ENERGY, VALUE, AND MONEY *

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ORIGINAL

INTRODUCTION

The creation of energy flow diagrams leads us to some new understandings about the principles of energy, and the relationship of these principles to value, to money, and, in addition, to a more quantitative understanding of the varying qualities of different energy sources in support of useful work. In the paragraphs that follow, a narrative is developed that starts with the first and second energy laws and the Lotka principle of natural selection for systems with maximum power. The integration of these concepts shows how the requirement for generation of order is as much a necessary part of energy laws as the degradation of order. From these concepts a characteristic closed, autocatalytic loop of high quality energy interacting with low quality fuel energy is recognized as a necessary part of all systems that undergo natural selection . This loop is accompanied by a circulation of money where human economic affairs are concerned. This paper is intended as 1) a review of basic energy principles, 2) a restatement of some relatively new and original propositions about energy, 3) a further illustration of the use of energy diagrams to represent complex systems and 4) an introduction to energy cost-benefit procedures.

BACKGROUND

There have been many attempts to use energy to measure value, starting with Marx in the last century, at a time when neither the physical concepts of energy nor the conventions of measurement were developed. The technocrat movement of the early part of the century was based on energy ideas, but

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apparently, however, without a clear measurable connection between the work of man as an individual and that of his machines, environment, or the man - catalyzed activities by which his own energy was amplified. The energy certificate, which was a much publicized value system based on energy, although its means of calculation in terms of physical work was not clear. (Technocrat Magazine, 1937). Orson Welles suggested an energy based society based on "aerodollars" - an energy assessment.

Our effort to clarify the relationship of energy and money was started with a realization of the counter current systems relationship, that is, in money based societies money flowed proportionately, but in opposite directions, to the energy required to produce the purchased goods and services (Odum, 1967). These ideas were further developed in book form (Odum, 1971) which included a formulation of the energy circuit basis for money and the suggestion that useful work was the natural basis for value if contribution to survival of one's system is the ultimate criterion for existence. Hannon (1973) recommended an energy standard of value while examining the energy of consumers and their essential needs, however his presentation did not consider the qualities of energy in contributing useful work. We have attempted to overcome this shortcoming by simulating energy and money in a basic model of agricultural production and consumption (Odum and Bayley (1974). In this paper we also suggested a means for adjusting money to energy flow as a national means of eliminating inflation and making the energy certificate work as a money standard. Unlike previous efforts energy flow is related to money flow. In this essay, the energy network language is used to clarify energy, energy-money relationships and the work contributions of energies of various qualities.

ROOTS OF ETHICS IN ENERGY LAWS AND ECOLOGICAL PRINCIPLES

Ecological and other systems which survive and prosper have characteristic patterns adapted to the realities of energy laws and ecological principles. Since human systems are subject to the same energy constraints as any other system, any ethic for the survival of man must meet the same requirements. According to this analysis culture is formed by the trial, selection and survival process which produces a structure of information that tends to retain successful patterns, at least until conditions change. Eight laws may be pertinent:

(1) The first energy principle states that energy is neither created nor destroyed. In any diagram, such as Fig. 1-5, all energy* inflowing to the system must be accounted for either in storage increases or in outflows. Energy flows out as work, dispersed heat, or as exports of potential energy capable of driving processes elsewhere. This law is illustrated in Fig. 1 where 100 kilocalories of energy incoming to a system (dashed line box) per day measured as heat equivalence is accounted for as 100 calories heat outgoing (90 + 10). Another example is given in Fig. 2 where two different kinds of energy flows interact in a process that requires them both and generates a third and fourth kind of energy outflow. Here again the sum of the inflowing rates (300 plus 10) must equal the outgoing rates (280 plus 30).

(2) The second energy law requires that some potential energy be degraded as dispersed heat in all processes. A heat sink symbol is required on energy diagrams for each component process and pathway (Fig. 3). From this law come the concepts of order as requiring work, since without an input of ordering energies, molecules tend toward random structure.

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* Unless specifically noted otherwise, energy units are Calories of heat equivalence. Later in this chapter we use Calories of Fossil Fuel Work Equivalence, a different measure.

The energy degradation principle teaches us that some of the energy passing through an energy transformation process is degraded in quality and ability to do further work because the concentrated energies become dispersed into dilute and dispersed random motions of heat of the environment. Such flows are often described as irreversible and this loss of energy availability to do work is indicated with a pointed arrow into the environment with a symbol we refer to as a heat sink. In Fig. 3 90 kilocalories of heat dispersion accompanies an energy transformation that generates 10 kilocalories of high quality energy flow. In Fig. 2 280 kilocalories of energy is dispersed as heat while 30 kilocalories of high quality energy output is generated from the two interacting inflows. We will consider the meaning of energy "quality" in subsequent sections.

Sometimes we measure the energy degradation flow by the ratio of that heat flow to the absolute temperature of the environment into which the energy is dispersed. This ratio is called entropy, and in Fig. 3 the entropy increase is computed as 0.3 kilocalories per degree. The energy degradation principle requires a continual dispersal of heat and thus an overall increase in the entropy. The entropy ratio is a measure of the loss in energy quality.

Any storage of order, concentrated matter, structure, information or other kinds of quality energy is potential anergy that tends to disperse into the high-level disorder of the environment. Random motion tendencies disperse the storage into a more uniform pattern through degradation processes we are used to observing and calling deterioration or depreciation. A storage of order can be maintained only by supplying a flow of ordering energy. As illustrated in Fig. 4, the storage (tank symbol) is maintained by an inflow of energy which is transformed into a higher quality of energy flowing at a rate of 10 kilocalories per day into the storage to replace a similar amount lost in normal depreciation.

(3) Alfred Lotka (1925) presented an energy codification of Darwin's principle of natural selection. We may call Lotka's hypothesis the principle of maximum power selection. Systems develop variety as choices and the system retained by natural selection is the one that develops more power and channels power into useful work of adaptation.

For example, in simple energy storage processes represented by Fig. 5, more power is stored when the backforce loading is half of the input force. Since energy storage, such as accumulation of biomass, is essential to control the systems feedback operation, then adjustment to maximum power loading is competitive. From these principles, we learn that there are particular energy criteria for the surviving ethic. Since selection and evolution are as important to man as the first two laws of thermodynamics, we may wish to call the great energy ordering principles of Darwinian selection the "fourth law of thermodymmics." The third law states that entropy is zero when disorder of heat energy is zero.

(4) Obligation to develop order and interaction feedback. Lotka's principle implies that those systems survive that develop structures that maximize the useful power flow in competition with other systems because the greater energy resource maximizes competitive ability and leads to their choice by natural selection. Energy can be diverted to any competitive process. Fig. 6 shows a system that develops quality energy storage and then uses this to amplify and control the inflowing energy source. The systems which develop the kind of feedback amplifier shown in Fig. 6 draw more power, have more flexibility, and are the ones which prevail. The feedback is a reward loop because it feedsback high quality energy effects to help the energy process it drains. The downstream unit rewards the upstream process. Whereas the energy degradation principle dictates a tendency for concentrated energy storages to disperse, Lotka's principle says that because of competition that develops

in any energy flow, some order must be developed as part of the overall degradation process, since whichever systems develop this loop will draw more inflowing power. As illustrated in Fig. 6 some high quality energy flow must be used constructively in the system's operation because the effect must be greater per calorie than the energy in the inflow to the structure where some is degraded. The feedback must be an interaction rather than a sum so that high quality feedback can have a multiplier effect.

(5) Competitive exclusion is a property of parallel systems that draw on a common energy source (Fig. 7). Because of the Malthusian growth ability of any population of self-reproducing units, in the absence of control mechanisms, one of the parallel systems will increase growth with respect to the other and cause extinction of its competitor. This is an energy principle that explains cancer, the dominance of a species of beetles in grain, and the survival of only one species of micro-organism in a chemostat culture. Competitive exclusion is an adaption for survival in colonizing new areas and energy sources, but once the energy sources have been colonized, it is destructive, over-simple, inefficient, and is replaced by diverse and controlled systems. Systems may control or release competitive exclusion tendencies according to their adaptive needs for growth or leveling of growth. For well formed diverse ecosystems using all the energy inflows, competitive exclusion does not increase energy effectiveness. There are roles for competition and cooperation that help maximize power, depending on the availability of energy for growth.

(6) Compensation with reward loops. Any unit which draws potential energy from another(for example, a predator from a prey), diminishes the competitive ability of the supplier because of this drain, and may cause its competitive exclusion unless it can benefit its supplier in proportion to this drain. Since some potential energy is lost as heat along the pathway downstream,

the downstream unit must return its services to the upstream with some amplification factor for the upstream flow to be helped as much in its power flow as it was drained downstream. If this is not done that entire energy pathway will have less competitive ability and will be selected against. For example, the downstream units may be animals which do services for the plants, such as in exchange for their supplying foods. Farms and cities have this relationship as shown in Fig. 8 and 9. In other words, new components of a system must contribute to that system in order to join it. This is equivalent to the requirement in human systems of having a job. These feedback loops are self designing because they provide immediate reward loop reinforcement that makes pathways permanent if they are effective in augmenting useful energy flows. In other words, the system "learns" with this mechanism. We can also call such self organizing processes self design. By the reward loop principle, we see mechanisms by which there is an allegiance of parts to the whole. In Fig. 6 10 calories of higher quality energy acting as a 2 x amplifier compensate the upstream pumping intersection for 20 calories drained.

