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Net Energy Analysis Theoretical and Methodological Considerations

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NET ENERGY ANALYSIS: THEORETICAL AND METHODOLOGICAL CONSIDERATIONS

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Abstract

This paper takes a critical look at net energy analysis beginning with a summary of its major assumptions and objectives and an examination of the important theoretical and methodological difficulties encountered in this new discipline. An economic rationale is developed for placing a positive value on environmental services provided man by nature even when the supply of these services exceeds demand. The author concludes that the value weights developed by net energy analysis contain little information of use to decision makers and that the vitally needed insights of environmentalists, ecologists, energy analysts, and others can and should be integrated into traditional economic analysis.

1. INTRODUCTION

Since the early 1960s, policy makers have become aware of environmental and energy related problems. Increasingly, however, the use of market-determined values and economic techniques to guide environmental and energy decision making is being challenged. Woodwell (17), Schumacher (14) and others have argued that services provided mankind by the environment are extremely undervalued.

Others, including Congress, have proposed that traditional economic analysis at least be supplemented with the net energy analysis utilized by Odum (12), Berry and Fels (1), Chapman (2) and Slesser (15). This congressional mandate is contained in section 5 of the Non-Nuclear Energy Research and Development Act of 1974 (Public Law 93-577) which states that "the potential for production of net energy by the proposed technology at the stage of commercial application shall be analyzed and considered in evaluating proposals."

Some take a stronger position, however, but have stopped short of proposing that net energy analysis replace traditional economic analysis. For example Gilliland (6) recently stated that net energy analysis is more comprehensive and "can provide more information of a less conflicting nature to policy makers" and has concluded that, in energy analyses, the use of "energy as the physical measure of environmental and social impacts, of material, capital and manpower requirements, and of reserve quantities reduces the need to compare or add apples and oranges."

Many of the above criticisms are merely that traditional economic techniques cannot or have not yet achieved precise results, hence are inaccurate or inappropriate.

Many economists have made these criticisms themsleves and have attempted to correct these deficiencies.* Of deeper concern, however, are criticisms that seek an alternative conceptual framework to guide decision making or to value inputs and outputs. While no net energy advocate has, to my knowledge, explicitly favored that it replace traditional economic analysis, the use of net energy accounting to value inputs and outputs and to guide decision making is more than a switch to a different numeraire and has far-reaching implications, particularly for the allocation of resources. Economists have traditionally used market-determined prices (corrected for market imperfections and so forth) to fulfill these functions; hence the use of net energy accounting represents, perhaps unknowingly, a marked departure from economic theory.

Given this background, the fact that net energy analysis is a new discipline, and the fact that net energy analysis is already being used by several government agencies**, it would be useful to have a deeper understanding of net energy analysis and the prospects for achieving these objectives. The next section of this paper will review the major objectives of net energy analysis. Section III will examine the major theoretical and methodological problems of net energy analysis. Section IV will contain a summary and some concluding observations.

2. ASSUMPTIONS AND OBJECTIVES OF NET ENERGY ANALYSIS

2.1 Assumptions

As a former net energy analyst has noted (11), "Net energy analysis began with two reasonable suspicions and an apparently simple method for testing them." The first suspicion was that, as mankind turned to lower quality energy sources, gross energy output would increase but net energy, the amount available to final consumers, would fall and eventually approach zero. The second suspicion was that traditional disciplines, because of narrow viewpoints or the use of prices to measure energy flows, might overlook this ominous possibility. Net energy analysis offered, as an alternative, that all energy flows directly or indirectly supporting an energy technology or system be measured in physical units such as BTUs.

Net energy has been defined as the amount of energy that remains for consumer use after the energy costs of finding, producing, upgrading and delivering the energy have been paid (12). Labor, capital, information and material inputs (including the environment) are used to produce energy. Since each input requires some energy for its production, the energy contained in these inputs subsidizes energy output, with society receiving only the difference or "net" energy between the two.

The exclusive emphasis on energy and the energy content of inputs in net energy analysis rests on the concept of energy as the ultimate limiting factor, since substitutes for other inputs can always be synthesized from it. Energy may be divided into available energy (enthalpy) or unavailable energy (entropy). The second law of thermodynamics tells us that the entropy of a closed system increases

*For a listing of these economic studies, see (9).

**The Energy Research and Development Administration has stated that it plans to integrate net energy evaluation of technologies into the national plan for setting energy R & D priorities (4) and the Department of the Interior's Office of Research and Development has contracted for energy analysis of several technologies.

continuously and irrevocably toward a maximum. In addition it has been noted that (i) energy is the only commodity for which a substitute cannot be found, (ii) potential energy is required to run every type of system or production process, and (iii) energy cannot be recycled without violating the second law of thermodynamics (6).

