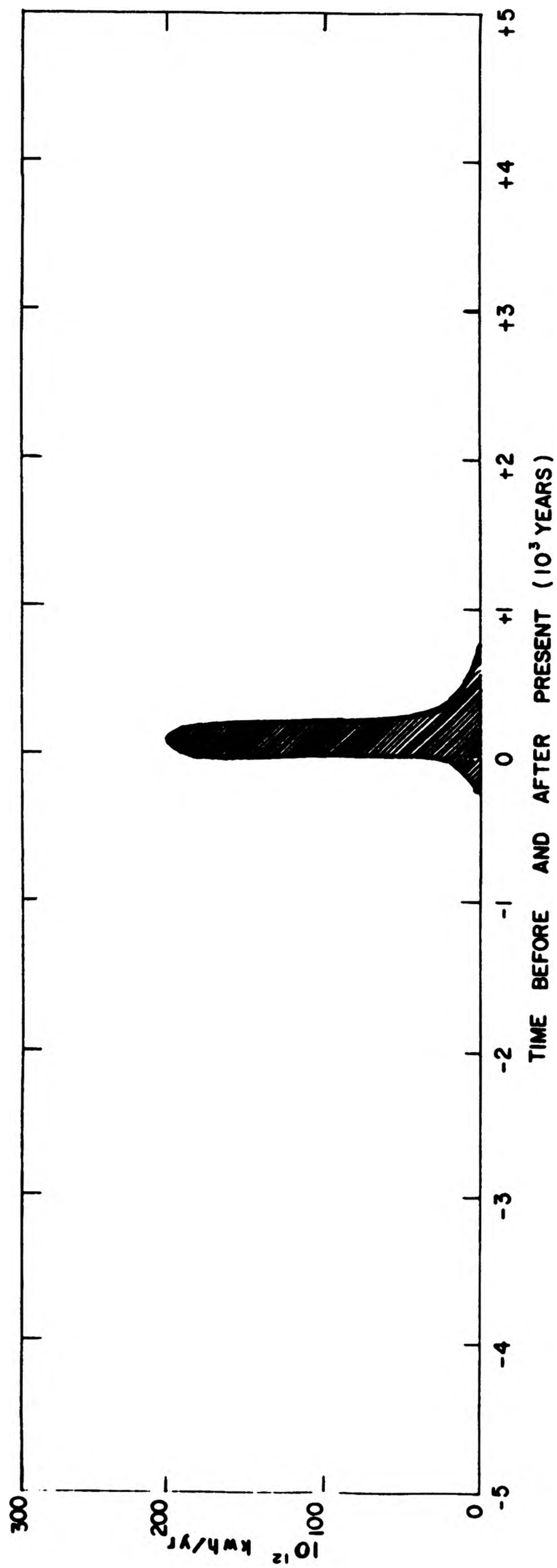
Larger, more efficient electricity stations lowered electricity costs. Larger systems for gathering and and transporting natural gas and petroleum, and larger installations for refining and processing the latter, lowered costs to the consumer of these fuels. Technological advances, operational improvements, and new vast high-grade fuel resources served to drive energy costs down, whether inflation was considered or not. Energy became the best buy in the marketplace, and the watchward was convenience, dependability, comfort, and luxury. The populace was convinced that energy sources were limitless in extent and type. Lifestyles, homes, businesses, and recreation activities became heavily energy based and very wasteful in a headlong effort to render all work, play, and living into a completely effortless human existance.

It is in this framework of existing edifices, policies, and attitudes that the doubly damaging and only somewhat related occurrences of fuel resource limitation and increased marginal cost struck. These occurrences are new in contemporary times. Resource limitation is fundamental. Technological fixes and operational and management efforts toward improving the various efficiencies involved in providing energy from a given fuel resource are successful only if the resource is abundant--let alone available. The technology involved in developing an entirely new (or different, in the case of wind or solar energy, for example) energy source has an extremely long lead time. The effects of these advances on the energy future are severely delayed. Large conversion stages, yielding healthy additions of readily available energy based on any new or different energy source, will bring extensive materials, engineering, operational, management, and political problems. It is never clear at the outset whether these very real practical problems will be greater or lesser than the problems in existing energy sources. Nuclear energy and the projections of future cheap and limitless energy should serve as an historical lesson.