(7) Backward cycle of money in human relationship. Within the human systems there are the same downstream drains and feedbacks of work services from downstream, but there is the additional feature of a circulating currency that goes in the opposite direction. In Fig. 8 we show farms and a city. The currency is the dashed line which has a closed and continuous pathway flowing in proportion to energy passage and work but with high ratio to energy on the downstream side of the loop compared to the upstream part of the loop on the left of Fig. 3. There is an average ratio of dollar flow to total energy flow. In the U.S. economy it has been in the vicinity of 17,000 Kcal of fossil fuel energy per dollar for the economy as a whole.

Additional energy flows in support of the economy from renewable natural inputs such as sun, wind, tide and rain. The money circle, plus the programming of people to think of money as valuable, provides a mechanism for adjusting the feedback work loop to match the upstream to downstream power transfer. The money is used to buy feedback goods and services. The higher energy quality of feedback work loops are a means for returning as much energy effect as was lost into heat along the way. The upstream payment of high quality work services with high amplifier effects constitute a currency of work payments. The energy effect around the loop is constant. Return amplifier effect can be measured by the energy drained into heat in producing the high quality storage. From the relationship of money and work, we learn that the root of value in circulating money is energy. If energy is cut off from an economic system, the dollar loses value until it buys nothing, since there is no energy inflowing to do the work after storages in the system have been depreciated.

If we examine systems with both man and nature, such as the overall diagram for the planet in Fig. 9, we find that only part of the system's work loops have currency cycles, whereas a large part of th earth's budget is not included in the economy of currency. It is the energy system of the vast areas of forests steppes, and seas that is the general one; money is involved only in relationships between people. From these principles we see the limitations of money and previous theories of value based on only a part of the basis for man's survival.

(8) <u>System tracking by self design of culture, religion, and behavior.</u> Human behavior programs are the means by which the stored energies are developed and reinvested (Fig. 6) by a society. Culture and behavior may be reprogrammed with each generation during periods of rapid change making the social system much more responsive to change than that of a biological system which requires genetic selection. If those patterns of ethics, religion, and culture that

accompany the emerging successful patterns are accepted and taught then the behavioral patterns may be regarded as an informational tracking system always adapting, with, however, a slight lag, to those systems that are surviving. That behavior follows the established success of a system design in no way lessens its importance. However, for making future plans in times of change it would be always late to ask people what they want or to look at existing behavior as a guide to need. To predict what will be the need requires the prediction of the future energy pattern. With some lag, the highly flexible reprogramming of social and individual behavior are likely to change attitudes and people will demand that which the system needs for survival by the time planning actions have been implemented. In circuit language these programs are shown by the feedback system which has the self-designing property of learning, reinforcing those pathways which work at providing continued power flow. In the system of Fig. 6b, for example, diversity of information and behavior can be reinforced if its feedback accelerates power as shown.

(9) Surviving systems develop the property of resisting accelerations. In Newtonian physics, a force of acceleration is always matched by a counter impeding force from the item being accelerated whether it be the inertial force of a heavy weight, the turning inertia of a heavy wheel, or the magnetic backforce of an electric current being accelerated. Systems of other types may have developed this property also. Let us generalize the concept of inertial backforce to energy circuits containing populations of flows, including those that have the delicate flows and high amplifying potential of information. One may use the same differential equation as for the physical systems. In equation 1, (N) the population fackforce is given as proportional to the acceleration of flow (J) with $\mathcal{L}$ a coefficient of the relationship that is a measure of the properties of stubbornness in the network.

$$N = \mathcal{L} \frac{dJ}{dt} \qquad (1)$$

Some systems are self designed to have more inertia than others. For example at the social level $\mathcal{L}$ is a measure of conservatism. During a period of application of force to a system, there are impeding back forces that represent the input energies going into energy and information storages. After force application is over the storages may affect forward flow. As with the simpler physical analogs, energy is stored and the system affected most when it resists most. It remains an open question as to when large inertial properties are desirable in adapting to the larger environment. In electrical systems inertial properties manipulated to gain stability, to produce oscillations, or instability depending on the timing characteristics of the network being designed.

ENERGY THEORY OF VALUE

The principles enumenated above guide us in the development of a general theory of value and ethics. The first premise of the theory is that the patterns of surviving systems are right to those surviving with these systems. Moral ethic for man comes from institutionalizing surviving patterns as ultimate values, because other patterns that have been selected against are no longer defended. We hasten to warn the reader not to jump to erroneous conclusions about what properties go with surviving systems as many people did at the time of Darwin. Selfish or destructive behavior of components leads to the extinction of their system and themselves. Survival of a unit requires survival of its support system. Any unit must contribute special work to its system or become extinct along with its suppliers. The requirement for survival of a part therefore is service to at least one other unit of its system. The value of a part to the system is its contribution to useful work where useful work is work that maximizes further energy gains and effectiveness of energy use.

The diagram of energies in the reward loops (Fig. 6 or 10) suggests the amount of this work that is necessary. Potential energy degraded in energy flow to the right goes into the heat sinks, but this energy makes possible development of the high quality energy of the downstream unit which may be a higher animal in the forest or a specialized city worker in the human system. The amount of energy necessary for the high quality flow is this energy degraded. For survival under competition a feedback must have as much positive energy effect as the negative loss. Through amplifier action on the input, the feedback exerts multiplier action upstream at the intersection of the feedback and main power flow. The energy value of the downstream unit may be measured either by the calories degraded as heat in the system up to that point, or by the magnitude of the amplifier action of the feedback on the main flow because these two effects are equal when the system is competitive. The values of the services of the downstream units are measured by the upstream energy flows responsible in generating them. If part of the downstream operation involves information storage, as with the programming of a specialized human ability, the accumulated total of energies involved in that development over time are a measure of that value to the system, providing the reward loop (feedback) has been established. In summary, energy value for the work of upgrading energy is the energy flux in the productive process upstream. For stored structure, accumulated energy cost of developing the structure is the capital value in energy units.

The energy theory of value allows the evaluation of all kinds of services and of accumulated works whether they be by man or not and whether they involve money or not. The assessment of values by this system allows each loop of a system as in Fig. 9 to receive appropriate consideration in planning and protection. Survival of the combined system of man and his supportive natura and industrial systems requires maximum utilization of all available energies The importance of each subsystem to the whole is in proportion to the whole quantity and quality of its energy contribution.

QUANTITATIVE MEASURES OF ENERGY QUALITY

In Fig. 11 a high quality flow interacts with a larger but lower quality energy flow, the high quality one serving to control the other and amplify its own role. The ratio of energy flow harnessed to quality energy used in feedback was 30 fold; and amplifier ratio of output to quality energy inflow was 3 to 1. The same kind of intersection and amplification is involved in the feedback of stored energy to amplify inflow into the storage as shown in Fig. 6. Here a high quality-low quality amplifier interaction is shown except in this case the intersection process generates the same quality of energy that it stores and feeds back for input amplification. If natural selection favors the system relative to competitors, the feedback pathway must operate economically. The feedback of quality energy needs to have as much amplifier action as necessary, no more, no less, to generate the high quality energy used in the storage, in replacement of depreciation losses, and for the amplification work. To feedback more is to waste high quality energy; to feedback less is to make a net drain on the system, either of which is non-competitive. Since the loop ultimately regenerates as much quality energy as it uses (at steady state), we may regard the feedback loop as a constant value loop. One may measure energy flow amplifier value either as the energy required to generate the high quality feedback, or one may use the amplifier ratio of the intersection as a measure of the value of the feedback. In the example in Fig. 6 20 kilocalories go into storage in order to develop a feedback of 10. Thus 2/1 is the energy quality increase. A Calorie in the feedback loop by this consideration is twice as valuable as a Calorie in the main flow. Or, using the alternative calculation, 10 kilocalories generates 20 kilocalories of new energy inflow if it interacts with the energy source. Thus, the feedback amplifier effect is 2/1.

The ultimate energy value of an energy flow, that is, its quantity times quality, maintains a constant value in a loop, where energy value is defined as the energy released value that the flow develops as it feeds back upstream (Fig.6, 10).

TWO ENERGY VALUES

It should now be clear to the reader that there are two energy values associated with each pathway that has amplifier intersections. There is the heat equivalent energy value of the flow were it dispersed into heat without interactive work on other energy flows. For example, in Fig. 6 and 11 the feedback alone has a heat equivalence value of 10 kilocalories per day. The second energy value of the same flow is the energy release value of the flow as and if it actually interacts with other flows. In the example of Fig. 6 the feedback loop has the energy amplifier or release value of 20 kilocalories per day. The ratio of these two energy flows may be regarded as an energy quality ratio. For values greater than 1 we may regard the energy as of high quality, and when the value is very high we may call the flow information, following the common custom of calling items of high energy release value information. These two Calorie values of the same energy flow are emphasized in Fig. 12. The "energy alone" value decreases down the pathway and around the loop but the "energy amplifier release" value is constant around the loop. For every intersection between a high quality energy and a low quality energy there must be one that has greater than 1 ratio of energy flow to output and one that has a ratio less than one. The flow that has a less than one energy quality ratio is usually regarded as the fuel energy source. Most layman's practice regards only this flow as energy.

