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Energy Analysis of Flat Water Recreation: An Economic Assessment

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ENERGY ANALYSIS OF FLAT WATER RECREATION:

AN ECONOMIC ASSESSMENT

by

Craig Leon Howell

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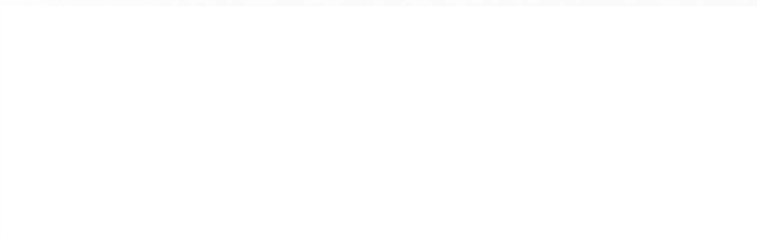of the requirements for the degree

of

MASTER OF SCIENCE

in

Economics

Approved:

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Logan, Utah

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ABSTRACT

Energy Analysis of Flat Water Recreation:

An Economic Assessment

by

Craig Leon Howell, Master of Science

Utah State University, 1984

Major Professor: Dr. E. Bruce Godfrey
Department: Economics

Energy analysts believe that traditional economics and
energy markets undervalue the only absolutely limited
resource, energy. They have produced methods to supplement
or supercede economics.

However, theoretical underpinnings of these methods
include an energy theory of value which is shown to be too
narrow to support workable economic models or numeraires.
Sample rankings of recreational values on four Utah
reservoirs, using energy analysis and economic methods, show
that the two methods yield opposite rankings.

(72 pages)

CHAPTER I

INTRODUCTION

Economics concerns itself with the efficient allocation
of resources. It is generally recognized that traditional
economics may not adequately deal with some problems of
allocation. Some of those problems include non-market
goods, externalities, imperfect or restricted markets and
intergenerational resource allocations (Bator, 1958, and
Scitovsky, 1954). Other disciplines have recognized these
problems and offered alternative solutions but these may be
no better than traditional economic solutions. One of the
alternatives that has been suggested is energy accounting or
energetics.

In the 1950s, Dr. Howard Odum, a systems ecologist at
the University of Florida, formulated calculations
suggesting that a research project using algae as an energy
producer was a net energy consumer because the project was
kept in operation only through the use of fossil fuels
purchased with research funds. Odum concluded that energy
tallies could give a more accurate reading of a project's
feasibility than economics. He subsequently constructed
engineering schematics for the energy flows in the economy

and environment. Other researchers soon joined Odum and
energy accounting was developed.(Clark 1974).

Energy accounting broadens the traditional engineering
input-output energy efficiency ratios to include the energy
inputs and outputs of the system under consideration. As
represented in Figure 1 which is a simplified schematic
diagram of energy origin, use and disposal, the accounting
procedures either ascertain how much energy is available to
final consumers (net energy --Y-F in Figure 1.) or how much
insitu energy is needed to deliver a given energy to the
consumer (gross energy -- G-F in Figure 1.)
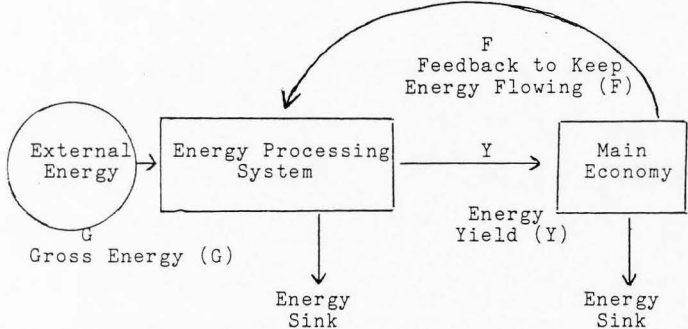
Figure 1.   Schematic representation of energy flows
            with net and gross energy shown

(Source Odum, 1977)

Within the last few years as public awareness of the
possibility of energy shortages grew, significant interest
has been manifested in energetics as a supplement to

traditional economic analysis. Energy accountants maintain that energy accounting delivers crucial information on energy scarcities not provided by traditional economic methods. Economics with the engineering, medical, sociological and environmental fields seeks to define the costs and efficiencies of resource decisions. The necessary data and models satisfactory to all are not easy to obtain nor are the correct policy implications easy to draw. Thus, energetics is a significant advancement if more accurate information or modeling results from it. Evaluation of energetic theory and methods is therefore important. An economically efficient use of resources will not occur when a market does not exist. One of the areas where markets often do not exist involves the provision of outdoor recreation. As a result, this area provides an example that can be used to evaluate the failure of a market solution and what energetic methods/methodology can add to the existing situation.

Objectives of Study

In order to obtain a clearer idea of the theoretical and practical utility of energetics, I propose to:

1) Evaluate energy analysis and methods from an economic point of view;

2) Estimate recreation values on the same reservoirs

using energetic and economic methods; and

3) Compare and evaluate the results obtained in procedures 1 and 2.

CHAPTER II

THEORETICAL FOUNDATIONS OF ENERGY ANALYSIS

Resource Scarcity

The U. S. conservation movement accepted the classical
economist's, Ricardo (1966) notion of absolute resource lim-
its but rejected laissez faire as an efficient means of
allocating natural resources. Men such as Pinchot and Muir
argued that government intervention with an eye toward the
welfare of present and future generations could improve on
the unfettered process of natural resource markets (Pinchot
1910).

The movement was successful in fostering conservation
legislation during the early 1900s (e.g., the Parks Act of
1907 and the CCC of the Roosevelt era). Concurrently,
another group, the technocrats (possessing a healthy disre-
spect for markets), developed under the leadership of Howard
Scott. This group wanted to replace the monetary system
with energy units. They argued that economic theory was
incapable of handling technological change and fluctuations
in resource availability.

Naturalist philosophy, the scarcity doctrine and the

technocratic ideology, suffered setbacks up until the late
1960s and early 1970s because many professionals associated
with natural resources were influenced by spectacular tech-
nological achievement and embraced the notion that tech-
nology would ameliorate scarcity and environmental difficul-
ties (Smith 1974, and Burt and Cummings 1970). However,
with the advent of the 1973 oil embargo and other supply
shocks, natural resource managers began once again to pay
particular attention to exhaustible resource stocks.

In fact, many now suggest that world resources cannot
support continued economic growth for several reasons (Ford
Foundation 1974). First, resources are not completely sub-
stitutable for each other. Eighty-two of the ninety-two
natural elements together comprise less than 1% of the
earth's crust (Brobst, et al 1973). Many critical indus-
trial elements comprise minute fractions. As a result,
shortages of some critical elements may develop (e.g.,
chromium). Meadows, et al (1972) were perhaps the first
technologist to use systems analysis techniques to forecast
the demise of civilization through resource depletion and
pollution.

Second, an increasing number of scientists suspect that
the traditional hypothesis that large quantities of lower
grade but minable ores are available is false. The tradi-
tional hypothesis is based on a unimodal ore grade
distribution in which larger amounts of lower grade ores are

available as smaller quantities of high grade ores are
depleted. This situation is depicted in Figure 2. The new
hypothesis (see Figure 3) is based on a bimodal ore grade
distribution in which only the high quality ores under the
right most curve in Figure 3 are minable. The more abundant
lower grade ores under the left most curve n Figure 3 wouldn't
be economically minable. If the new hypothesis is correct,
minable ores would be exhausted much sooner than has been
traditionally supposed.
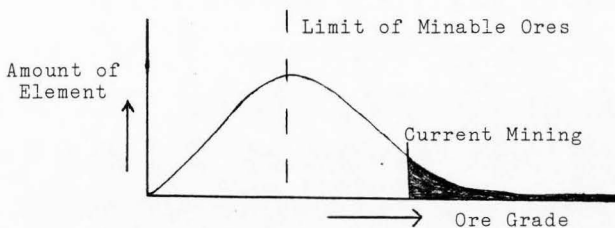
Figure 2. Traditional hypothesis of ore
distribution
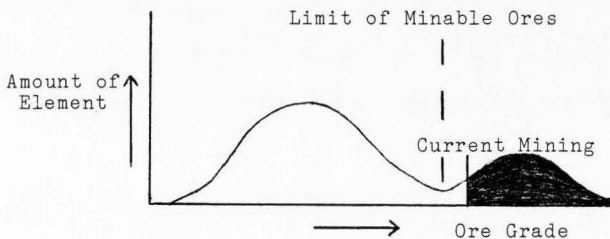
Figure 3. New hypothesis of ore distribution
(Source Skinner 1976)

Third, resource managers have recognized that given

foreseeable technology and energy constraints, the earth's nonrenewable resources will be exhausted in finite time if extraction rates are positive and nondeclining.

Resource Misallocation

Energy accountants assert that economics does not allocate finite resources and particularly the limiting one (energy) correctly (Cook 1975, Berry and Fels 1973, Clark 1974, Odum 1973, Slesser 1974 and Hannon 1975). The common assumption among these authors' arguments is that even competitive markets are often not energy efficient. Many tasks could be done at lower energy costs and energy inefficient markets should be curtailed.

For example, Hannon (1975, p. 96) of the Energy Research Group at Urbana, after noting that the relative cost of electricity decreased from 1925-1975, said:

> The point is two fold. The cost of electricity has failed to represent its importance in the market place and the situation has grown worse with time.

Barry Sedlik (1979, p. 30) stated that economists do not deal adequately with depletable resources.

> If the price goes up economists say you increase supply. But, increasing the energy supply is not desirable because you are dealing with a nonrenewable commodity.

Others contend that economic market models work well only when resources are infinite, Bell (1977), or when market planning horizons are infinite, Berry (1972).

Empirical evidence is offered. The studies of Berry and Fels (1973), Hannon (1975) and Pimentel, et al (1975) show that significant energy savings could be realized in the production of goods ranging from cars to crops. The concept shared by these researchers is that economics ignores energy constraints and therefore results in an inefficient allocation of energy resources.

In summary, the energetic view is that economics is penny-wise and energy-foolish--the ultimate long-run foolishness. Thus, some energetic researchers suggest that an energy theory of value be used to allocate energy resources.

The Energy Theory of Value

The energy theory of value holds that energy is the sole limiting production factor. Life exists on a slope between concentrated energy (low entropy) and dispersed energy (high entropy). The second law of thermodynamics states that irrevocable percentages of energy becomes unavailable for man's use as energy is processed by living organisms or degraded through natural processes. Therefore, finite energy resources are an absolute constraint. On the other hand, materials are not physically destroyed, but only changed. Given enough energy, they can be recycled. It is easily argued that we have the same amount of materials now as in the dawn of history. Berry (1972), Gilliland (1975) and Hannon (1975) conclude that energy is the most important

resource because it is the only truly exhaustible one. All others can be recycled or synthesized, given enough energy. Thus, the value of a good is simply the amount of energy used to produce it. Hannon (1975) asserts that only through adoption of an energy unit of value and appropriate restructuring of the economic and legal system can correct allocation of resources be obtained.