In this context, it is wise to always remember that even at current or projected prices, Arab oil is still a bargain. It is (and will probably remain cheaper) than the marginal cost of synthetic oil. Something must be done--and it will--either as a result of a decision and clear policy or as a result of no decision and no policy. One present emphasis is to "think small". This emphasis has much merit and will have a significant effect only when many small sources become equivalent to a few large sources. The proposal here is that both extremes must be considered and developed.

Looking forward into the more distant future, recall the famous graphic description by M. King Hubbert of the historical epoch of the exploitation of fossil fuels (13). He indicates that the time required for the complete exploitation of coal resources will be of the order of that for petroleum - a century or two for the exhaustion of the middle 80 percent of the ultimate cumulative production. Figure 4 shows this graphic description of Hubbert. On a time scale starting 5000 years ago and extending to 5000 years in the future, the epoch of fossil fuels is shown to be only a transitory event.

Considering nuclear energy and realizing the extent of uranium resources, a similar limited epoch of ura-

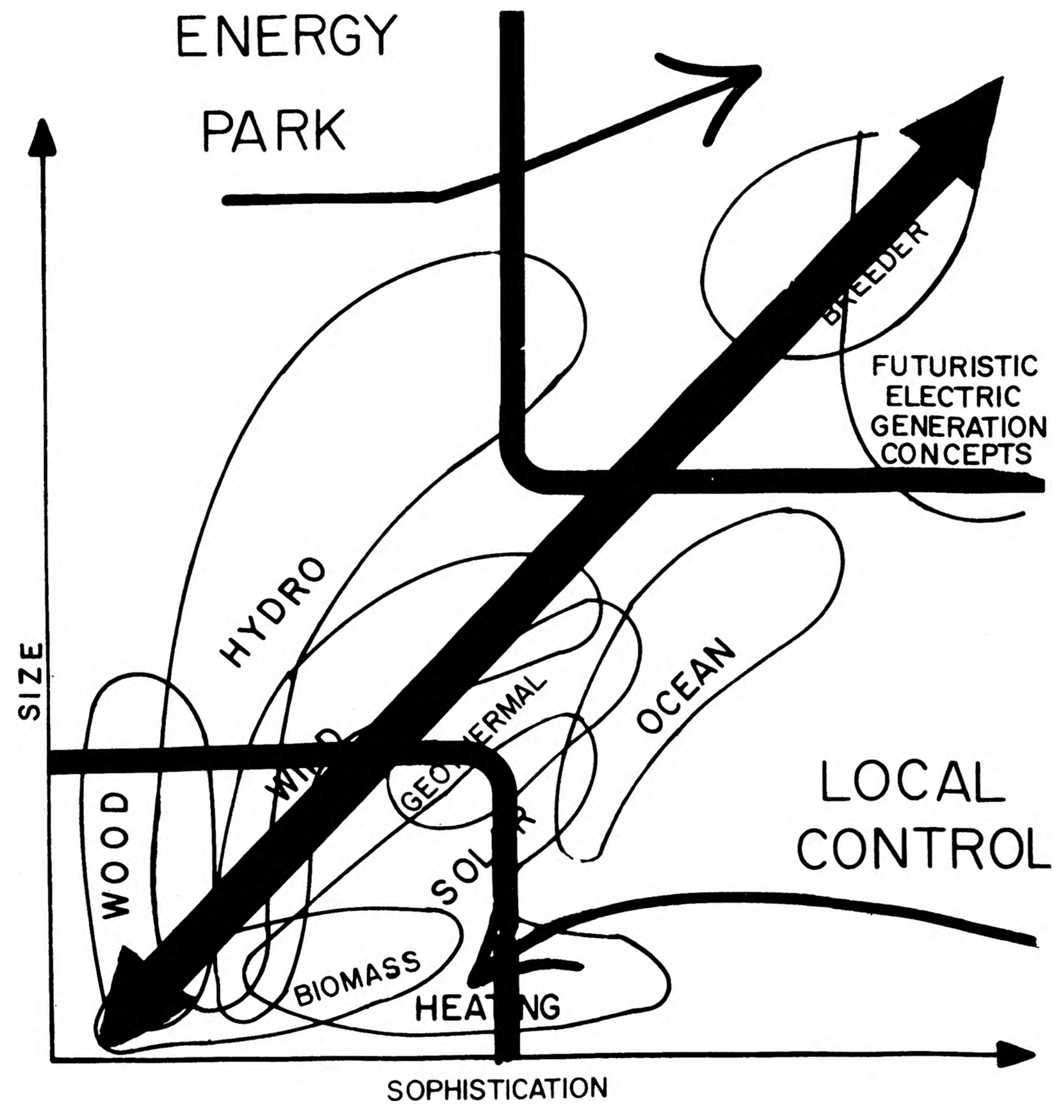


EPOCH OF FOSSIL - FUEL EXPLOITATION IN PERSPECTIVE OF HUMAN HISTORY FROM 5000 YEARS IN THE PAST TO 5000 YEARS IN THE FUTURE

FIGURE 4

nium exploitation can be expected. Assuming the burner-breeder mix of a breeder technology, the converter type reactor used in consuming uranium will obviously pass from the scene. The effect of these events of fossil fuel and uranium exploitation on the ranges of energy conversion stages of different energy sources on the size-sophistication domain is shown in Figure 5. Figure 5 is a copy of Figure 1 where the fossil and converter fission sources have been removed. The extremizing effect discussed here is dramatically displayed in Figure 5.

In going toward still larger systems some advantage can be taken of economy of scale through operational and management practices. These advantages will do little more than counterbalance problems and diseconomies resulting from large energy sources. A small nuclear industry presented only future problems in the area of waste management and proliferation. A strong, growing, already large nuclear industry brings these