If a system receives enough energy it may develop an excess of the ordered high quality product over and beyond that necessary for feedback to augment the flow. Such a system may accumulate the high quality product or export it to other processes as shown in Fig. 10. In that example, there is a net yield of 10 kilocalories per year of net high-quality energy yield.

ENERGY QUALITY SCALE

The behavior of complex energy systems results in the degradation of some flows while other flows are upgraded. These processes occur in chains so that a succession of transmissions degrades initial energies quantitatively while repeatedly upgrading small amounts of energy. Examples include food chains, chains of information processing, or hydrological eddy chains, etc. By using data for known energy processes as they have developed in real conditions of maximum power selection, and by arranging them in chains, it is possible to determine empirically the observed Calorie equivalents for generating one type of energy from another. These chains help us develop a conversion scale from the most dilute, low quality energy like sunlight through energies of intermediate quality like food or petroleum, to the most concentrated energy-releasing flows that we call information. See Fig. 13. One measures the Calories of energy input as a measure of the next step up in energy quality. Each stage in the energy quality chain allows us to calculate the Calories of the input-quality energy required to generate the higher quality energy output. Ultimately, one may refer the several qualities of energy in a system to their equivalent Calorie values of one type of energy or back to the incoming, most dilute energy; that of sunlight entering the earth surface.

When all energies are expressed as equivalent of one type, we can compare their ability to do work of that type. In some of our calculations of energy quality we have been expressing other energy qualities in units of chemical potential energy of carbohydrate food and fiber, since this is a label of Calorie data widely known in general nutrition usage and because it is at an intermediate energy quality in the scale between sunlight and information. However, the energy scale in Fig. 14 allows one to readily refer any energy quality to the energy that would be required to generate it from any other quality of energy. In dealing with questions of public policy, fossil fuel work equivalents are used as common denominator.

One corollary of the maximum power principle is the principle that high quality energies are not used for low or intermediate quality roles directly, but instead high quality energies are looped back as amplifiers on lower quality fuel energies to generate maximum energy flow. Thus one should not use protein as fuel, but should use the protein for enriching the nutrition of a carbohydrate source. One should not use electricity, a high quality energy, to heat a house alone, but should use it to operate heat pumps or other devives that can tap a second low quality energy source. One should not burn cookbooks to heat one's lunch. When we say "should not," we mean that systems that survive will not do these things because they will be uneconomic compared to competitors and will be eliminated by competition.

Our culture has been misled on the universality and severity of energy laws because during times of rapid expansion of new energy resources, such as petroleum, there is a relatively brief period when growing systems that are in energetic lead over competitors can and must generate many energetic choices including many that are wasteful and ultimately are selected against. The energetically ineffective choices are maintained during that period when the system is energetically richer than others up until the time that all available energy flows are being used and there is no longer a competitive race for expansion of energy using capacity. A sharp premium on competition against waste is reasserted as soon as the energy resources of competitors are similar. The generation of choice and competing alternatives is a property of any energy flow and is part of the continual hand-in-glove refitting of systems to their varying energy opportunities.

TABLES OF WORK EQUIVALENTS AND ENERGY COST-BENEFIT DECISIONS

Since flows of potential energy are the source of all value, then the energy values may be used as a measure of value that includes both items of nature without man's economy and those that are accompanied by the flow of money in man's economic system. As we have learned from the scale of energy quality one must convert all such values into the same quality of energy equivalent before making a comparison. Having done this one may examine the various flows of a system of man and nature to determine the relative energy effectiveness of the various flows to survival. If there are proposed changes in public enviornmental projects one may draw the energy network of the present system and the network of the system with the proposed changes, and calculate the total energy values for both cases to see which will generate the most work and thus which will be most competitive in natural selection. The system with the most useful work will be the one which will have the most viable and competitive economy. Since human economies depend in large measure on the unmonied flows of nature as well as the monied flows, it is the system that maximizes the total energy value that uses the most natural subsidies to the economic system making it viable, making its products cheap, and its balance of payments favorable.

Sometimes we call the tabulating of work equivalents as "energy cost-benefit analysis" since it is like the money cost-benefit analysis except this energy procedure includes all the work of the whole system and it evaluate external inflows that money does not. In making decisions about which system is most energetic over a short run one must also consider the energy costs of making the transition and energy flows that may be lost during transition periods.

Money circulates in closed loops whereas energy moves in from outside, makes loops and leaves as degraded energy. If the ratio of the flow of money to flow of energy overall were kept constant, the dollar would become an energy certificate. Only energy can be used to measure inflow of energy from deposits or from environment. If energy flowing decreases, money inflates.

The value of a flow of high quality energy is not realized unless the high quality items of material or information reach their useful intersection in some other part of the system since high quality information depends on its intersection with a fuel for its value to be realized. Written information, for example, is only valuable if it is read by the person able to use it in other energy roles. High quality energy is energy-costly to store and degrades readily.

EQUATIONS

The energy circuit language shown here has mathematical equivalents for the modules, pathways, and energy conventions and constraints and some of these are more fully treated in other chapters and elsewhere. The diagrams are visual mathematics with the constraints of the real world. The translations to more traditional mathematics of differential equations are needed only for communication of definitions in traditional terms with those new to the visual mathematics or when some procedure such as patching standard analog computers requires going through regular equations. In the next paragraph equations for flows of money and energy are given for several price conditions.

EXPRESSIONS FOR MONEY EXCHANGE AND PRICE

Depending on the situation there is more than one relationship between the flow of money and flow of bought goods and services (energy). Money is a counter current with the ratio of money to energy flow being price. Several alternatives for price control are given in Fig. 15, providing different behavior to model simulations depending on alternatives used. One example is the fixed price situation in which the flow of money generates a proportionate flow of energy, goods, and services. Money is considered to flow in proportion to its accumulation. The current tendency is for money to turn over about 4 times a year.

Where a model is of a small system imbedded in a larger one the price is not changed by the small system and the price becomes an external variable and forcing*function (Fig. 8). When a model is of a large system the flows of energy and the flows of money may have their own driving tendencies independently and the ratio of the two is the price generated by their relationship.

In another situation the competition among a variety of alternatives provides purchase from the pathway with the largest quantity (energy goods and services) for sale since it has the lower price. Price is inversely related to the quantity being sold and the resulting equation turns out to be a product of the purchasers money and sellers quantity. Where a balance of payment is required, the price of sales is adjusted to the price of purchases

In situations where the tendency to spend money is influenced by the quantity of goods and if the price is also dependent on the that quantity, then the flow of money increases as the square of quantity of goods offered for sale, and the money circulation becomes much more noisy. These and other equations are pertinent depending on the energy conditions controlling the system. The last price equation in Fig. 15 has effect of diminishing returns.

ENERGY INVESTMENT RATIO FOR ECONOMIC VITALITY

Sometimes we are asked why the maximum power principle would not cause energy-intensive fossil fueled urban economies to spread completely over the land. In places where urban growth has been extensive it has become dependent on outside subsidy. Many have asked why this was wrong and why it would not lead to economic vitality. The answer has to do with maximizing the power of the next-sized system. Each system can and must send out goods and services to external areas in exchange for a balance of payments of special return services that have equal augmenting effect. The development of the symbiosis enables the two areas to do more collectively than either alone since one complements the other if they are somewhat different in their production and offerings. Notice Fig. 15, which includes the sale of goods and services for money which must then be used to purchase special, high-quality, external energy. The system is maximized by getting the extra energy, but it cannot continue to develop additional external inflows beyond the point at which its sales are no longer competitive. When the ratio of energy from outside to that from inside is greater than is general in external competitors, the prices of sales will no longer be competitive and growth will stop. If there is overshoot, there will be depressed economic conditions. All energies in such comparisons are first converted to one quality: fossil fuel work equivalents. The investment ratio in Fig. 2 is 1.4 and any development which tries to put more purchased energies than in ratio 1/0.4 compared to internal energies supplied free will make the system non competitive.

As readily available world energy supplies become depleted this ratio will decrease with less fossil fuel attracted per unit of natural energies.

ENERGY MATCHING FOR THE WHOLE PLANET

For the survival of the whole system of man and the planet which is still in a peculiar regime of trying to expand usage of fossil fuels, some special procedures are presently needed to establish a more stable pattern of man and nature. The present pattern of competitors racing to tap the fossil fuel and other energy sources has the properties of competitive exclusion and instability characteristic of cancer. In the 1970's urban work is about 10% of the total global organic budget using heat units, but 72% of the total budget using fossil fuel work equivalents. It may not be safe for our industrial system to grow further, to overload the planet, and develop non-optimum energy usage patterns that are not competitive in the long run. The oil producing nations did the right thing for the world in 1973 when they set limits on rate of oil production. For stabilizing our present system and allowing the pattern of energy ethics to develop a survival pattern, we suggest an international plan for control of planetary energy and limiting the fossil fuel to that for which the present life support system can provide matching energy on the investment ratio principle.