Many energy accountants do not think that adopting an energy unit of value and Hannon's other measures are necessary. Thus, at least three major groups have emerged who accept an energy theory of value in differing degrees.

Odum's group, including Gilliland and Hannon, take the strongest pro-energy theory of value position.

In his major work on energetics, Environment Power and Society, Odum (1971) suggests that:

1) All progress is due to special power subsidies; and

2) Power is the common denominator to all process and materials.

In a later work (1976, p. 30), H. Odum and E. Odum clearly state that energy is the mainspring of value. "It is not human beings and their money that determine what is important. It is the world's energy." Thus, energy is the sole determinant of efficiency. "The greater the net energy obtained by a process, the more efficient the process" (Odum 1973, p. 220).

Others elaborate Odum's hypothesis. Hannon (1975) suggests that energy intensive nations should raise the

relative price of energy to induce more labor intensive
technologies, thereby increasing energy productivity. Berry
(1972, p. 10) said; "It is desirable to minimize the con-
sumption of thermodynamic potential in achieving any goal."
This is the thermodynamic analog of the statement: "It is
undesirable to throw away money needlessly."

The second group of energy accountants say they reject
the energy theory of value but seem to tacitly accept it.
Slesser (1977), for example, states that outside the Odum
school, no one to his knowledge accepts the theory. He then
says that energy accounting is superior to economics in
forecasing energy requirements and thus in normative fore-
casting. From Slesser's statements it is clear that he does
not think the market energy values are high enough.
Economic markets may under value energy for several reasons.
First, markets may not account for related non-market goods
like pollution. Second, the true value of energy may not be
reflected by regulated or otherwise imperfect markets.
Third, markets might not allocate energy across generations
correctly. Fourth, markets which are influenced by sub-
jective human demand may not price energy at its true value.
Slesser does not mention the first two reasons. When he
criticizes economic forecasts of energy requirements, he
alludes to the intergenerational allocation of resources.
In addition, his faith in the normative superiority of ener-
getics and therefore an energy numeraire shows that he

thinks that the energy markets do not assign energy its true value. Therefore, Slesser appears close to accepting an energy theory of value.

The least sanguine group, including Bell (1977) and Bullard (1975), clearly reject the energy theory of value. They argue that energetics can play only a secondary role in project evaluation. Bell, for example, agrees that energy accounting is useful only when comparing similar projects for energy efficiency. Bullard (1975) states that energy accounting may be useful in much the same way as environmental impact statements are. It should be noted that this group views energy as a critical but poorly acknowledged constraint because there would be no need to emphasize energy if markets accurately reflected energy scarcity. Thus, this group implicitly assumes some type of market failure.

Definition of Names

Among energy analysts, there is general agreement that the second law of thermodynamics proves that finite energy sources are an absolute constraint. None have attacked the notion that energy is the only absolute constraint because materials can be recycled. However, disagreement exists on two concepts:

1) An energy theory of value; and

2) The use of energy analyses as a normative policy

tool.

Only Odum's group explicitly accepts the energy theory of value and its corollary that all values can be imputed to energy. Both Odum's group and some energy analysts like Hannon and Slesser argue that energy analysis is a normative policy tool. The last group, including Bell and Bullard, reject both concepts. Instead, they expand traditional engineering energy efficiency based on the Carnot engine cycle to include energy efficiencies of non-power producing goods and services. This group supposes no normative superiority. However, energy "efficiency" (abbreviated to efficiency in the literature) is at least an implicit goal. Hereafter, to facilitate discussion, those who explicitly or implicitly accept an energy theory of value, including Odum, Slesser, Hannon and the like will be referred to as ener-getists and their work energetics because of their normative approach. The second group, including Bell and Bullard, who simply expand the range of energy efficiency analysis, will be called energy accountants and their work energy account-ing. Energy analysts and energy analysis will be used to denote both groups and their work. Later sections that dis-cuss empirical methods will require the distinction between the gross energy accounting and net energy accounting schools. Net energy accountants are energetists. Some gross energy accountants, e.g., Slesser and Hannon, are energetists, while others, including Bell and Bullard, are

energy accountants.

Energetists who see energy analysis as a major replacement or supplement to traditional economics follow a logic and come to conclusions that can be summarized roughly in the following manner. First, non-living earth resources are finite. However, since energy can be used to recycle or process low grade minerals, energy is the ultimate limiting constraint. In order, then, to insure future welfare, we must conserve energy as much as possible. Present market forces do not recognize the critical nature of the energy constraint. Extra market forces must move the economy toward a steady state. To achieve this, the present decision matrix must be changed to reflect the importance of energy.

Energetics, using the more stable and accurate energy numeraire, reflects energy pre-eminence and should supplement or replace economics.

Two energetic conclusions are clear:

1) That energy accounting can improve intergenerational resource allocations; and,

2) That an energy numeraire is superior to dollar units.

Improving Intergenerational Allocation
Through Energy Accounting

Energy analysts assert that markets under value energy

and fail to consider finite fossil fuel stocks. As a result, the present generation squanders fuels and resources that should be left for future ones. Ecologists who espouse this position maintain that economies compete according to Lotka's principle (1922). This principle states that the system which survives is that which maximizes the useful power from all sources. This means that energy-inefficient but fast growing biosystems are adapted when new energy sources open but slower growing, more energy efficient biosystems are adopted once virgin energy sources are tapped and competition for available energy increases. Energetists agree that few new energy supplies are available and that economic growth is non-adjustive. A steady economic state with zero growth that husbands energy resources is the system that will survive, given present constraints. Odum (1973) suggests that unless such a steady state is approached now, ecological and cultural disasters are unavoidable and that energetics can correct the market myopia and help smooth transition to the steady state.

Energetists theorize that in a steady state, the energetic interest rate will be zero. A zero interest rate insures that present and future wealth is valued equally because it is impossible to save a current dollar to gain more than one dollar in the future. Positive interest rates, on the other hand, cause future incomes to be discounted, i.e., to borrow one dollar today one must give up

more than one dollar in the future. As a result, these
groups suggest society should not have a positive interest
rate for two reasons. First, energy is measured in units
that do not change over time. Hence, the inflation portion
of the interest rate is zero. Second, in a steady state, no
material gains are possible in the future through current
savings and therefore a dollar saved today cannot yield more
than one dollar in the future (Clark 1974).

Energy Units as Numeraire

Energetic advocates agree that an energy unit, be it
BTU, KWH, etc., is or should be stable. Two years or 1000
years from now, a unit of energy will still be a unit of
energy. This does away with the problems of inflation and
price movements due to changes in demand.

A classical example of the fallacy of market values is
that of oil shale. It was projected that when oil reached
$3.73/bbl, or $6.80/bbl, or $15.00/bbl, or $21.00/bbl, or
$25.00/bbl, (Bell 1977, p. 5), extraction from oil shale
would become feasible. Energetists argue that the energy
content of a BTU will never change. As a result, energy is
a more telling and stable numeraire. In the words of
Malcolm Slesser (1977, p. 259),

> Free market shale oil would never be economical until
> oil from crude has a gross energy requirement per bar-
> rel close that of oil shale

See also Gilliland (1975). Furthermore, because energy is

the only absolutely limiting factor, long term costing is
best done in energy units (Berry 1972 and Slesser 1977).
According to this view, energy analysis, because future
energy costs are more stable than future prices, is a better
indicator signalling future problems than discounted dollar
costs. This advantage is derived from the fact that work
values of energy are affected by technology alone which
changes slowly. "Technology will not help in five years;
will be of little help in 15; but can do anything in 50"
according to Teller (1976). On the other hand, dollar
values are more volatile being subject to changes in demand,
supply, technology and inflation.

Furthermore, energy analysts point out the difficulties
economics has with non-market goods such as pollution and
destruction of scenic areas. First, it is pointed out that
benefit/cost ratios do not measure all the effects of man's
action on his environment. Second, clearly the economic
measures can change drastically depending on such things as
the discount rate used and the relative evaluation of
aesthetic and recreational opportunities. Finally, using
dollars to compare environmental and social benefits and
costs is literally an exercise in comparing wild ducks and
super highways. Energetists express all values in terms of
the amount of energy used in goods produced or lost when the
eco-system is altered. At least three proponents state that
energetics is the true measure of environmental impact (Odum

1971, Berry 1972 and Cook 1975). Cook, for example, thinks
that the primary benefit of energetics is to arrive at
evaluations of externalities not based on aesthetics but on
energy value to society. Slesser (1975, p. 171), espouses
the strongest form of this dogma: "To measure the cost of
things in money" which is, after all, nothing more than a
highly sophisticated value judgment, "does not offer a firm
basis for evaluation." Berry adds (1972, p. 9):

> Actually, if economists were to look at scarcity in a
> more complete way, their estimates would come closer
> and closer to the estimate of thermodynamicists.

In summary, energy analysts maintain that economics
overlooks absolute energy constraints and as a result,
misallocates resources. To correct these problems, ener-
getists suggest employing an energy theory of value and the
resulting energy numeraire to correct resource misalloca-
tions. Energy accountants urge greater use of energy effi-
ciency ratios in project evaluation. Procedures which
energy analysts have developed to facilitate their sug-
gestions will be explored in the next chapter.

CHAPTER III

EMPIRICAL METHODS USED BY ENERGY ANALYSTS

Energy analysts disagree on some issues and as a result
have developed several empirical methodologies.

When Odum and others developed energetics, several
questions arose. For example: Should the sunlight and
labor be included in energy calculations; should the empha-
sis be on maximizing the energy available to consumers or
minimizing the insitu energy used to produce final energy;
what energy units are to be used; what conversion between
energy sources is correct; how are material resources such
as metal to be valued in energy terms; how is energy mea-
sured?

These questions caused divisions among the supporters
of energy analysis. The situation is so undecided ener-
getist P. F. Chapman (1974a, p. 91) said: "There are as
many methods as there are workers in the field." However,
there appears to be two main schools. Odum and his follow-
ers assume that energy is the only limiting factor in an
economy. They therefore include sunlight and labor in their
accounts because both represent energy input. Odum's group
usually employ net energy analysis which seeks to find the

net energy available to the consumer.

Others including Slesser (1976) and Bullard (1975) theorize that energy is important and is under represented in economics but for project analysis, the energy contained in sunlight and labor is disregarded because both are present whether or not a project is built. This group is generally referred the gross energy accountants. They adhere to the methodology of the International Federation of Institutes for Advanced Study in Sweden (IFIAS 1974). IFIAS views energy accounting as the determination of the energy sequestered in the process of making a good or service.