LONG RANGE PROJECTION OF SIZE AND SOPHISTICATION RANGES OF ENERGY CONVERSION STAGES

FIGURE 5

problems into the present. The advantages of the energy park concept in the energy scenario projected here is that the diseconomies of scale can be counterbalanced through operational and management improvements and, most importantly, that the area of service of the energy park will be large enough and diverse enough and will include significant locally-controlled energy supplies such that the demand on the energy park will be statistically much lower than the total potential demand represented by the area of service.

The success of the energy park concept in the framework indicated here is based on the success of accumulating enough instances of locally-controlled energy sources. The government has already made it clear that the emphasis of energy policy is going to be on conservation and individual involvement in a diverse variety of locally-controlled energy sources.

Due to the neglect of the smaller energy sources through the technological developments of the past few decades, the marginal cost of energy from these sources can be expected to decrease. Aided by indirect government subsidy through such things as tax relief, technological, operational, and management improvements in all areas of the small energy sources will be made. The drought in this area will be followed by a flood of unique ideas, monetary support, and a great deal of effort and consideration.

An example of this thinking is typified in an assertion of the late Douglas E. Elliott (14). He proposed that England's expansion of its use of gas, with the arrival of the North Sea supplies, should take the form of small gas engines in homes, farms, and businesses. The engine would operate when heat is needed, where the heat is derived from the waste heat of the engine. However, additional benefit is that the "waste" of the heat production system is electric energy furnished to the electric grid. Elliot claimed that England would not have to build another electric power station until the year 2000. The question raised here is that, even with natural gas at its true marginal cost, is there a role for small gas engines in the production of heat for the home, small village, factory, etc.? An associated aspect of this concept is that there is room for a locally-controlled energy source in larger population centers. The larger population centers have distinct difficulty with many energy sources, such as solar, wind, and wood.