Following the lessons learned from stabilizing ecological systems, and using the principle of matching purchased fuel ratio to natural energy flow, according to a world wide ratio we need to arrange through international process of treaty, United Nations, etc., a distribution formula for total fossil fuel (and nuclear fuel) for the planet. In the previous section we introduced the energy investment ratio as the criterion for predicting the amount of economic development based on purchased energy that would be competitive, maximize power, and stabilize the vitality of an economy. Extending this principle to the planet as a whole, energies could be allocated for sale to each part of the globe according to the level of free unpurchased energies, all being expressed in fossil fuel equivalents. Energies would be sold and economic development thus encouraged up to the point at which the purchased fuels ratio to free fuels was that of the world average. At present the ratio of purchased fossil fuel equivalents to free local fossil fuel equivalents in the United States is 2.5. Over the long run the ratio has to be set lower since fossil fuels are not enough to provide this ratio for the world for long. This plan would automatically induce conservation of free natural resources and environmental resource inputs as these would have to be maximized in order to maximize the fuels that could be bought. By having a formula, no one country could gain excess by virtue of being ahead in the scale of technological development.

Agreement from less developed countries may be achieved by promising a prorating of the fossil fuel and nuclear power of the world from its present distribution to one based on the amount of solar based energy in natural areas and in the agriculture that these areas maintain. In this way a premium is put on doing a good job with both. Agreement from the most industrialized countries may be achieved by showing that the prorating of power will eliminate the fear and waste of war and defense spending. If no country has excess power or opportunity to gain it, it has no opportunity for large scale aggression nor the fear of it. These measures could bring all countries an equal share of the planet's industrial power subsidies while utilizing existing solar patterns too.

By this reasoning, population is best regulated by controlling the systems input power rather than by influencing individuals in a billion bedrooms. Births are likely to adjust to economic realities which in turn are adjusted by the ceilings on fuel available for economic expansion. In short ecological language, the world with its input power flow stabilized will shift from its recent successional pattern to a climax (steady state). An even pattern of man and nature can develop again on the planet.

POWER EXPLOSION IF AN UNLIMITED ENERGY SOURCE DEVELOPS

Those with hopes for fusion and other new industrial energy ideas often speak of the desirability of an unlimited energy source. Unfortunately, the maximum power principle suggests that an unlimited power source would set off unlimited growth since those with such power excess would run over those attempting to limit growth but with less power than those growing. The principle of competitive exclusion and the characteristics of early successional growth that we have observed in the past two hundred years or that we observe in microbial cultures started with large energies would be set off again. With unlimited energy, the power comsumption of the planet could move from its present 10% of the solar budget to 100% and then 1000%. It is not likely that man's present ways or the life support system that has been capable of maintaining biosphere stability so far could do so with disturbance energy greater than the regular energy budget. Our life support protection from the seas and forests would be eliminated and as the planetary temperature and power increased so would the disorder and randomness that generates from high power flows. Something between the energy condition of the earth and the sun would result.

There are many scientists and politicians who advocate a continuing growth in industrial energies for this nation and the world, and there are many pressures for this growth. However, should such growth continue indefinitely, it would be increasingly at the expense of the biotic and other natural systems of the earth that support man. Such a system may be inherently unstable for man.

Fortunately, there are already limitations being placed on world power; the world's industrial energy growth may already be cresting into change towards a steady state or one of slowly declining energy as we have utilized the most accessible supplies of fossil fuels. Although a steady state based on renewable resources has different characteristics from our recent growth economies, the analogies in the natural world suggest that it can be a good state and one likely to be a good pattern for the life of man.

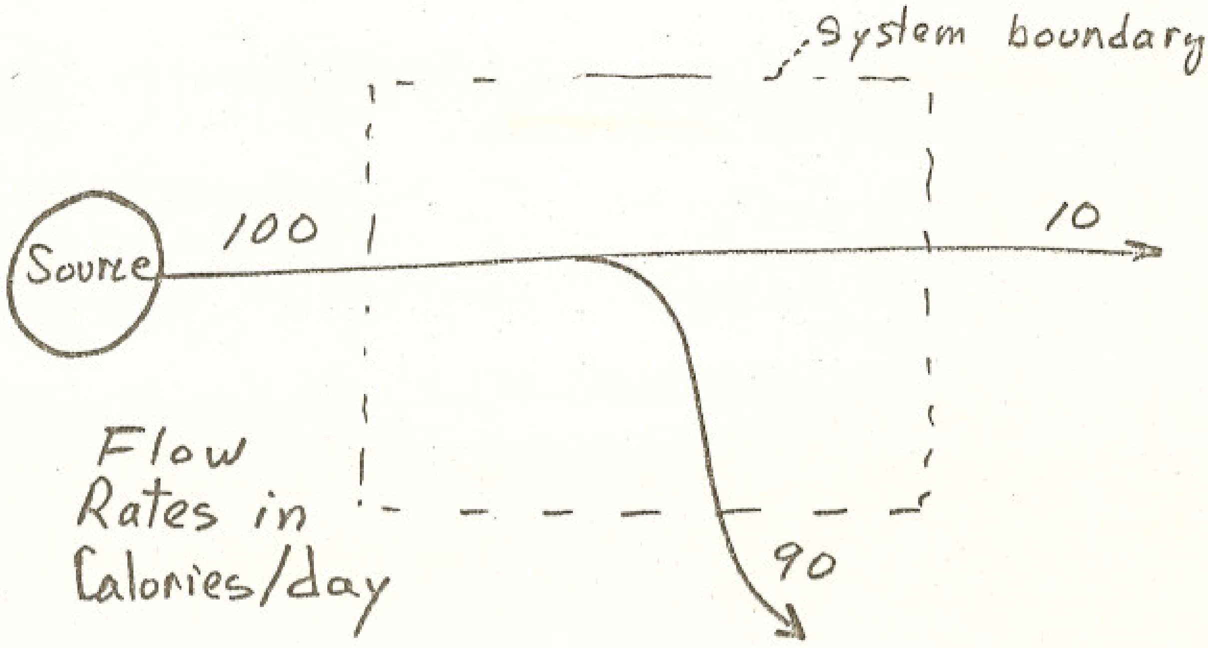


Fig. 1. Energy flow illustrating energy conservation principle.

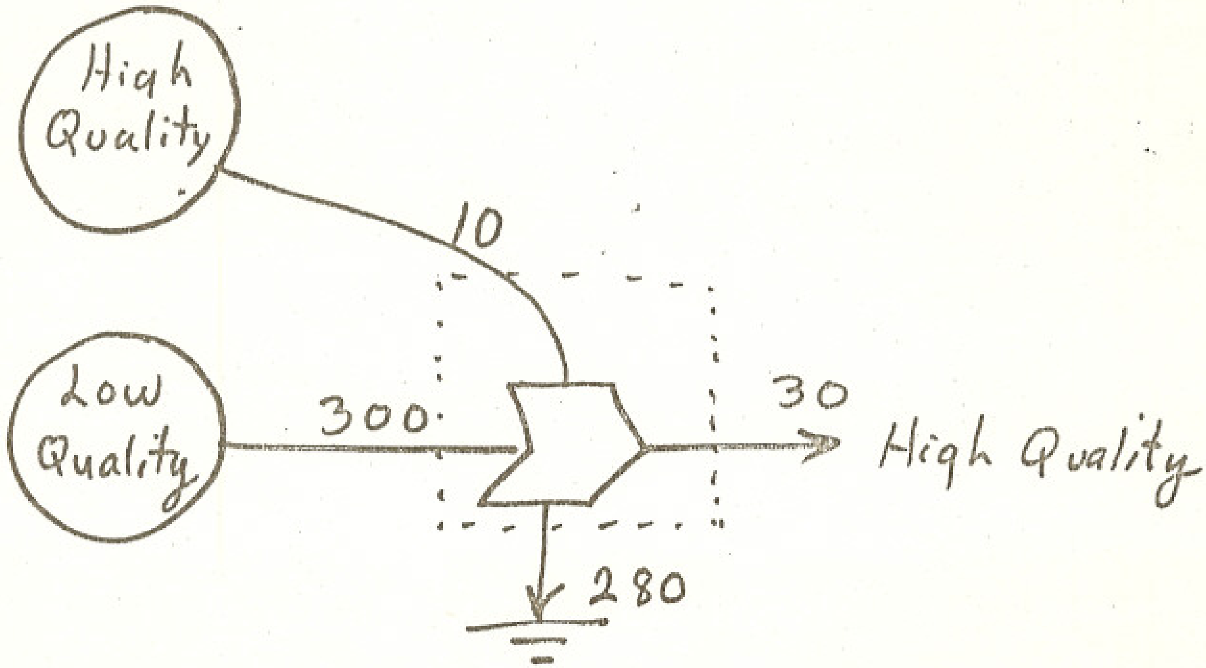


Fig. 2. Energy flow where one flow controls a larger flow both of which are essential to a high quality output to the right.