On a practical level, both major schools represent a duality; maximizing available energy to consumers is the same as minimizing energy insitu used per unit of final energy consumed. As a result, both methods have complimentary strengths and weaknesses. Net energy analysis focuses on energy delivered to consumers and does not evaluate the efficiency of the processes. Gross energy focuses on efficiency of providing energy and says nothing of total energy delivered to consumers.

A list of four energy analysis objectives is provided by Chapman (1974a, p. 94):

1) To analyze particular processes in detail to deduce an energy efficiency and hence make recommendations for conserving energy;

2) To analyze the consumption of energy on a large

scale either to forecast energy demand or to point to policies which could reduce future demand;

3) To analyze the energy consumption of basic technologies such as food production and mineral extraction to show some of the future consequences of technological trends or an energy shortage; and

4) To construct energy costs and examine energy flows so as to understand the thermodynamics of an industrial system. This type of long-range aim may be coupled to projects such as "world modeling" based on physical rather than monetary flows.

These general objectives are listed hierarchially so that a study under objective one could be part of a larger one under 2, 3 or 4. Energetic studies include all four objectives. Energy accounting studies include objective one and possibly two.

Regardless of ideology, researchers use four basic methods to carry out studies. First, energy analysts estimate costs of many energy intensive goods through basic research. Examples of this method include Bell's (1977) estimation of BTU/CY of concrete and earth work and the Colorado Energy Research Institutes' (1976) study of nine fossil fuel applications. The major problem with this method is that it is time consuming and requires expertise in the targeted processes.

Second, investigators with little time or expertise

find costs of many industrial items by referring to
statistical tables supplying energy consumed per unit of
output. Results are often order of magnitude estimates
because the energy used to process primary energy sources
and capital depreciation are not included in the estimates.

Process analysis is a third method used by energy
analysts. Analysts first identify all processes contribut-
ing to the final product. (See Figure 4.) Each individual
process is then studied to identify its inputs. Finally,
each input is assigned an energy requirement and the total
project energy is obtained through addition. Process
analysis suffers from three main drawbacks. First, arbi-
trary decisions about the system boundaries must be made
such as the limits of boundaries 1, 2 and 3 in Figure 4.
Second, energy values for some inputs are difficult to esti-
mate. Finally, the economy is often so complex that every
important secondary or tertiary input is not found. There-
fore, process analysis is often truncated at the primary
inputs.

The fourth method uses the national input-output (I/O)
tables to estimate energy requirements. An entry in the
Table X_{ij} represents the dollar amount of good "i", needed
to produce a dollar of output "j". (See Figure 5.)
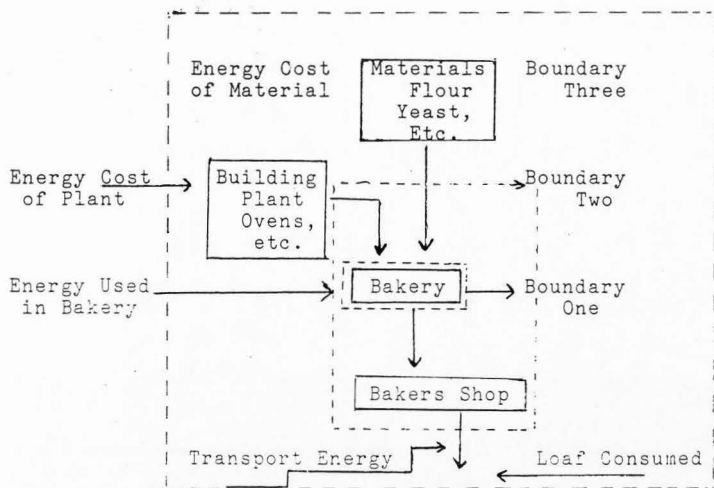
Figure 4. Boundaries for process analysis
(Source Chapman 1976.)

$$
\begin{array}{cccc}
X & x & P & = & B \\
\begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ X_{n1} & \cdots & X_{nn} \end{bmatrix} & & \begin{bmatrix} P_1 \\ \cdot \\ \cdot \\ \cdot \\ P_n \end{bmatrix} & & \begin{bmatrix} B_1 \\ \cdot \\ \cdot \\ \cdot \\ B_n \end{bmatrix}
\end{array}
$$

Figure 5. Mathematical model of an economy's
energy budget

For a given set of outputs, say vector P, the input
requirements, vector B, can be found by multiplying matrixes
X and P; that is:

$$XP = B$$

All goods (vector Z) needed to produce B can be found by the

same method:

$$Z = BX = X(X(P)) - X^2 P$$

Hence, all direct and indirect inputs used produce output P are:

$$XP^1 + X^2 P + X^3 P \ldots + X^n P$$

This series can be summed (Chiang 1974) and is equal to:

$$P(I-X)^{-1}$$

The result is that all the energy inputs for any given output can be obtained by multiplying the matrix $(I-X)^{-1}$ by an appropriate energy conversion (vector E) to obtain energy requirements e:

$$e = E(I-A)^{-1}$$

The energy research group located at the University of Illinois at Urbana (1980) developed energy requirements for all 357 goods listed in each of the 1963, 1967 and 1971 United States I/O tables. Chapman (1974b) developed less complete data for the United Kingdom.

There are some disadvantages to this approach as well. Clearly, the I/O tables are highly aggregated. Another disadvantage is that the I/O data is in dollars, not physical, units. This can lead to errors if goods have large transportation costs or price fluctuations. Furthermore, energy data derived from dollar denominated I/O tables are no more accurate than the data from which they are derived.

However, I/O tables have greatly speeded energetic analysis. Before tables were available, workers had to

analyze the process by which each good was made to assign energy costs. The tables make it possible to truncate the process whenever little information is available on the inputs or they appear to be relatively energy unintensive. Many examples of energy analysis are available from the University of Illinois Energy Research Group (1974). We now turn to the evaluation of the theoretical constraints of energy analysis models.

CHAPTER IV

ECONOMIC ANALYSIS OF THEORETICAL FOUNDATIONS

Much economic research has studied resource scarcity,
misallocations, theories of value and intergenerational
allocations and numeraires. Several problems remain
unresolved. Each issue will be examined and the potential
contribution of energy accounting will be discussed.

Resource Scarcity

It must be noted at the outset that there is debate as
to whether resources are truly finite in historical time.
Peterson and Fisher (1977, p. 692) state that:

> Minerals are like the juice in an orange. The total
> amount extracted depends on how hard the orange is
> squeezed and there is always a little left behind. . .
> this relates to the definition of reserves, the known
> amounts of a mineral that can profitably be recovered
> at current prices.

Mineral discoveries, technical change or price increases can
therefore increase reserves (Brobst, et al 1973). Barnett
and Morse (1963) wrote the seminal work on this subject.
They pointed out that in the period of 1870-1957,
tecnological progress and new resource discoveries
outweighed the higher costs of lower quality and

inaccessible resources in agriculture and mining. Their thesis was simply that the inseparable role technology plays in modern economic growth can circumvent both Ricardian and Malthusian scarcities.

More recently, Nordhous (1974) showed that relative prices of eleven minerals have fallen vis-a-vis labor since 1900. Substitution of labor and capital for natural resources and cheaper more abundant raw materials for more expensive materials are documented by Rosenberg (1973) and Humphrey and Moroney (1975).

Others have echoed this theme, i.e., resource stocks can only be defined in terms of technology. The most extreme view was expressed by McAvory (1979, p. 1): "Ultimately, there is no such thing as a nonrenewable resource." Cautions and dissenting opinions have been offered. Vernon Smith (1976) states that the rate of decline in mineral prices has tended to diminish in absolute magnitude over time. Mineral reserve studies also ignore environmental costs of mineral extraction (Fisher and Peterson 1976).

Georgescu-Roegen (1971) warns against extrapolating Barnett and Morse's data because it covers an abnormal period in which resource discoveries outstripped the ability to use them. Because low entropy (energy) is the "taproot of economic scarcity," any pricing system market or energetic will ultimately fail once the theoretical limits of usable material and energy are reached.

Even if critical shortages of materials or energy will lead to civilization's demise, the issue is whether energetics provides a better estimate of finite resources.

Economists recognize that reserve estimates need improvement. Peterson and Fisher (1977) and Herfindahl and Kneese (1974), for example, suggest closer collaboration with geologists on reserve estimations. Although energetists including Gilliland (1975), Berry (1972) and Odum (1973) agree that energetics provides better reserve estimates, they have yet to advance their own reserve estimates. In addition, a major conceptual problem awaits their efforts. Energetists define reserves in energy units while markets, if not society, define reserves as that which is recoverable, given current prices and technology. Prices reflect human tastes and.preferences (demand) and the human effort needed to procure goods and services (supply). Energy units do not reflect human desires or toil and as such cannot serve as a guide to the maximization of human welfare. Georgescu-Roegen (1979) shows a priori that energy analysts cannot provide better estimates of resource reserves that are economically exploitable. His analysis is reviewed on page 38.

Resource Misallocation

Energetists argue that economics is not efficient in an energy sense and thus misallocates resources. Few

economists equate energy efficiency with overall economic efficiency. Economic efficiency is a measure of the preservation of all resources with respect to the lowest dollar cost per unit of output. Thus, economic efficiency implies energy efficiency but not vice versa. For example, market forces dictate that a firm uses each resource "efficiently" relative to the other scarce resources employed in a process.

Let a firm make good (G) with labor (L) costing PL and energy (E), costing PE. The cost of producing a good (PG) can be found using the equation:

$$PG = (PE)(E) + (PL)(L)$$

If a unit of energy costs $1.00 and a unit of labor $5.00, relative efficiency dictates that six units of energy will not be used for a job that one unit of labor could do because energy to accomplish the job would cost $6.00 while labor could accomplish it for $5.00. Similarly, using 1/4 unit of labor to do what one unit of energy could do would be economically inefficient. In fact, market competition forces the firm to use resources in a ratio that equates marginal output per unit of resource cost for all resources. To employ resources in any other manner would mean that the output could be produced more cheaply by employing more of the factors that have a greater marginal product per dollar and less of those with smaller marginal product per dollar.

$$\frac{\text{Marginal Product of Labor}}{\text{Price of Labor}} = \frac{\text{Marginal Product of Energy}}{\text{Price of Energy}}$$

Therefore, economic efficiency implies efficient use of all resources in the sense that all resources are used to supply human desires, given relative resource prices and industrial techniques at the lowest overall cost.