4. HISTORICAL TRENDS IN VARIOUS ASPECTS OF SOCIETY

The trends observed in energy development were duplicated in almost all aspects of living. During the past few decades "bigger is better" mainifestations resulting from benefits of economy of scale have occurred in business and commerce, education, health services, housing, and transportation. The grocery business, which is the bellweather of retailing, changed from small "Ma and Pa" grocery stores to chain operation of supermarkets. The smaller grocery stores could not continue to be profitable in the environment of low profit margin, high turnover of goods, and decreasing expense percentages. These smaller grocery stores have continually decreased in number, as have smaller schools, hospitals and power plants.

The existing grocery business investment, accumulated over the years, is committed to extensive facilities, equipment, practices, and attitudes related to the supermarket concept. In a unique development, the Europeans in recent years have implemented the hypermarche. After 50 years supermarket experience in the United States, the hypermarche concept is just beginning to make inroads on this continent. In these markets the sales floor alone can exceed 250,000 square feet and many non-food items are sold (15). Recent stores in France include Mammouth, with an expected turnover of $1.3 billion in 1977, and Euromonche, with an expected turnover of $1.1 billion per year (16). They market everything from coffee to socks and resemble in many ways the product diversification of a shopping mall in one store.

These large stores are all sited central to population distributions. As a consequence, the consumer profits from quantity buying; but, in most cases, it is not worth the trip to buy a few items. As a result there has been the development of the small convenience food stores. These are typically located in neighborhoods, and markups are low on fast-moving items and very high on slow-moving items. It is projected that the wise family will coordinate the economics of the hypermarche, with weekly or biweekly trips for quantity buying, and the convenience of the small store, with as-needed trips for forgotten, perishable, or unexpected items.

Historically, hardware stores have followed the lead of grocery stores. The corner hardware stores have been replaced by the large chain stores with many prepackaged products. In recent years there has developed the big home and garden centers combining lumber yard, hardware store, and nursery items with other specialty items (such as Christmas products) in a single store. Very recently, small local hardware stores that carry primarily fast moving items, like hammers and nails, are coming into existance. A wise use of the combination of extremes in this case is also projected.

In education the "bigger is better" philosophy has been exercised at all levels, from elementary school to college. Today, however, there are indications that the extremizing trend will occur in education. The large state universities are becoming multi-college, high enrollment, extensive facility operations with many branch campuses and/or associated community colleges. On the other hand, there is great concern about the diseconomies of scale (such as increased transportation costs) associated with large consolidated elementary schools (17). The inconveniences and lack of diversification in the small community schools are counterbalanced by the discipline and drug-related problems of the large school. Indeed, the quality of education is questioned in a large school at educational levels below the college level (18).

In education, health service, business and commerce, and undoubtedly also in other areas such as transportation and housing, the extremizing trend is indicated. It seems as though the time in history is right to question the "bigger is better" philosophy, and rather than abandoning a concept that has demonstrated much value, the trend will be to integrate size and sophistication characteristics into a wise mix that optimizes benefit and penalty.

5. LOCAL CONTROL, GOVERNMENT INTERFERENCE, AND POSSIBLE ECONOMIC GAINS

The progression toward bigger energy production systems will continue. In many cases extensive fuel cycles will be involved. Technological breakthroughs, in fusion for example, will bring energy sources that are naturally larger and more sophisticated on line. Otherwise, for the purposes of centralization, security, fuel cycle management, operational and siting considerations, or slightly improved techonolgies will be involved in larger facilities.

It is in the area of small locally-controlled sources where large strides can be made. Technological improvements, new materials, control and automation advances, and better manufacturing procedures have not yet made their full impact on energy sources such as solar, wood, wind, and water. Some implications are interesting. It is possible for a household, business, or town to totally control the fuel cycle in these cases. Many small enterprises will be established in this area. In the case of wood, for example, people are familiar with local conditions regarding buying wood for limited use such as for a fireplace. Serious buying in quantity in most cases has not been tested. Competition in furnishing wood has not become keen. With the opportunity to purchase the energy source and to provide the spare time effort required to harvest the fuel, the true local prices of these resources has not been established.

Local systems can be independent, coordinated with large systems, and/or dependent upon large systems. A solar system must utilize a redundant backup system, only used when needed, representing potential demand on these other energy sources. Electric power utilities are committed to provide power when the demand occurs. This requires standby reserves. The capital investment involved in providing little used facilities increases the unit price for everyone. Policies such as household demand meter requirements become a possibility.