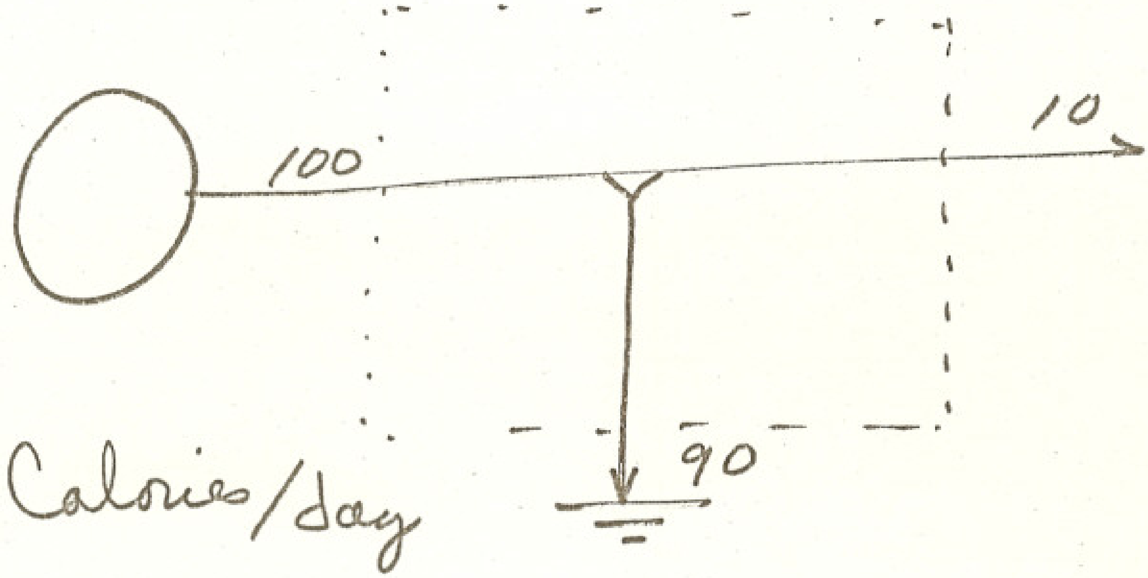


Fig. 3. Energy flow illustrating energy degradation principle.

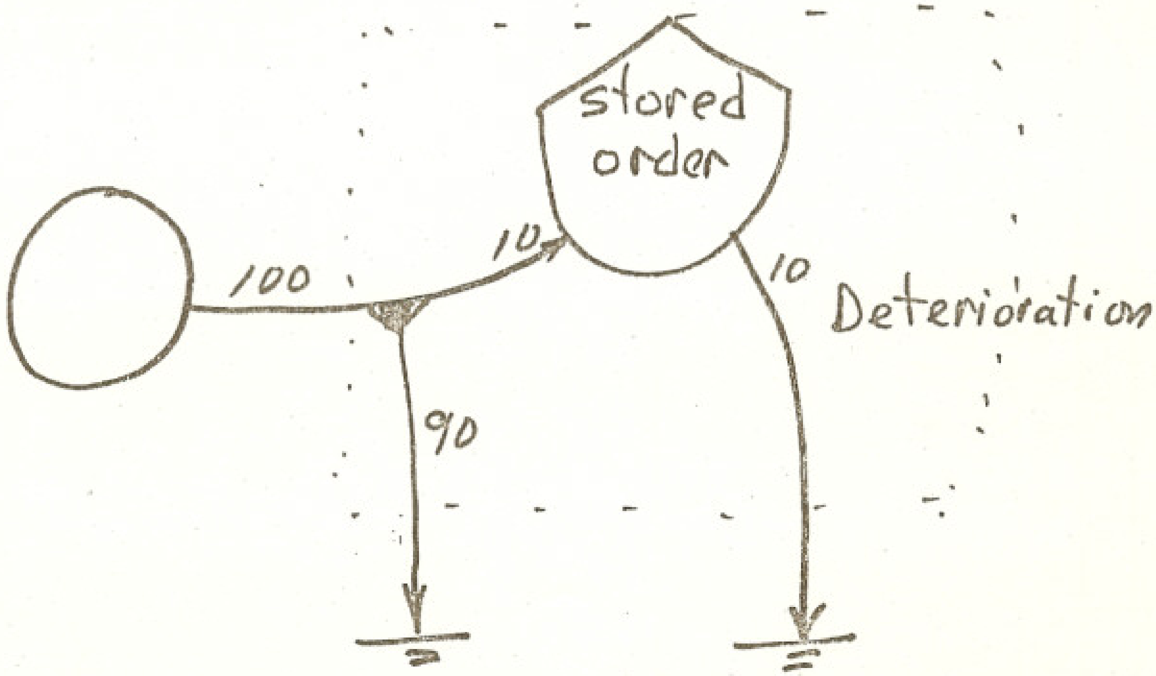


Fig. 4. Energy flow that stores high quality energy replacing that energy storage that deteriorates into randomness according to the energy degradation principle for all ordered storages.

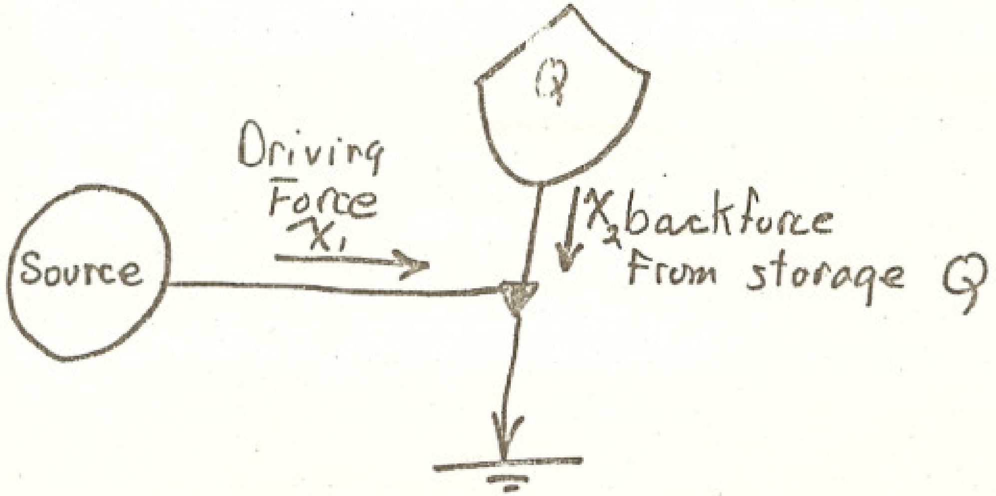


Fig. 5. Generation of new storage of potential energy under influence of driving force against the backforce due to storage. Flow into Q is:

$$J = \frac{1}{R}(X_1 - X_2) = \frac{1}{R}\left(X_1 - \frac{Q}{C}\right)$$

Where R is resistance and C is the packaging coefficient defined as force X_2 per unit quantity stored.

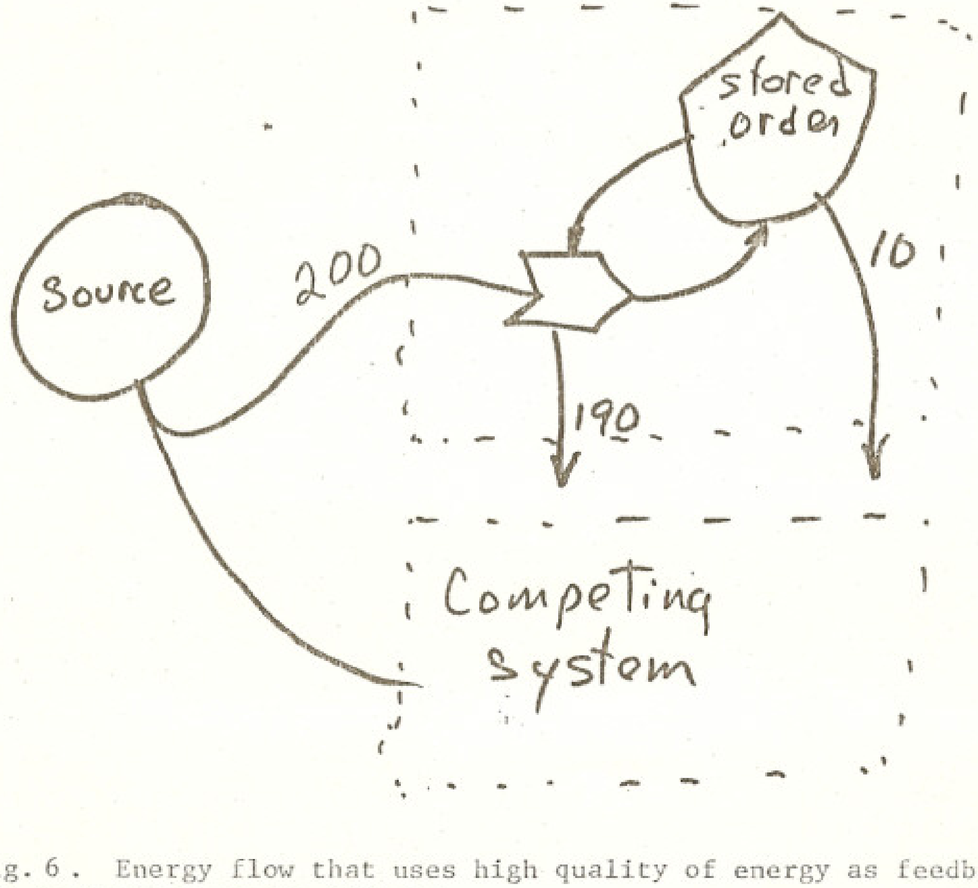


Fig. 6. Energy flow that uses high quality of energy as feedback amplifier and control on energy inflows.