Efficiency as espoused by adherents of the energy theory of value dictates that output per unit of energy expended be maximized. This definition of efficiency ignores the other constraints (in the example, Price of Labor) and is therefore economically inefficient. The theoretical basis for energetic efficiency is that energy is the only absolute constraint and therefore maximizing output per energy expended is efficient from man's point of view.

Economists do not ignore material constraints. However, economists agree that markets may waste resources or be "inefficient," depending on one's normative assumptions, and may misallocate resources in cases of monopoly, non-market goods, government regulations, externalities, commonly held resources and the like (Bator 1958, Scitovsky 1954). In response to these shortcomings, economists have developed several models to assess and correct market failures in non-renewable resource allocations. Highlighting of the relevant models follows. Gray (1914) formulated the first comprehensive theory of exhaustible resources. Despite the model's static nature, Gray was able to project price time

paths and the effects of taxes on the dynamic mining indus-
try. In his seminal work, Hotelling (1931) developed the
first dynamic model, i.e., one that would optimize present
and future extraction of a nonrenewable resource. More
recently, Gordon (1967) and Cummings (1969) used dynamic
modeling to determine optimal resource extraction rates.
These authors concluded that mineral reserves are capital
assets that receive a normal rate of return, i.e., are effi-
ciently utilized in an economic scene in the absence of mar-
ket imperfections. Hotelling (1931), Stiglitz (1976),
Sweeney (1977) and Weinstein and Zeckhauser (1974) have used
models to predict monopoly extraction rates without con-
census as to whether it produces an extraction rate greater,
lesser or equal to a free market.

Koopmans (1974) modeled extraction rates as interest
rates increase and concluded they would increase. Others,
e.g., Krutilla (1975), suggest that if exploration or other
large investments are needed to increase extraction,
extraction will decrease when interest rates rise.
Hotelling (1931), Herfindahl and Kneese (1974) agree that
exploration for reserves is decreased when exploration gives
neighboring property owners free mineral deposit informa-
tion. Schulze (1974) and Weinstein and Zechhauser (1974)
show that, with some caveats, a free market results in the
optimal amount of recycling. Ayres and Kneese (1969),
Fisher and Peterson (1976), among others, explore the

interaction between environment and resource extraction. Dasgupta, et al (1976) model extraction rates in the face of uncertain future demands and technology.

Such models suggest methods to correct misallocations and raise additional questions. More importantly, they show that markets allocate nonrenewable resources as well as other resources. Energetics has not developed competing or complimentary models. The energy theory of value will be examined to ascertain if it can support such models.

The Energy Theory of Value

One or more of the following criteria must be met if energetics is to replace or supplement economics:

1) Energy is the true limiting factor and as such is more important than traditional economics holds;

2) Energy is the only ultimate source of value;

3) The tools of energetics, e.g., energy numeraire and energy evaluations of environment, are superior to their economic counterparts; and

4) An energetic model reflects the world better than economic models.

Energy as an Absolute Constraint

Energetists claim that material dissipation can be completely reversed, given enough energy. Therefore, energy is the single absolute constraint. Several physics concepts

contradict this logic. First, the Heisenberg uncertainty principle (1927) showed that at the subatomic level, it is impossible to simultaneously observe the position and velocity of an object. The determination of the position depends on the ability to observe it. But, observing such small particles, even with something as delicate as light waves, changes the velocity of the particle. Thus, there is a theoretical lower limit to the size of particles which can be observed and gathered. Georgescu-Roegen (1979) arrives at the same conclusion using different means.

There is a strict material energy dichotomy. Energy cannot be used to purify materials indefinitely because Planck (1932) showed that no gas, liquid or solid can be freed from the last traces of foreign contaminating substances. Exceptions can occur only at absolute zero. But Nernst's third law of thermodynamics showed that absolute zero cannot be obtained. Georgescu-Roegen (1971) offers other (though more controversial) reasons. First, processes are perfectly reversible only if perfectly reversible machines exist; but, perfectly reversible machines must be frictionless. Frictionless machines exist only if the process is infinitely slow. Thus, no useful work can be derived from them. Second, in order to derive benefit from energy, material receptacles must be used. As the receptacles wear out, an infinite regress of materials is needed to process the energy. Finally, these physical

concepts demonstrate that materials and energy are limiting factors. If this is true, preoccupation with the energy theory of value is counterproductive.

Energy as the Sole Source of Value

To economists, the most serious problem with the energetic approach is that some energetists attempt to, in Hannon's words (1975, p. 101), "maximize productivity per energy unit" expended rather than social welfare. Economist Georgescu-Roegen (1979) flatly states that there is no direct connection between energy flows and the enjoyment of life. Utility is a flow derived from energy, materials and psychic intangibles. The energy theory of value leads to spurious economics because it fails to address the multiple source and objectives of human welfare.

The Energetic Model and Reality

The assumption that energy analysis yields information in addition to that provided by economics is held by all energy analysts. For example, the Colorado Research Group (1976) rejects the energy theory of value and then suggests that an energy criterion be used to evaluate projects alike in every respect except energy efficiency. This suggestion clearly implies that economics does not reflect differences in energy efficiency. However, the energy theory of value considers only one of a host of factors influencing economic

activity. Thus, the theory is unlikely to supply a satis-
factory economic model.

It is instructive to review other theories of value.
In the 17th century, commerce was often strapped for means
of exchange. A group of political economists of the time,
the merchantilists, assumed that the source of wealth was
precious metal and championed laws to foster bullion
accumulation. Misselden, for example (1662, p. 19), urged
that England "restrict trade within Christendom in order to
preserve treasure." Two centuries later, Marx noted the
travails of the laborer and expounded the labor theory of
value. Marx (1906, p. 46) said:

> We see then that which determines that magnitude of the
> value of any article is the amount of labor socially
> necessary or the labor time socially necessary for its'
> production.

Marx (1906, p. 114) also does not think market prices
reflect the true value of a good.

> Magnitude of value expresses the connection that neces-
> sarily exists between a certain article and the portion
> of the total labor time of society required to produce
> it. As soon as a magnitude of value is converted into
> price, the above necessary relation takes the shape of
> a more or less accidental exchange ratio between a
> single commodity and another; the money commodity.

One of the latest champions of the undervalued
production factor is Naisbitt (1984) who thought the value
of the revolution in information technology was
underestimated. "We need to create a knowledge theory of
value to replace Marx's obsolete labor theory of value."

Thus, merchantilists, Marxists, energetists and Naisbett have maintained that a single production factor is a key source of value and that market prices do not reflect this. A brief comparison of Marx's theory and the energy theory of value follows. Both Marxists and energetists maintain that a single production factor is the source of value and that market prices often do not reflect correct values.

The labor theory of value is criticized because it cannot explain value derived from scarcity or great utility such as the Mona Lisa. Energetics, similarly, cannot explain why the price of most goods and services does not correspond to their energy contents. Both Marxists and Odum's group are vague on qualitative differences in labor and energy respectively. Slesser (1974), for example, thinks it unfortunate that energy forms are not priced the same per BTU. He does not offer an explanation of these differences. Marxists and energetists maintain that interest rates would be zero if the correct numeraire were used and exploitation of the source of value stopped.

If either the labor or energy theory of value were used to price resources, serious allocative and equity problems would arise. For example, if interest rate, i.e., the price of capital, were zero and other production factors were priced according to the energy embodied in them, owners of resources would be paid only for the fractions of

technology, land, labor, etc., that are the result of energy expenditures. As a result, owners of non-energy factors would be paid less than the "full value" of their productive factors and would supply less of them, ceteris paribus. A serious equity problem would result because rents that normally would accrue to owners of non-energy resources would accrue to those owning energy resources. However, it should be noted that at least some energetists feel that democracy can't exist in the face of serious energy shortages and look to a socialist government to ameliorate allocation and ethical considerations.

Neoclassical economic theory offers a more complete explanation of the source of value. Value is derived from all inputs, including land, labor, capital, technology, energy and expertise; all of which have intrinsic value and therefore require remuneration. In addition, the pleasure consumers derive from the output also figures into the evaluation via demand. Table 1 summarizes the sources of value according to the labor, energy and neoclassical theories of value.

From Table 1, it is apparent that energetics does not account for the overwhelming majority of factors providing utility to people. In addition, some factors cannot be reduced to energy units (e.g., tastes). It is apparent that analysis based on an energy theory of value cannot tell us more about social welfare than neoclassical analysis.

Table 1. Summary of sources of value according
to the labor energy and neoclassical theories
of value

Determinants of Value

	Demand Factors	Supply Factors
Labor theory of value	None	Labor
Energy theory of value	None	Energy
Neoclassical economics	Price of related income, expectations, tastes transaction, costs, other	Cost of input, e.g., wages, rent, transaction costs, technology, expectations, other

Georgescu-Roegen (1979, p. 1046) provided a mathematic
proof of these conclusions. He starts with an input-output
technology matrix X. The X matrix is multiplied by a column
vector of energy equivalents $(b_1 \, b_2 \, b_3 \ldots b_n)$ denoted b.
Multiplying X and b yields a vector of energy needs to pro-
duce each good, e. Therefore,

1) $xb = e$

relates production of goods to total energy budget (e).

Georgescu-Roegen takes the same technology matrix X
multiplies it by the price vector for each item $p = (p_1 \, p_2 \, p_3 \ldots p_n)$ to obtain a total dollar budget B. That is:

2) $xp = B$

B is a column vector $B = (B_1 \, B_2 \ldots B_n)$ where $B_i = (p_i k_i \ldots + P_1 X_1)$ and K_n and S_n represent the price of

capital and other factors of production.

In the energy model (equation one) the energy budget e can, given technology x, yield energy costs for every good. In case two no price determinations are possible because there are more variables, e.g., P_k and P_n, than equations. In two, the B values can only be determined when these values are supplied by markets. Market prices reflect the tastes, incomes, preferences and expectations of consumers that energetic analysis does not address.

Georgescu-Roegen (1979, p. 1048) concludes that:

> It is now perfectly clear that in absolutely no situation is it possible for the energy equivalents to represent economic evaluations. Although the matrix of the price system 2 is the same as that of the energy equivalents the former cannot be equivalent to the latter.

The deficiency of energetics as a decision tool is evident in public works evaluation. Benefit/cost ratios are the traditional method used. The benefit/cost test is a "potential pareto optimal criterion." The true pareto optimal criterion is that a project makes no one worse off and at least one person better off. By this criterion, a project would be feasible only if those who benefit could and did compensate the total losses of those who lose. The potential pareto benefit/cost test considers a project worthwhile if compensation to losers could be made whether or not it is. Clearly, under a benefit/cost test if the sum of losses and gains is positive there is an increase in

social welfare. Society therefore pursues pareto optimal or potential pareto optimal solutions in order to increase or maximize social welfare. Adopting an energy criterion, e.g., energy efficiency of processes or maximum net energy to consumers, decreases the likelihood of reaching the pareto optimal allocation. For example, net energy accounting often does not account for differences in energy quality or availability. Therefore, if net energy analysis were used to maximize net energy available to consumers, exploding a hydrogen bomb could appear more beneficial than producing one million bushels of wheat.