In any account, local, state, and federal governments have and will become involved in these issues. The present emphasis is toward conservation and the increased use of smaller systems. The effect will be compounded and the government activity will further stimulate an already moving trend. The extent of the effect of this government involvement on interference cannot be underestimated.

The large system is flexible but vulnerable. A large electric energy park has the capability of being patched into homes, businesses, industrial complexes, and towns that have other energy sources as their primary supply. The loss of the energy park, or even a portion of the facility, in terms of downtime can be catastrophic without small system availability. The small energy systems perform the function of a damper, in the sense of energy availability as well as cost, in the total energy system. The small systems will add resiliency to the overall mix of our nation's energy supply.

In summary, local control will become in fashion. More people will sacrifice convenience for economics. The effect will be measurable and will be enhanced by governmental action. More than a fair share of attention will be paid to small systmes. Innovation will result and the extent to which small systems will be utilized will be surprising. Most marginal cost advantages will be reaped from the smaller systems. For certain cases, in small systems energy can be derived at present costs of less than $1.00/MBTU (million BTU). In comparison, most energy systems considered today produce energy at a cost ranging from $2.00 to $40.00/MBTU. Probable technological advances will reduce the relative numbers for the smaller systems.

REFERENCES

1. Squires, Arthur M., "Expanding the Use of Coal", A Conference on American Energy Choices before the Year 2000, City College of New York, January 1978.

2. Langeared, Eric and Robert A. Peterson, "Diffusion of Large-Scale Food Retailing in France: Supermarche et Hypermarche", Journal of Retailing, vol 51, No 3, 1975, pp 43-63.

3. Harrington, Geri, The Wood Burning Stove Book, Macmillan Publishing Co., Inc., New York, N.Y., 1977.

4. "The Feasibility of Generating Electricity in the State of Vermont Using Wood as a Fuel: A Study" submitted by J. P. R. Associates, Stowe, Vermont, to the State of Vermont, Agency of Environmental Conservation, Department of Forests and Parks, 1975.

5. Watson, Donald, "Designing and Building a Solar House", Garden Way Publishing, Charlotte, Vermont, 1977.

6. McGuigan, Dermot, "Harnessing the Wind for Home Energy", Garden Way Publishing, Charlotte, Vermont, 1978.

7. McGuigan, Dermot, "Harnessing Water Power for Home Energy", Garden Way Publishing, Charlotte, Vermont, 1978.

8. Shelton, Jay and A. B. Shapiro, "The Woodburner's Encyclopedia", Vermont Crossroads Press, Waitsfield, Vermont, 1976.

9. "They're Cookin' with Wood", Newsweek, January 2, 1978, p 53.

10. Riodan, Courtney, "Local and Regional Economic Impacts of Energy Complexes", Civil and Environmental Engineering Aspects of Energy Complexes, and Engineering Foundation Conference, New England College, Hennileer, N.H., August 1975.

11. Hubbert, M. King, "Survey of World Energy Resources", The Canadian Mining and Metallurgical Bulletin, Vol. 66, No. 735, pp 37-54, July, 1973

12. Risser, Hubert E., Environmental Geology Notes, No. 64, Illinois Geological Survey, July 1973.

13. Hubbert, M. King, "Survey of World Energy Resources", The Canadian Mining and Metallurgical Bulletin, Vol. 66, No. 735, pp 37-54, July, 1973

14. Elliott, Douglas R., personal communication to Arthur M. Squires, 1971.

15. "Chain Store V. Hypermarche", Stores, April, 1975, p 32.

16. "French Hypermarkets, War in the Air", The Economist, October 29, 1977, p 92.

17. Sher, Jonathan P., edition, Education in Rural America, A Reassessment of Conventional Wisdom, Westview Press, Bolder, Colo., 1977

18. Barker, Roger G., and Paul V. Gump, Big School, Small School, Stanford University Press, Stanford, Calif., 1964.