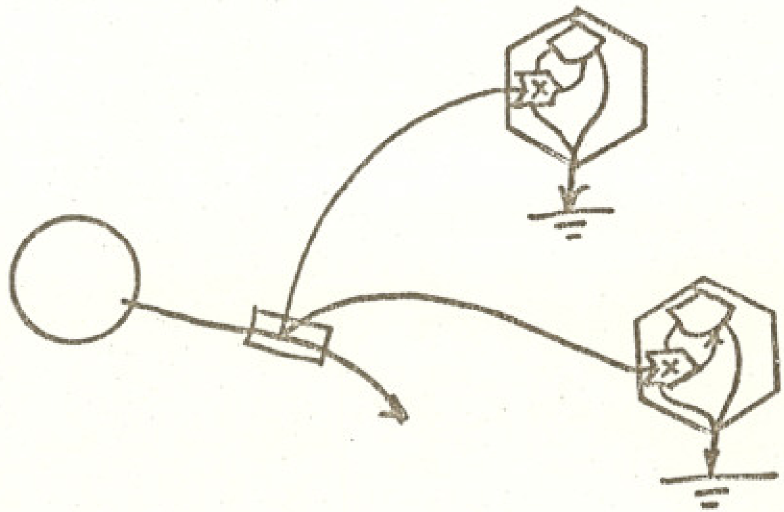


Fig. 7.Competition for limited energy source which leads to competitive exclusion.

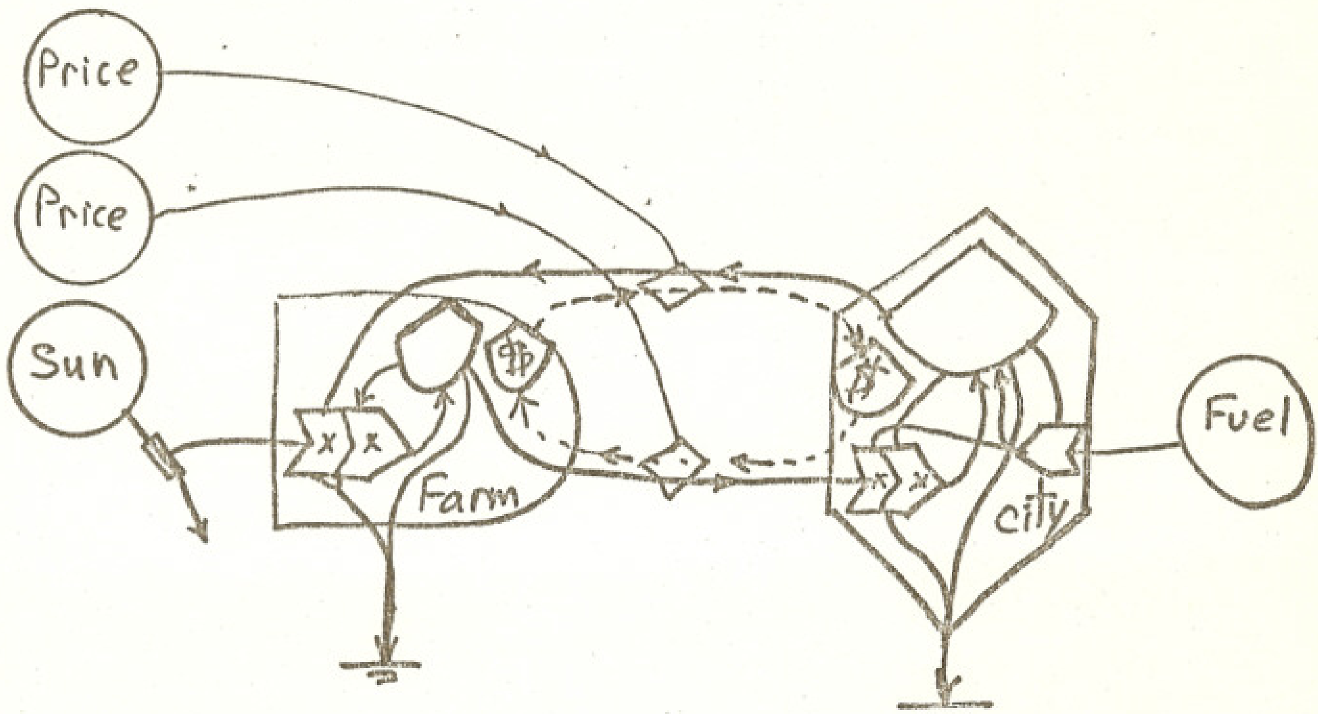


Fig. 8. Farm and City economy with solar and fossil fuel sources.

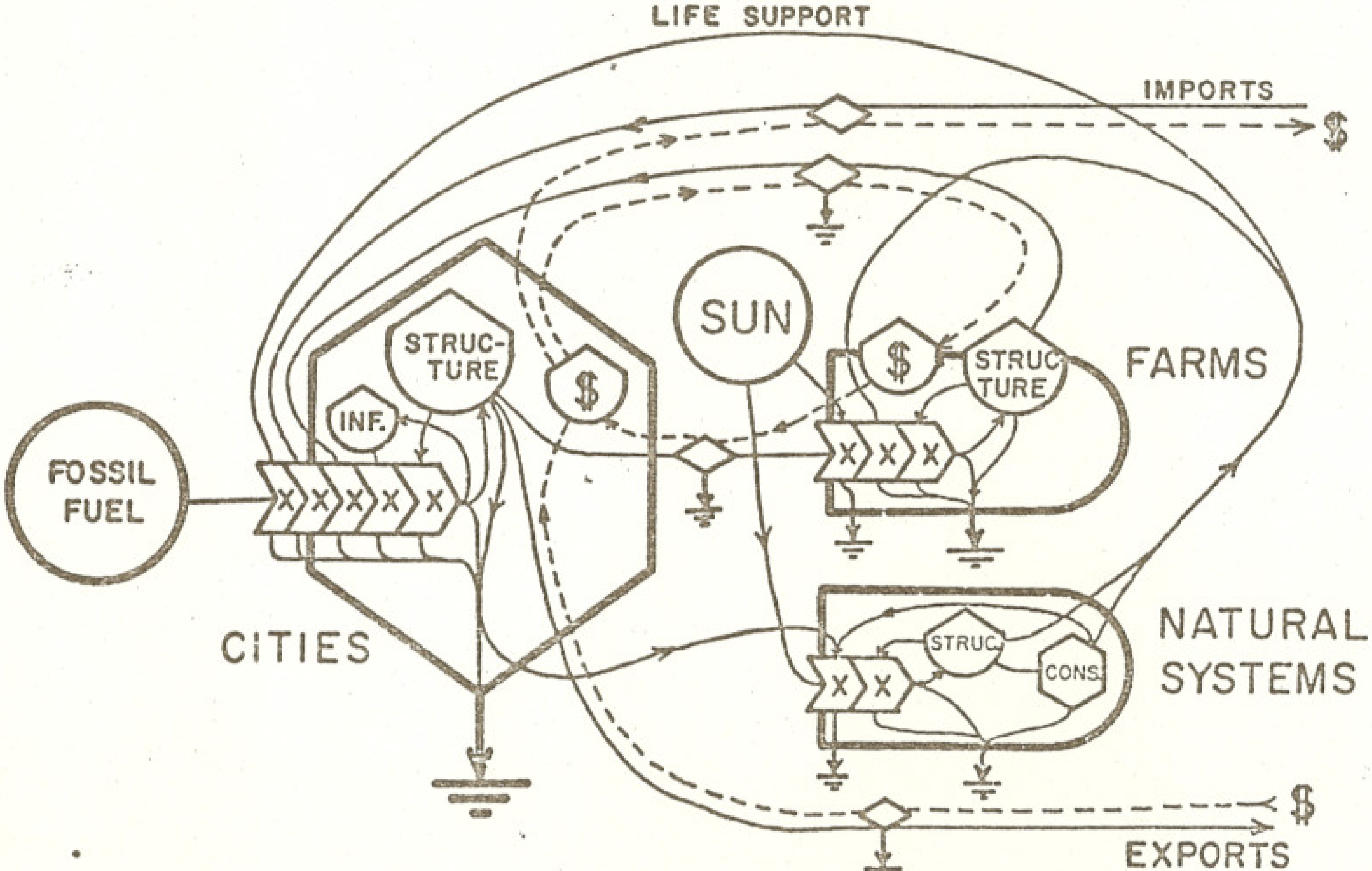


Fig. 9. General system diagram for energy basis for a country aggregated into urban, agricultural and environmental components.

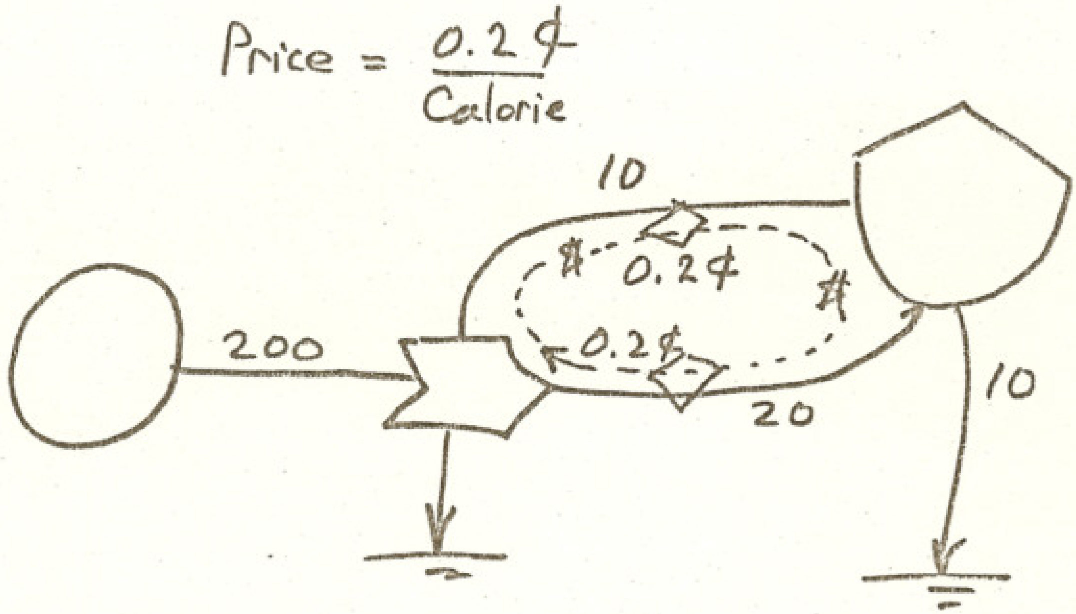


Fig. 10. Constant value loop with currency circulating.