Energy Analysis Efficiency and Reality

Energy analysis expands traditional engineering energy efficiency ratios to include all project inputs and outputs. Energy efficiency (abbreviated to efficiency in energy analysis literature) is based on the theoretical maximum work available from a Carnot engine. The theoretical Carnot engine cycle is firmly based in the first law of thermodynamics. However, the law pertains only to energy efficiencies. Thus, energy efficiencies must give way to the wider concept of economic efficiency when project values are in part the result of materials constraints and human desires. For example, energy efficiency is only part of the basis for economic evaluation of steam driven electric turbines. The market value of the metals and technologies used

in producing the turbine must also be considered. When the
project includes a large percentage of materials or tech-
nology, e.g., a dam or electronic computer, energy account-
ing is less applicable because subjective human values play
larger roles in project evaluation.

Therefore, if energy analysis is to provide relevant
information, energy analysts must realize that:

1) Economic efficiency is a broader measure than
energy efficiency;

2) Regarding energy efficiency as efficient in a
social sense is flirting with an energy theory of value or
the notion that energy is the sole absolute constraint; and

3) Energy efficiencies may or may not provide informa-
tion relevant to economic evaluations.

Economic Evaluation of the Energy Numeraire

Despite Berry's and Slesser's assurances to the con-
trary, the use of energy numeraire does not give us the
information needed to allocate resources. First, the energy
numeraire is not stable. Technology changes can cause
energy numeraire fluctuations in a relatively short time.
For example, in 1963, the Kilo-calorie to dollar ratio was
21,200; in 1970, 17,300 and 15,800 in 1972 (Gilliland 1975).

Second, energy is not the sole source of value. There-
fore, the value of the marginal physical product should be
equated for all resources not just energy. This principle
can be illustrated with the oil shale example. The

energetic notion that oil shale is economically feasible
only when the net energy from oil shale approximates that of
crude oil is completely false. If large increases in demand
or OPEC decreases in supply cause price increases large
enough so that oil shale is profitable, producers will not
hesitate to produce oil shale, whether or not it is a net
energy producer. Crude oil owners would simply earn rents
on the cheaper crude energy sources. The idea that energy
resources will be produced until energy content of all
sources are equal is a partial analog of the economic para-
digm:

$$\frac{\text{Marginal Product X}}{P_x} \quad = \quad \frac{\text{Marginal Product Y}}{P_y}$$

This formula accounts for the subjective evaluation (e.g.,
convenience and cleanness) of different energy resources and
their relative costs of production. When we oppose the
above economic formula with the energy equivalent, marginal
energy product X = marginal energy product Y, we see that
energetics numeraire short run stability is brought through
the loss of relevant information.

Changing market evaluations reflect changes in human
abilities for whatever reason to gain utility from an object
in a welfare maximizing society; such changes cannot be
ignored. Third, although it may be true that energy
accounting conceivably could measure all of the energy flows
that cross an ecosystem's interface, it does not solve the

problem of evaluating the worth of such energy quantities to people or even to plants and animals. Is an acre of wild hay as valuable as an acre of soybeans just because their net energies are the same (Bell 1977)? Are Canadian geese and whooping cranes, which are approximately the same size, of equal value? The basic problem is to design human welfare values where no subjective market exists. The use of an energy numeraire is a step backward in that people do not value BTU's qua BTU, but for what each type of energy contributes to human welfare.

Intergenerational Resource Allocations

The notion that a zero growth steady state is that optimal path for present and future generations is subject to much debate. Koopmans (1974) shows, for example, that given convex utility functions, even with a zero interest rate, society will choose to consume nonreplenishable resources at above minimum subsistence rates. Many economists, among them Baumuol (1968) and Huettner (1975) postulate that resource consumption in the present will allow us to increase the standard of living in the future via capital accumulation and technological changes. Zealous conservation under these conditions would mean taxing the present poor to subsidize the future rich. Other economists disagree with this rosey assessment, e.g., Schumpeter (1934) and Georgescu-Roegen (1979) and Rawls (1971). Regardless of

the outcome of this debate, for the foreseeable future, zero growth is not an acceptable national political goal of any western democracy. Witness, for example, the political ramifications of recession and depression on United States presidential elections.

Economists are far more united in their rejection of the notion that a steady state would produce a zero interest rate. The basis for this assessment lies in both the material and psychological worlds. The material realities dictate that capital goods in a steady state wear out. Therefore, there will always be choices between consuming and saving to replace capital, which capital to replace, when to replace it and the length of the pay back period. On the human level, the concept that passed some point increased consumption results in diminishing marginal utility is well established. This notion leads directly to the assessment that there is a positive price that must be paid for foregoing current as well as future consumption. The same logic holds for aggregate consumption and pre-ferences. In addition, inasmuch as most biologists theorize that the lot of any species is ultimate extinction, human society, if it is risk adverse, will generally discount an uncertain future, albeit to a smaller degree than private individuals. However, some question the ethics of discount-ing the future (Neher 1976 and Nash 1975), but do not dis-pute the fact that individuals and society do discount the

future.

Economists have questioned what the correct social rate of discount is. The majority writing on the subject conclude that the optimal social discount rate is less than the private market rate because of risk incurred by private investors and/or corporate taxes (Harberger 1968). Harberger derives perhaps the most accepted social rate of discount which can conceivably be tested empirically. In addition, some economists, notably Harberger, show that the private individual's interest rate differs from the market rate because of taxes or fixed individual savings.

Dissenting economists, notably Marglin (1963), argue that private market determined interest rates have no bearing on the optimal social discount rate.

In summary, although there is not total agreement among economists as to the proper discount rate, or modeling techniques, intergenerational resource allocation must be decided in one manner or another. Economists have sought theoretical and empirical evidence of the correct path or paths to follow. More work must be done. However, energy analysis does not appear capable of yielding significant information on intergenerational allocation over and above a market decision because:

1) Energetics has not developed and cannot support a model of intergenerational resource allocation, see page 28. Therefore, energetics cannot assume, considering current

modeling, positive growth and interest rates and current political realities that their arguments regarding zero growth and zero interest rates are to be regarded as anything more than normative statements.

From the preceding discussion, it is evident that:

1) Energy is probably not the only limiting factor;

2) Energy is not the ultimate source of all value; and

3) Energy numeraires are not superior to dollars when evaluating human desires and costs; and

4) Energetics models of the economy are non-existent and the theoretical foundations for them are deeply flawed.

Therefore, energetics, as far as it embraces an energy theory of value, is of no practical modeling significance in resource allocation.

We now turn our attention to energy and economic analysis and their comparisons of flat water recreation at selected Utah reservoirs.

CHAPTER V

SURVEY TECHNIQUES

To compare economic and energy analysis results, a
survey was undertaken to obtain data on recreational energy
use, travel distance and time spent on four selected Utah
reservoirs.

The same questionnaire was employed to gather data for
both the economic and energy analyses.

Questionnaire Design

The basic data regarding recreationists on Willard Bay,
East Canyon, Rockport and Hyrum reservoirs was provided
using the questionnaire found in Appendix A. Information
concerning the parties' origin, size and length of stay,
type of vehicle(s), type of boat, size of boat motor(s) and
the percent of time spent in various activities was
gathered. Previous questionnaires with similar objectives
were used as sources for the questionnaire construction.

Interviews

Questionnaires were administered in two ways. The
majority were gathered through personal interviews with

recreators as they visited each site. Approximately 20% of
the questionnaires were gathered by Utah Department of Parks
and Recreation (UPR) personnel. The latter method meant
that only brief instructions were given to respondents.

Sampling Procedure

The target population consisted of those who recreate
on the four selected Utah reservoirs. An effort was made to
obtain a random sample of recreators from July through
August on each site. However, since only one interviewer
was employed, a completely random sample was not obtained
for each reservoir. Effort was allocated with respect to
reservoir size with Willard Bay receiving the most and Hyrum
the least time.

Data Biases

Several factors affect the possible bias of the data.
First, because questionnaires were taken only from July
through August, no measurement of early (May-June)
recreators was obtained. Second, the quality of the data
differed because Rockport and East Canyon data were gathered
to a great degree by UPR rangers who generally gave less
personal attention to the project than did the interviewer.
As a result, a percentage of the questionnaires from these
sites were not filled out completely and were not useable.
Third, only 20 observations were made at Hyrum, making the

results statistically unrepresentative. The low number of observations was due to lesser number of survey days and unwillingness of recreators to fill out a questionnaire or be interviewed. Fourth, the assumption that the sample was an unbiased sample of the population could not be made because the samples were not gathered on random days or times. Finally, the size of some motors was given in cubic inches. This required a conversion to horse power for comparability. This conversion may inject some bias into the on-site energy consumption figures. It is not known in which direction or to what extent these problems bias the results.

Steps Taken to Mitigate Bias

The percentages of recreators from different origins was computed from the samples. These were compared to the estimates made by UPR personnel. The two estimates were closely correlated, differing by no more than 3% for any origin and site except Hyrum. In that case, the sample listed Salt Lake City as the origin for 82% of the recreators. This compared to the UPR estimate of 10% from Salt Lake City and 66% from Cache County. Because so few observations were made at the Hyrum site, UPR personnel estimates were used in the analysis which follows.

Flaws in the Data

After surveying was completed, it was noted that the length of stay question had not been understood and/or filled in by many respondents. This made the quality of recreation variable inaccurate and negated any attempts at quantifying results. What follows is an example of techniques used by energy analysts and economists using the flawed data.

CHAPTER VI

THE ENERGY MODEL FOR FLAT WATER RECREATION

The energy model used in this study to analyze energy costs of recreation on Willard Bay, Rockport, East Canyon and Hyrum reservoirs is the one developed by Clair Batty, David Bell and Thomas Stoddard (Stoddard 1980). Recreation energy costs were broken down into two categories: travel energy expenditures (E1) and on-site energy expenditures (E2).

This study uses gasoline consumption as a surrogate for total travel energy expenditures for two reasons:

1) The calculations were made easier; and

2) The other energy costs, car wear and tear and oil, are small compared to gas consumed by cars in sample.

Estimates of gasoline use for travel to each reservoir was found using the following equations:

1) $\dfrac{X_1 (mpg_1) + . . X_n (mpg_n)}{\text{number of cars in sample}} = \text{avg. mpg}$

when X_n = # of car type n in sample and mpg_n = avg. mpg of n type car;

2) $O_1(m_1) + O_2 (m_2) \ldots + O_n (m_n)$ = miles traveled to site by sample recreationists

when O_n is origin n and m_n is miles from origin n to site;

3) $\dfrac{\text{\# of recreation sampled on site}}{\text{\# of recreationists visiting in given year}}$

= fraction. Thus;

4) $\dfrac{\text{miles traveled to site by sample recreationists}}{\text{avg. mpg of cars in sample}}$ X $\dfrac{1}{\text{fraction}}$

= gallons spent traveling to site

On Site Energy Expenditures (E2)

E2 was assumed to consist of gas used to power motor boats. This assumption was made because:

1) Calculations were much simpler; and

2) Power boating is by far the largest energy consumer in flat water recreation.

The following equation was used by Tom Stoddard (1980) to find estimates of on site energy consumption.

1) $\dfrac{\text{Summation of horse power in boat surveyed}}{\text{\# boats surveyed}}$ = $\begin{array}{l}\text{Average horse}\\\text{power in boats}\\\text{surveyed}\end{array}$

2) $\dfrac{\text{\# of boaters surveyed in sample}}{\text{\# of boaters in year}}$ = fraction

It was then assumed that boaters staying less than twelve hours spend 9/10 of their time boating and boaters staying longer than twelve hours spend 1/4 of their time boating. Therefore:

3) 1/4(# of long stay boats)(# of long stay hours) + (9/10)(# shorter stay boats)(# of short stay hours) x

$$\frac{1}{\text{fraction}} \quad X \text{ avg boat h.p. x } \frac{\text{gallons}}{\text{boat hour}}$$

= gallons of gasoline used annually.

Using the data gathered from on site questioning, E1 and E2 were found for each reservoir. The energy consumption figures per visit ranked highest to lowest are in Table 2.

Table 2. Sample recreational gas consumption at four Utah reservoirs

1)	East Canyon	40.79 gallons/visit
2)	Rockport	33.99 gallons/visit
3)	Hyrum	28.81 gallons/visit
4)	Willard	27.51 gallons/visit

Usefulness of Energy Expenditure Method

As was shown previously, use of energy analysis to evaluate projects other than those requiring energy efficiency in the thermodynamic sense contributes no normative information because it fails to reflect the multiple objectives of human welfare and relative resource constraints. However, since energy efficiencies are analyzed by totaling energy costs and miles traveled is a proxy price for willingness to pay for recreation, the utility of recreators is implicitly represented by this ranking. For example, because people expend more energy and thus

money at East Canyon than at Willard Bay, a case might be
made that they enjoy it more; otherwise, they would spend
less and go to Willard Bay. Energy expenditures in gallons
of gasoline (Q) is directly related to the economic measure
gross expenditures, i.e., price times quantity of gasoline
used (PQ). The usefulness of the energy expenditures and
gross expenditure methods will be discussed after the empir-
ical gross expenditure example is presented in the economic
model chapter.

Energetics and the Energy Expenditure Rankings

The energy theory of value implies that energy should
be conserved whenever possible. For this reason, energetic
ranking of the reservoirs might list the smallest energy
consumer per visit first, the largest last, that is:

Table 3. Sample energetic ranking of four Utah
reservoirs

1)	Willard	27.51 gallons/visit
2)	Hyrum	28.81 gallons/visit
3)	Rockport	33.99 gallons/visit
4)	East Canyon	40.79 gallons/visit

Thus, energetic rankings might contradict economic
rankings that purport to measure consumer welfare. This
ranking will be compared with the economic counterpart after
these estimates have been developed.

CHAPTER VII

THE ECONOMIC MODEL OF FLAT WATER RECREATION

It is generally accepted that flat water recreation has value. The problem is that public agencies often supply the facilities for flat water recreation. As a result, unlike most goods, this type of recreation is not sold in markets that assign prices. Some have argued that flat water recreation is priceless. Until recently, most planners have agreed with this argument and thus refused to measure its value. However, if it is accepted that whatever exists can be measured, the value of flat water recreation must have some definable quantity. The task, then, is to develop a theoretical framework for economic evaluation of flat water recreation and the associated empirical procedures.

Economic Demand

The basic demand principle is that the quantity demanded by consumers varies inversely with the price. At a low price, a large quantity will be demanded. At a high price, a relatively small quantity will be demanded. At a low price, a relatively large quantity will be consumed. Figure 6 is a typical linear demand curve for good X.
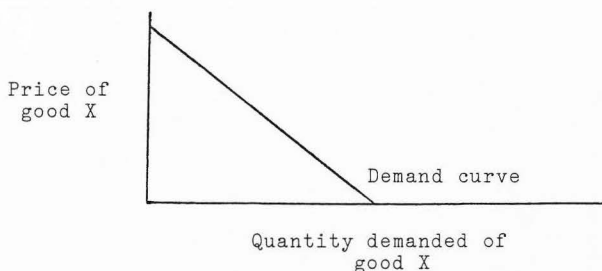
Figure 6. Typical demand curve

Economic values measure how much people are willing to give up to enjoy a good or service. The concept is the same for marketed as well as non-marketed goods, e.g., flat water recreation. Consumers of any economic good receive satisfaction equal to or greater than the price they are willing to incur. Goods sold in markets cost consumers the market price plus the time and effort needed to make the transaction. These outlays regulate the amount of the good consumed. Likewise, the monetary and time, e.g., travel; costs of a recreational activity will regulate how much recreation is consumed. In order to construct a flat water demand estimate, an appropriate money and time cost price must be determined. If these costs can be determined, then a statistical demand estimate can be made that is comparable to market priced goods.

There are two cost related decisions that a recreator must make. First, in the long run he must decide whether to

buy recreational equipment of a fixed nature, e.g., jeeps, tents and boats that commit him to a specific type of recreation. These costs, once incurred, do not affect the decision to recreate on any given day or at any given place. The second decision that a recreator makes is a short run decision. He must decide when and where to recreate. Important considerations in this case include time, travel and any on site costs that are incurred while recreating. These costs are valuable and affect the decision whether or not to participate in a particular recreational activity. These costs are thus the pertinent costs for surrogate pricing of non-marketed goods in the short run.

The economic model used in this study to assign values to recreation activities on the Utah reservoirs: Willard Bay, Hyrum, Rockport and East Canyon; is the travel cost model of Hotelling and Clawson. The simple model reviewed by Martin and Gum (1974) is employed to obtain demand curves. Consumed surplus is then calculated from the demand curves. The model makes three key assumptions (King and Davis, 1978, p. 28):

1) Entry Fees: It is assumed that an individual would react to an increase in entry fees in the same manner as to an increase in travel costs;

2) Specification: The assumption is made that all relevant and statistically significant variables which affect trip-making behavior are properly specified in the

travel cost model. Under this assumption, unbiased esti-
mates of the slope of the site demand curve may be found;

3) Capacity Constraints: It is assumed that observed
data points used to estimate the original model are true
demand points. That is, there is no unobserved demand that
goes unsatisfied.

If for any given reservoir these assumptions are not
true, then the results must be qualified. It will be
assumed that deviations from the above conditions occur
equally on all sites. Therefore, since only a ranking is
desired deviations need not be specified.

The first step in the development of the model is to
construct a demand function for the total recreational expe-
rience on a given reservoir. This is done by utilizing
transportation cost as a surrogate for the true price of
recreation. Freeman (1979) and Willig (1976) provide justi-
fication for using a single cost, e.g., transportation
costs; as a surrogate for true price of a good. The
statistical demand curve is then one in which (transporta-
tion) costs are mapped against recreation measured in trips
to site as in Figure 7.

Transportation
costs
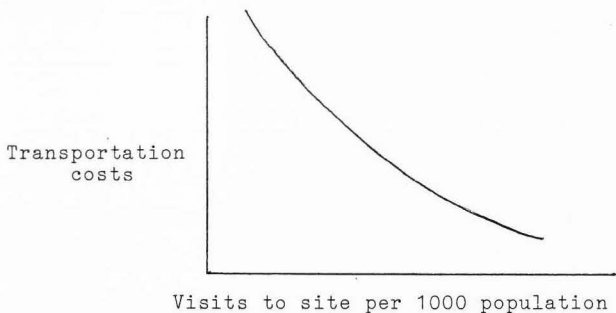
Visits to site per 1000 population

Figure 7. Response curve for the recreational
experience on a reservoir

The second step is to derive a statistical demand curve
for the reservoir site itself from the response curve for
the recreational experience. This is made possible by
assuming that the recreators would react to changes in costs
at the site, e.g., entrance fees; in the same manner they
would react to changes in the costs of the recreation expe-
rience as a whole. The demand curve for the reservoir site
is derived by relating posited added costs, e.g., higher
entrance fees; to the number of visits that would occur at
each higher price. The resulting demand curve is in terms
of added costs and total visits to the site; that would
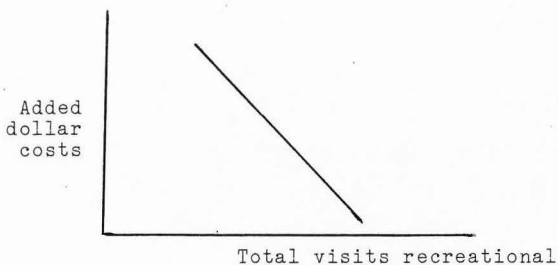occur at prices higher than the observed price, (see Figure
8).

Total visits recreational

Figure 8. Demand curve for reservoir

The specific procedures of these steps are outlined in the empirical example which follows.

Empirical Example

The East Canyon recreational demand curve is derived as an example. The costs of travel from each origin to East Canyon as assumed to be the same for every visit from a given origin. The number of visits is put on a basis of per 1,000 population from the origin; see Table 4.

Table 4. Sample demand for total recreational experience: East Canyon reservoir

Origin	Cost	Visits from origin	Visits/ 1,000 population
Morgan	$2.00	82	15.49
SLC	$4.80	6,566	9.38
Ogden	$7.00	1,313	9.12
Provo	$14.40	246	1.24

Total visits to site: 8,207

By plotting cost (column 1) against visits/1,000 population
(column 4), a statistical demand curve for the total recrea-
tional experience is determined. This estimated curve is
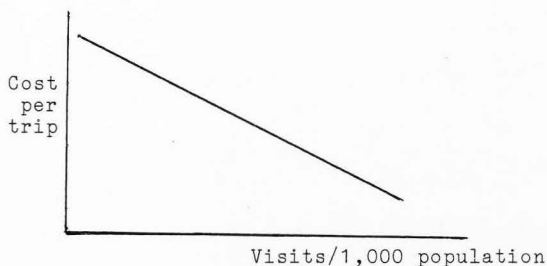shown in Figure 9.