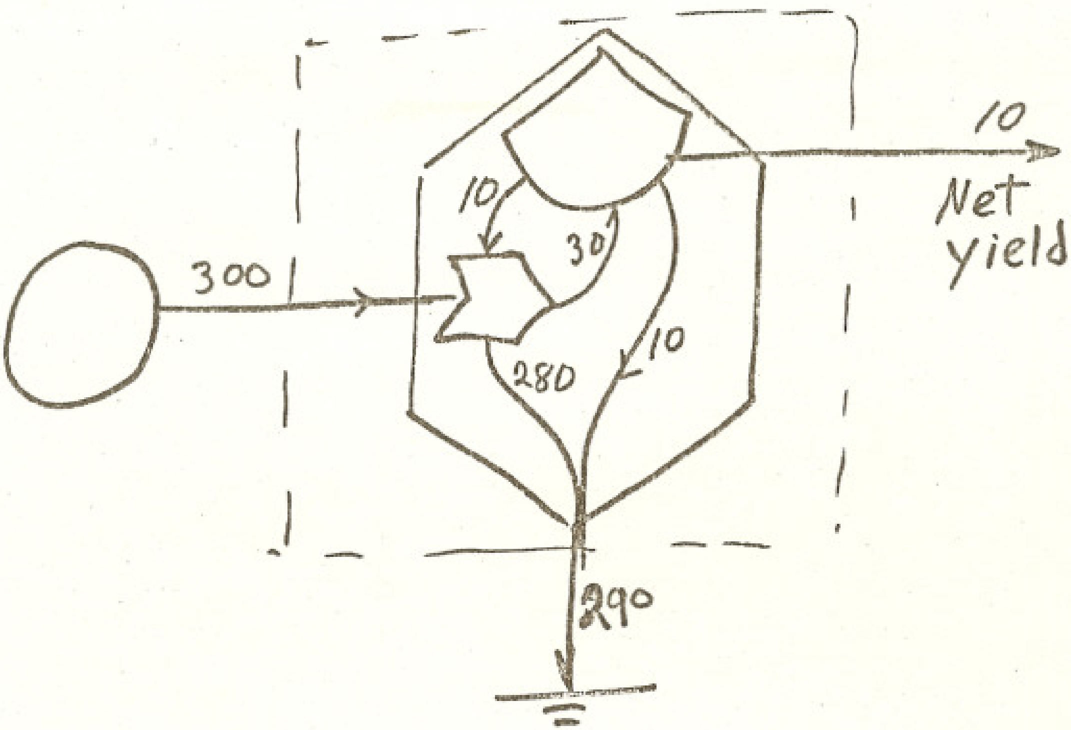


Fig. 11 Energy flow that generates a net yield export of the high quality energy of the type generated in the system for maintenance.

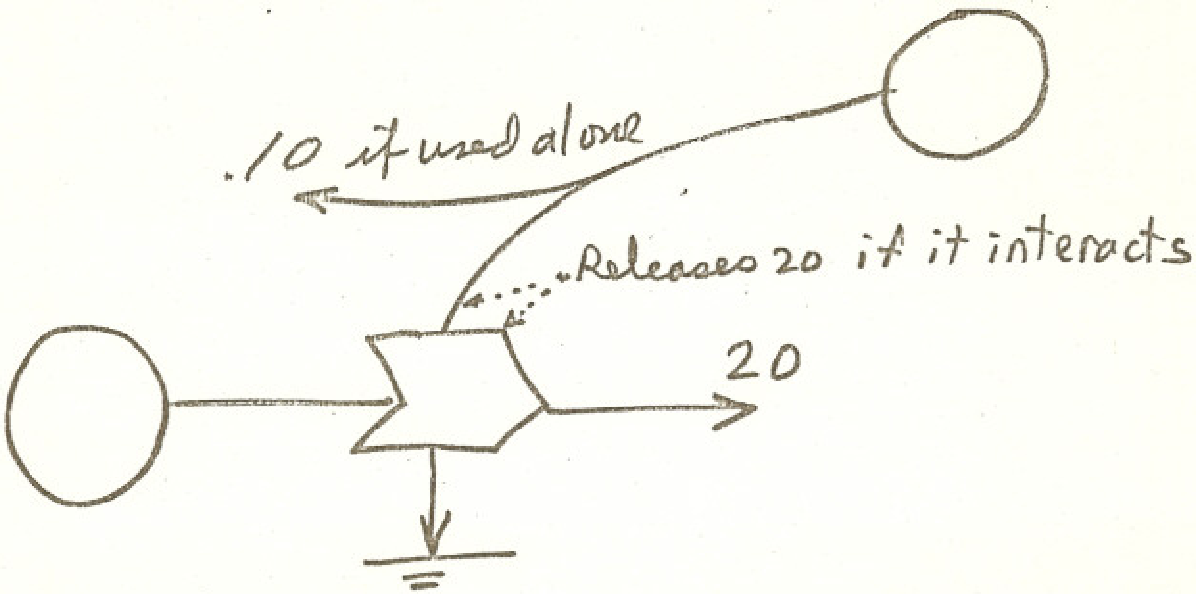


Fig. 12 Two energy values for a pathway: energy alone (10 Kcal) and energy release value (20).

$$\frac{\text{Type 2}}{\text{Type 1}} = 0.1 \qquad \frac{\text{Type 3}}{\text{Type 2}} = 0.1 \qquad \frac{\text{Type 3}}{\text{Type 1}} = .01$$

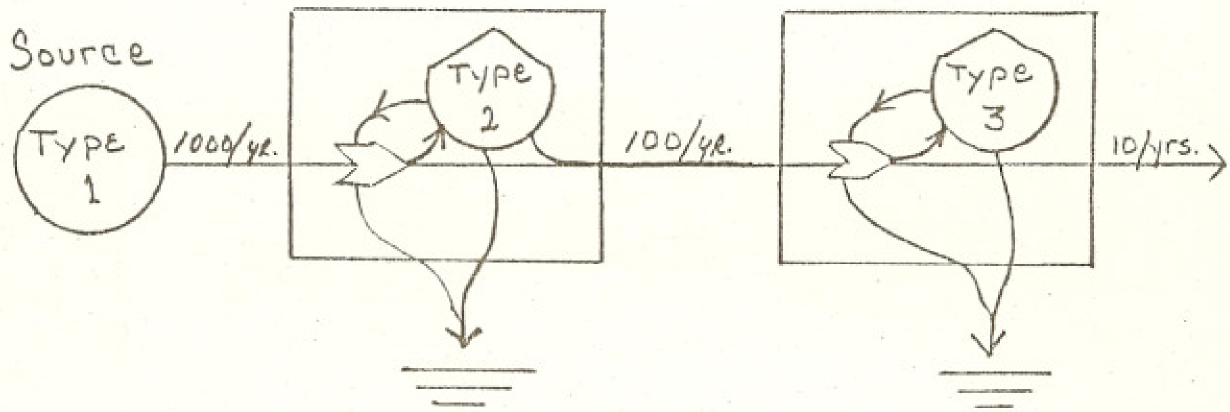


Fig. 13. Energy conversion factors are the ratios of conversions in steady state flows where energy costs of maintaining structure are paid from the inflow so that the energy chain is in a simple line.