Figure 9. Statistical demand curve for recreational
experience East Canyon reservoir

Next, an equation is found that gives the best fit to
the data in Table 4. Exponential, logarithmic and power
functions were all tried. The power function $y = AX^B$ where
$A = 50.48$; $B = 1.2$ and $R^2 = -.89$ fit the data best according
to the R2 statistic. The demand equation visits = 50.48
(travel cost) 1.2 is then used to derive a demand curve for
recreation on the reservoir in the following manner. The
total projected number of visits is calculated at each
posited increase in travel costs. (The fitted power func-
tion demand curve is used for this instead of Table 4
because the travel cost increases are in $1.00 increments,
making estimates of visits between the data points in Table
4 necessary.)

For example, by adding increments of $1.00 to the travel costs of the recreators from each origin, the corresponding projected number of visits can be determined by using the equation, $V = 50.48 \ P-^{1.2}$ V is in visits per 1,000 residents of the respondents origins. Therefore, in order to obtain total trips taken at each extra cost, the visits per 1,000 population must be multiplied by the number of thousand residents of each origin. The number of trips taken per each additional dollar cost is the sum of total visits projected from each origin at a given increase in cost. For example, Table 5 shows that at zero additional cost, a total of 6,557 trips to East Canyon are projected, and 116 from the Morgan area; 5,340 from the Salt Lake City area; 697 from Ogden and 404 from the Provo area.) From columns 1 and 2 of Table 5, a statistical recreational demand curve for a reservoir can be constructed (see Figure 10).

The same curve fitting procedures were used and the best fit equation is the power function $y = AX^B$ where A = 9948.88 B = -0.8 R^2 = -.97.
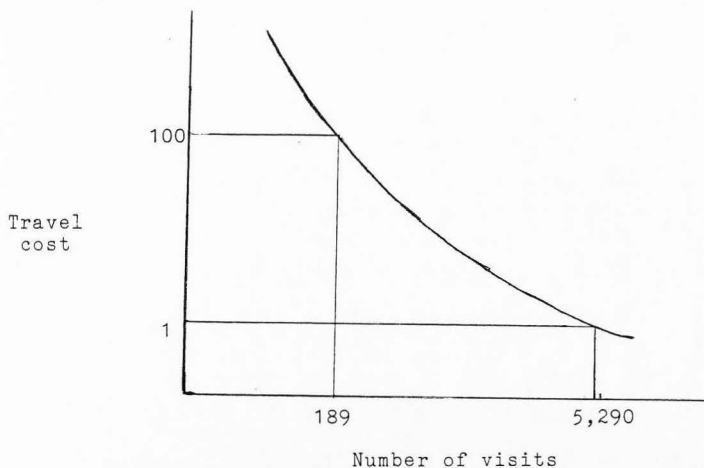
Figure 10. Recreational demand for East Canyon reservoir, Utah

Consumer Surplus

Consumer surplus is the most accepted measure of recreational values (Schuster and Jones 1982). It measures the surplus satisfaction that a consumer receives from a commodity above the price he had to pay for it. The central idea is that consumers have a price they are willing to pay rather than do without the item. If a consumer pays less than he would be willing to, he has incurred a surplus. For example, if the price of recreation in Figure 4 were zero, 189 people would still be willing to pay $100 for the opportunity to recreate there. Hence, at the zero price, each of these 189 would be receiving a consumer surplus of $1,000. If the price is zero for all consumers, then the total

Table 5. Sample projected visits from cities to four Utah reservoirs

Extra Cost	Total Visits	Morgan Pop. 5,300		Salt Lake City Pop. 700,000		Ogden Pop. 144,000		Provo Pop. 199,000	
		Visits/ 1,000	Total Visits	Visits/ 1,000	Total Visits	Visits/ 1,000	Total Visits	Visits/ 1,000	Total Visits
$0	6,557	21.89	116	7.63	5,340	4.84	697	2.03	404
$1	5,290	13.40	71	.6.07	4,252	4.13	534	1.87	373
$2	4,421	9.43	50	5.01	3,510	3.58	515	1.74	346
$3	3,790	7.36	39	4.25	2,975	3.15	454	1.62	322
$4	3,310	5.85	31	3.68	2,573	2.81	405	1.51	301
$5	2,932	4.91	26	3.23	2,260	2.53	364	1.42	282
$6	2,629	4.15	22	2.87	2,010	2.30	331	1.34	266

surplus of all consumers is measured by the area under the demand curve. In the case of East Canyon, we can integrate the fitted power function $V = 19948.88 \ (T.C.)^{-.8}$ from 1 to 100. One and 100 are used instead of zero and infinity because both values represent 1 inflection point as the curve asymptotically approaches the axis. Therefore, estimated consumer surplus for East Canyon is:

$$V = \quad 19948.88 \quad T.C.^{.2} \quad \bigg/ \begin{matrix} 100 \\ 1 \end{matrix} \quad = \$75,200$$

Statistical demand curves and consumer surplus estimates were derived for Willard Bay, Rockport and Hyrum in a similar manner. Power function ($y = AX^B$) yielded best R^2 fit for all reservoirs.

Consumer surpluses per visit ranked from highest to lowest are as follows:

Table 6. Sample consumer surpluses for four Utah reservoirs

1)	East Canyon	\$9.14/per visit
2)	Rockport	\$8.35/per visit
3)	Hyrum	\$6.93/per visit
4)	Willard	\$6.35/per visit

This ranking is the same as that derived previously with energy accounting techniques. It is the opposite of the probable energetic ranking.

Usefulness of Consumer Surplus

A caveat about the use of consumer surplus estimates is required. First, consumer surplus is not comparable to market price. If marketed and non-marketed goods are compared consumer surpluses should be found for both types of goods (Dyer and Hof 1979). Exceptions to this rule may occur when a single factor greatly influences consumption of a non-marketed good which represents a large segment of the total supply, e.g., as is the case of travel costs to a large reservoir used for recreation (Binkley 1980).

The Gross Expenditure Method

The gross expenditure method sums the total cost to recreators participating in an activity. Gross expenditures on East Canyon are calculated as an example.

The travel costs for a round trip are estimated from each origin by assuming that all recreators from that origin face the same travel expenses. The visits by origin are multiplied by an average cost for a round trip from that origin (Table 7).

Next, on site expenditures (E_2) are estimated. Gasoline for boating is, in this example, considered the single on-site cost. Gasoline consumption on the four reservoirs is estimated in the energetic model chapter. The figure for East Canyon is 241,170 gallons, assuming a cost of $1.00 per

gallon, the total 1979 gross expenditure for East Canyon
reservoir recreation was $329,998.40 or $40.21 per visit.

Table 7. Sample travel costs for East Canyon
reservoir

Origin	Total travel cost	Visits from origin	Travel cost
Morgan	$ 4.00	82	$ 328.00
Salt Lake	9.60	6,566	63,033.60
Ogden	14.00	1,313	18,382.00
Provo	28.80	246	7,084.80

Total travel cost: $88,828.40

Gross expenditures for the other reservoirs were esti-
mated in the same manner. The 1979 gross expenditures per
visit on the four reservoirs, ranked first to last, were:

Table 8. Gross expenditure rankings of Utah
reservoirs

1)	Rockport	$41.58 per visit
2)	East Canyon	$40.21 per visit
3)	Hyrum	$36.02 per visit
4)	Willard	$30.24 per visit

These rankings are nearly the same as those for expenditure
method and consumer surplus, except Rockport and East Canyon
are reversed. However, if we assume a 10% error factor,

there is no statistically significant difference between the Rockport and East Canyon estimates. The rankings are the inverse of the probable energetic ordering.

The Usefulness of the Gross Expenditure Method

The concept underlying the use of gross expenditures as a measure of value is that people receive values corrresponding to their recreational expenditures. Otherwise, they would not make them. However, if recreation were abolished, most of the recreators' money would simply be spent on other goods and services. Economists contend that losses in satisfaction from a shift away from recreational goods would not equal gross expenditures. Thus, gross recreational expenditures are not comparable with net economic benefits that would be estimated for the alternative uses of the resources. The energy expenditure method has the same deficiencies as gross expenditures because gross expenditures are a function of energy expenditures.

Comparison of Energy Accounting, Consumer Surplus, And Gross Expenditure Empirical Results

The three methods used to find recreation costs, energy expenditures, consumer surplus and gross expenditures all yield the same rankings. This is to be expected in the case of energy expenditures and gross expenditures. Both use analogous procedures, i.e., a physical quantity (Q) as its

monetary value (PQ) and the same data. Consumer surplus (CS) rankings should be the same as those of gross expenditures since E = TC where E = expenditure and TC = travel cost and CS = f(TC) assuming TC and f(TC) are positive and monatonic transformations.

Thus, the three measures, energy expenditures, consumer surplus and gross expenditures, should theoretically yield the same rankings. The energetic ranking should not be the same because the goal of energetics is to conserve energy or its corollary maximum output per energy unit expended. The explicit goal of economic welfare measures such as consumer surplus is to maximize human welfare. Human welfare often is a function of energy consumption.

The goals of economic analysis and energetics may then be opposites and opposite rankings may result.

Because the energy expenditure and gross expenditure methods have little theoretical basis supporting policy decisions, these methods are not recommended. The energetic rankings of energy expenditure utilizes the energy theory of value which is too narrow. Consumer surplus estimates with the appropriate caveats are recommended.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Traditional economics may not deal adequately with some problems of resource allocation. Energy analysis has been suggested as a supplement or replacement for economics in resource problem areas. However, energetic methods are not superior to economics because:

1) The energy theory of value is too narrow;

2) Other materials also appear to be absolute constraints;

3) Energetics does not lead to models that correlate well with reality;

4) Energetics does not lead to definitive conclusions on intergenerational resource allocation; and

5) The energy numeraire is too narrow to address the wide range of human desires.

The sample empirical results show that for the boating recreation study gross expenditures (the summation of $P_i Q_i$) energy accounting methods (the summation of Q_i) and consumer surplus (the integration of total costs) yielded the same project rankings with respect to recreation outlays. This was the expected result. Consumer surplus is the most

widely accepted method for evaluating willingness to pay for non-marketed goods. Rankings based on minimizing energy costs of recreation are the reverse of consumer surplus. Thus, if energetics were used as a policy tool, reservoirs with the highest consumer surplus (or utility) would be the least likely to receive funding and vice versa. The preferences revealed by consumer behavior are not consistent with minimizing energy costs and the associated energy theory of value.

Energy accounting can add significantly to methods of efficient resource allocation if it is used to point out areas of potential increases in energy efficiency. Energy accounting per se has little normative significance.

The study's empirical results could easily be improved by:

1) Using full individual data as outlined by Martin and Gum (1974);

2) Reducing inherent biases in demand estimation as outlined by Beardsley (1971);

3) Improving the sample; and

4) Improving the data gathering techniques.