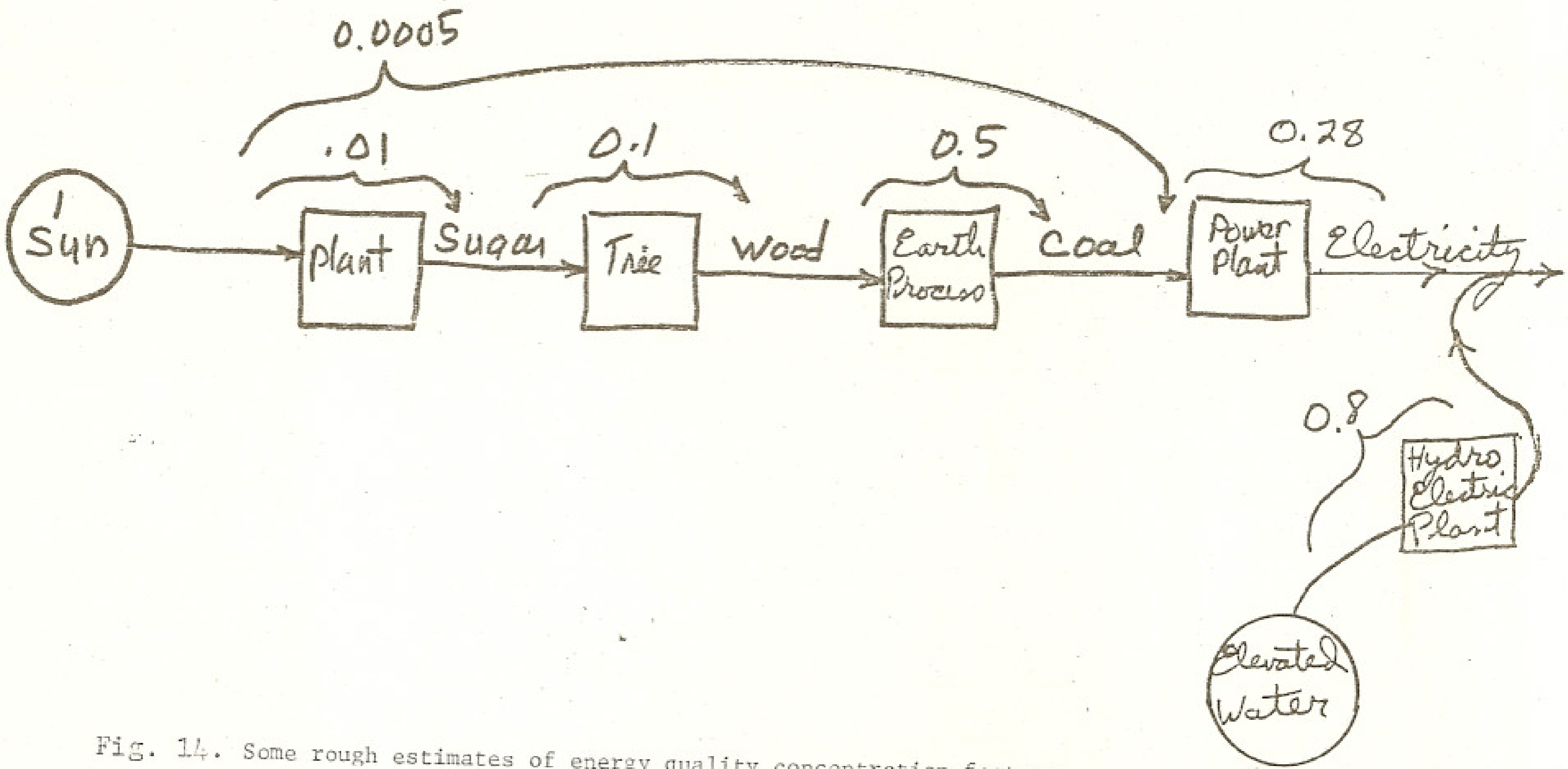
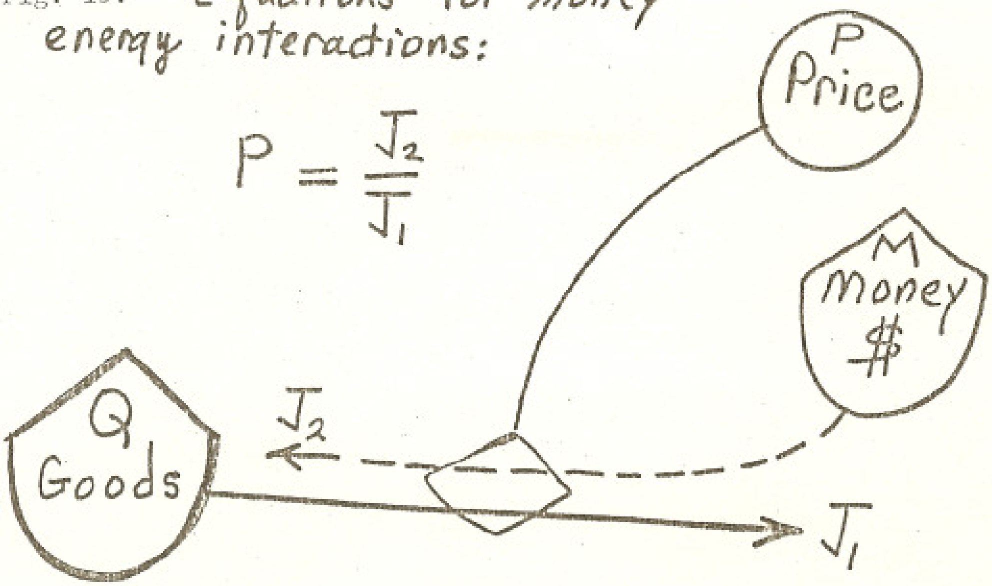


Fig. 14. Some rough estimates of energy quality concentration factors. Low Quality energy is on the left.

Fig. 15. Equations for money energy interactions:

$$P = \frac{J_2}{J_1}$$



Money tends to be spent 4 times per year

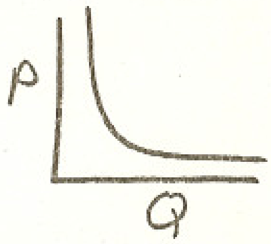
$$J_2 = k M$$

Price controlled externally

$$J_1 = \frac{k M}{P}$$

Price inverse to quantity of Goods for sale

$$P = \frac{K_1}{Q} \qquad J_1 = \frac{k}{K_1} M Q$$



Spending inverse to price also

$$k = \frac{K_2}{P} \qquad J_1 = \frac{K_2 M Q^2}{K_1^2}$$

Price variable with limit

$$P = \frac{k + Q}{K Q} \qquad J_1 = \frac{k K M Q}{k + Q}$$

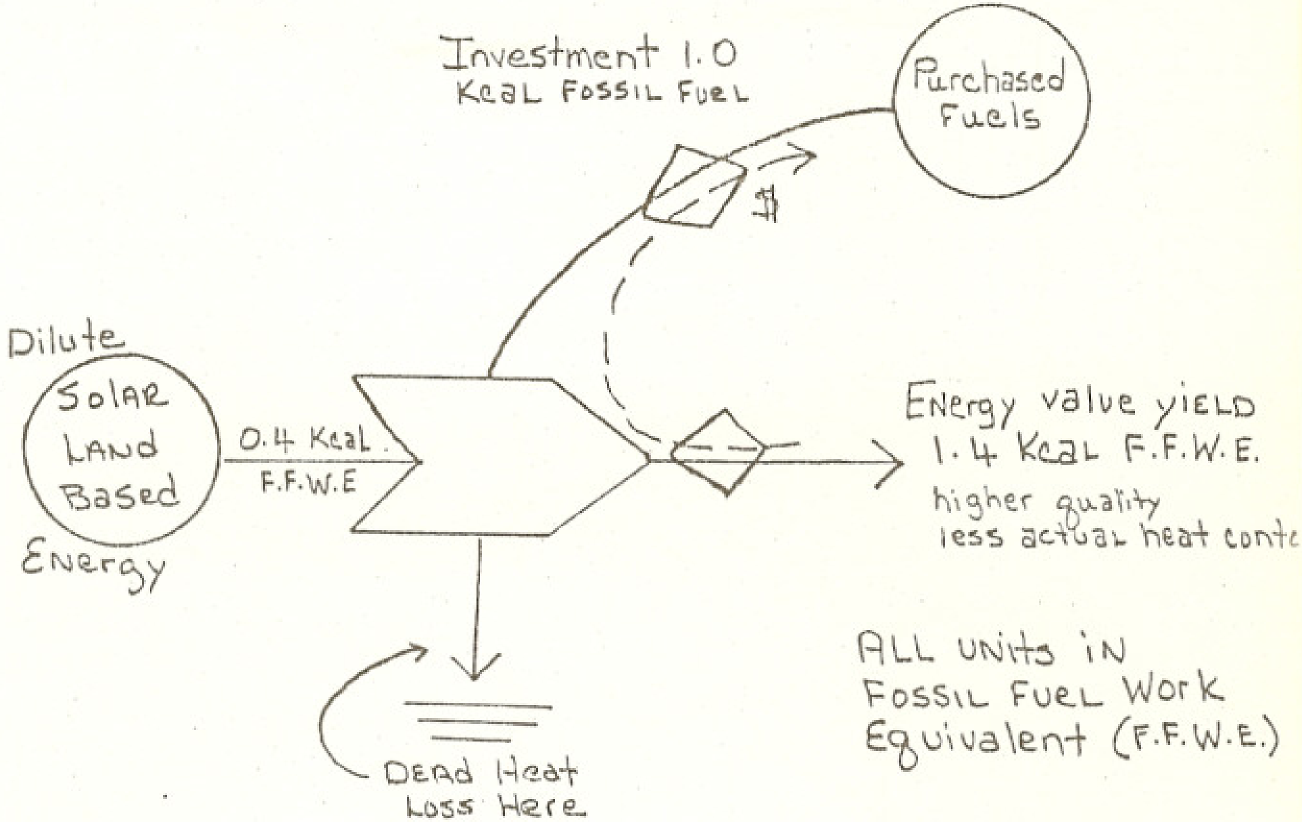


Fig. 16. Diagram showing competitive ratio in United States for balance of fossil fuel investment to output that is augmented by use of solar dilute free energy.

LIST OF FIGURES

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