However, little gain would be expected by improvement of the empirical results since the question of the efficacy of energetics is based upon theoretical grounds.

A critical re-evaluation of the theoretical underpinnings of this paper would be warranted if

significant data revealed that individuals regarded energy availability (as stocks) as a direct argument in their utility function, rather than an input to the consumption process.

LITERATURE CITED

Ayres, R. J. and Kneese, A. V. 1969. Production consumption and externalities. _AER_. 59:282-97.

Barnett, H. J. and Morse, C. 1963. _Scarcity and growth: the economics of natural resource scarcity._ Baltimore, Maryland: Johns Hopkins Press.

Bator, F. M. 1958. The anatomy of market failure. _The Quarterly Journal of Economics._ 72:351-379.

Baumol, W. 1968. On the social rate of discount. _AER_. 58:788-804.

Beardsley, W. 1971. Bias and noncomparability in recreation evaluation. _Land Economics_. 47:175-180.

Bell, D. A. 1977. "The development of a thermodynamic energy accounting system and its application to power project evaluation." Thesis, Utah State University.

Berry, R. S. 1972. Recycling thermodynamics and environmental thrift. _Bulletin of the Atomic Scientists_. 28:9-15.

Berry, R. S., and Fels, M. 1973. The energy cost of automobiles. _Bulletin of the Atomic Scientists_. 29:10:11-17.

Binkley, C. S. 1980. Recreation benefit estimation by consumer surplus: a further note. _Journal of Forestry_. 78:22-24.

Brobst, D., et al. 1973. _Mineral resources_. Geological survey circular 682. Washington, D.C.: Government Printing Office.

Bullard, C. 1975. The energy cost of goods and services. _Energy Policy_. 3:268-278.

Burt, O., and Cummings, R. 1970. Production and investment in natural resources. AER. 60:576-590.

Chapman, P. F. 1974a. Energy budgets 1. Energy costs: A review of methods. Energy Policy. 2:91-103.

Chapman, P. F. 1974b. Energy analysis of the census of production. Buckinghamshire, England: Open University Research Group.

Chapman, P. F. 1976. Method for exploring future. Long Range Planning. 9:2-11.

Chiang, A. 1974. Fundamental methods of mathematical economics. New York, New York: McGraw Hill.

Clark, W. 1974. It takes energy to get energy; the law of diminishing returns is in effect. The Smithsonian. 5:84-91.

Colorado Energy Research Institute. 1976. Energy accounting studies of nine fossil fuel applications. Boulder, Colorado: University of Colorado Press.

Cook, E. 1975. Saving the environmental gout and economic cabbage. Exxon USA. 13:11-15.

Cummings, R. J. 1969. Some extensions of the economic theory of exhaustible resources. Western Economic Journal. 7:201-210.

Dasgupta, P., et al. 1976. Resource depletion and research and development. Palo Alto, California: Stanford Press.

Dyer, A. A., and Hof, J. G. 1979. Recreation benefits and applied benefit cost analysis: a rejoinder. Journal of Forestry. 78:25-26.

Fisher, F. M., and Peterson, A. C. 1976. The environment in economics. Journal of Economic Literature. 14:1-33.

Ford Foundation. 1974. A time to choose: America's energy future. Cambridge, Massachusetts: Ballinger Publishing Company.

Freeman, A. M. 1979. The benefits of environment improvement: theory and practice. Baltimore, Maryland: Johns Hopkins Press.

Georgescu-Roegen, N. 1971. The entropy law and economic process. Cambridge, Massachusetts: Harvard Press.

Georgescu-Roegen, N. 1979. Energy analysis and economic valuation. Southern Economic Journal. 45:1023-1058.

Gilliland, M. 1975. Energy analysis and public policy. Science. 189:1051-1056.

Gordon, R. L. 1967. A reinterpretation of the pure theory of exhaustion. Journal of Political Economy. 75:274-86.

Gray, L. C. 1914. Rent under the assumption of exhaustibility. Quarterly Journal of Economics. 28:466-489.

Harberger, A. C. 1968. On measuring the social opportunity cost of public funds. Paper presented at annual meeting of the water resources research committee western agriculture economic research council. Denver, Colorado.

Hannon, B. 1975. Energy conservation and the consumer. Science. 189:95-102.

Heisenberg, W. 1927. On modern physics. New York New York: C. N. Potter Company.

Herfindahl, O. C., and Kneese, A. V. 1974. Economic theory of natural resources. Columbus, Ohio: Merrill Company.

Hotelling, H. 1931. The economics of exhaustible resources. Journal of Political Economy. 39:137-175.

Huettner, D. 1975. Net energy analysis: an economic assessment. Science. 192:101-104.

Humphrey, D. B., and Moroney, J. R. 1975. Substitution among capital labor and natural resources products in american manufacturing. Journal of Political Economy. 83:57-82.

King, D. A., and Davis, L. S. 1978. Recreation benefit estimation: a discussion summary. Journal of Forestry. 78:26-28.

Koopmans, T. C. 1974. Proof for a case where discounting advances doomsday. Review of economic studies, symposium on the economics of exhaustible resources. Chicago, Illinois: Economic Publisher, 117-120.

Krutilla, J. V. 1975. The economics of national environments: studies in the valuation of commodity and amenity resources. Baltimore, Maryland: Johns Hopkins Press.

Lotka, A. J. 1922. Contributions to the energetics of evolution. Proceedings of the National Academy of Sciences. 8:147-188.

Marglin, S. A. 1963. The opportunity costs of public investment. Quarterly Journal of Economics. May:274-289.

Martin, W., and Gum, R. 1974. The demand for and value of hunting, fishing and general rural outdoor recreation in Arizona. Tucson, Arizona: Agricultural Experiment Station, University of Arizona.

Marx, K. 1906. Capital. New York, New York: The Modern Library Random House, Inc.

McAvory, P. 1979. Energy analysis. Wall Street Journal. May 3:1, 30.

Meadows, D., et al. 1972. The limits to growth. London, England: Earth Island Publisher.

Misselden, E. 1662. Free trade or the meanes to make trade flourish. Quoted in Roll, Martin. 1942, A history of economic thought, p. 62. New York, New York: Prentice Hall, Inc.

Naisbitt, J. 1984. Megatrends. New York, New York: Warner Books.

Nash, C. 1975. An evaluation of cost/benefit analysis criteria. Scottish Journal of Political Economy. 22:121-136.

Neher, P. 1976. Democratic exploitation of a replenishable resource. Journal of Public Economics. 5:361-371.

Nordhous, W. E. 1974. Resources as a constraint

on growth. <u>AER</u>. 64:22-26.

Odum, H. T. 1971. <u>Environment power and society</u>.
New York, New York: Wiley Interscience.

Odum, H. T. 1973. Energy ecology and economics.
<u>Ambio</u>. 2:220-227.

Odum, H. T., and Odum, E. C. 1976. <u>Energy basis
of man and nature</u>. New York, New York: McGraw
Hill.

Odum, H. T. 1977. Letters to the editor. <u>Science</u>.
196:258.

Peterson, F. M., and Fisher, A. C. 1977. The
exploitation of extractive resources: a
survey. <u>The Economic Journal</u>. 87:681-721.

Pimental, D., et al. 1975. Energy and land constraints
in food protein production. <u>Science</u>. 190:754-761.

Pinchot, G. 1910. <u>The fight for conservation</u>.
New York, New York: Doubleday, Page and Company.

Planck, M. 1932. <u>Theory of heat</u>. London, England:
MacMillan and Company.

Rawls, J. 1971. <u>A theory of justice</u>. Cambridge,
Massachusetts: Harvard Press.

Ricardo, D. 1966. <u>Economic essays</u>. New York, New
York: A. M. Kelly.

Rosenberg, N. 1973. Innovative responses to material
shortages. <u>AER</u>. 63:118-180.

Schulze, W. D. 1974. The optimal use of non-
renewable resources: the theory of extraction.
<u>Journal of Environmental Economic Management</u>.
1:253-273.

Schumpeter, A. 1934. <u>The theory of economic develop-
ment</u>. Cambridge, Massachusetts: Harvard Press.

Schuster, P. and Jones, B. 1982. Extra market
valuation for resource allocation: a critique.
<u>Proceedings of range economics symposium</u>.
Provo, Utah: Agricultural Experiment Station.
103-125.

Scitovsky, T. 1954. Two concepts of external economics. The Journal of Political Economy. 62:143-151.

Sedlick, B. 1979. Energy analysis. Wall Street Journal. May 3:30.

Skinner, B. J. 1976. A second iron age ahead? American Science. 64:263.

Slesser, M. 1974. Energy analysis: an update. Technological Assessment. 2:201-203.

Slesser, M. 1975. Accounting for energy. Nature. 20:170-172.

Slesser, M. 1976. Net energy analysis re-examined. Energy Policy. 4:175-177.

Slesser, M. 1977. Letters to the editor. Science. 196:259.

Smith, V. K. 1974. An optimistic theory of exhaustible resources. Journal of Economic Theory. 9:384-396.

Stiglitz, J. E. 1976. Monopoly and the rate of extraction of exhaustible resources. AER. 66:655-661.

Stoddard, T. 1980. "Energy analysis as a tool for evaluating man-made recreation." Thesis, Utah State University.

Sweeney, J. L. 1977. Economics of depletable resources: market forces and intertemporal bias. Review of Economic Studies. 125-142.

Teller, E. 1976. Windows into the future. Logan, Utah: USU Press.

University of Illinois Energy Research Group. 1974. Energy cost of goods and services. CAC document no. 140. Urbana, Illinois: University of Illinois at Urbana Champaign Press.

Weinstin, M., and Zeckhauser, R. 1974. Use patterns for depletable and recycleable resources. Review of Economic Studies. 371-92.

Willig, R. D. 1976. Consumers surplus without apology. AER. 66:589-597.

APPENDIX

UTAH STATE DIVISION OF PARKS AND RECREATION AND
UTAH STATE UNIVERSITY: USER SURVEY
****

Name: _____

Address: _____

Phone: _____ Boat #: _____

Type of Vehicle (circle): Car (small, intermediate, full),
  Pickup, Van, 4-Wheel Drive, Motor Home

Camping Equipment (circle): Tent, Camper, Trailer, Other

Type & Size of Boat and Motors:
  inboard, inboard/outboard, jet, sail, paddle
  size of boat: _____ size of motors: _____

No. in party: _____ Time spent on site: _____

Percent of time spent: ___ fishing, ___ skiing, ___ boating
                       ___ camping, ___ ORV, ___ other

Were other sites visited on this trip? Yes, No. If so, where
_____

What could we do to make your stay more enjoyable? (use back)