As society uses up its higher-grade energy resources it will require more and more energy inputs (a larger energy subsidy) to produce a given amount of energy. While gross energy production may increase rapidly over the next few centuries as we consume our remaining fossil fuel resources, net energy will certainly increase less rapidly and may eventually begin to decline, particularly if one views earth, moon and sun as a closed system. Regardless of the exact scenario assumed, however, energy is clearly regarded as the ultimate limiting factor particularly since substitutes for other inputs can always be synthesized from it.

2.2 Objectives

The basic objective of net energy analysis is to identify the ultimate sustainable limits to human activities (3) and (16). Since energy is viewed as the ultimate limiting factor, pursuit of this objective logically requires that all inputs be valued solely in terms of their energy content. This is particularly true of environmental inputs or services which many net energy analysts feel are undervalued by traditional economic techniques. In fact, the correct valuation of environmental services is essential if ultimate sustainable limits are to be properly assessed. This fact and the importance attached to environmental services by many net energy analysts suggest that proper valuation of environmental services be regarded as a sub-objective of net energy analysis.

3. THEORETICAL AND METHODOLOGICAL ISSUES

3.1 Theoretical Issues

Turning first to theoretical difficulties, it has been shown (9) that net energy analysis is an energy theory of value. Inputs such as labor, raw materials, machinery and so on are valued according to their direct and indirect energy content alone. More than just appropriate selection of the numeraire is implied, however; prices are formulated as if energy were the only relevant resource constraint, and the relative scarcity of nonenergy inputs becomes a factor only if it leads to a change in the energy content of these inputs. In essence, all nonenergy resources are viewed as transformed energy, and in this one-commodity world all derivative products are priced according to their energy content.

In essence, net energy analysis assigns values based solely on supply considerations while totally excluding demand considerations. Georgescu-Roegen (5), however, has argued that low entropy (energy supply) is a necessary but not a sufficient condition for assigning value. Sufficiency requires that one account for the enjoyment of life (demand factors). At best, net energy analysis can identify only a continuum of possible energy values (a supply curve) and not some unique value or ultimate limit for human activity.

Gilliland (7) recognized this problem and argued that "over the long term, low entropy may provide the basis for defining the boundaries of utility and demand." Yet the ultimate, sustainable energy supply curve would undoubtedly stretch over a wide range of energy values (prices) and output levels. Furthermore, the position of this supply curve at any future point would depend on technological progress, hence the range of ultimately sustainable energy output levels and values is expanded enormously.

In fact, given our meager abilities to measure or understand past technological change, let alone forecast future changes (8), it appears safe to conclude that net energy analysis will offer no accurate prediction of the ultimate sustainable boundaries of energy demand (or value).* Once this is recognized, it is clear that current energy policy cannot be guided by pronouncements as to ultimate limits. As Leach (11) has noted, "The future is opaque, a dark mirror, and no less to energy analysis than to the rest of mankind. Ultimate limits can wait on more urgent and closer concerns."

3.2 Methodological Issues

Given that net energy analysis cannot achieve its basic objective of defining ultimate limits to human activity, one can still inquire whether the value weights it produces contain other information useful to decision-makers. Again, however, there appear to be both methodological and theoretical reasons to question the information content of net energy calculations.

Turning first to methodological issues, Leach (11) has identified several of concern.** The most important of these is the extent to which external inputs should be counted in net energy calculations, i. e., where should the boundary between supply and demand be drawn? At one extreme, the predominate opinion is to draw the boundary between the energy supply system or facility and the rest of GNP as conventionally defined. For example, the energy used to build and run gasoline stations or new towns for oil shale workers produces "goods" within GNP and is therefore not to be counted as a cost on the energy supply sector.

At the other extreme, the prevailing opinion is to capture all possible direct and indirect effects including many remote multiplier and "knock on" effects (12). As noted in (11), however, this would include "the additional energy associated with higher living standards for well paid Alaskan oil workers, the energy to provide all social facilities and infrastructure for new energy developments, and all hidden subsidies provided by natural ecosystem changes."

Clearly, the latter approach, favored by Odum and others, will generate much larger energy subsidies and hence lower net energy calculations than does the GNP approach. Leach concludes (11) that until this boundary problem is settled, "net energy analysis will be arbitrarily inconsistent, uncertain and show large variations . . . (making) . . . Public Law 93-577 virtually unworkable . . . and (suggesting) that net

*Note that economic analysis would also fail to define these boundaries.

**Problems created by uncertainty and joint production are not discussed here. The reader is referred to Leach (11) for treatment of these issues.

energy analysis has no magic answers to some old dilemmas."

One can, however, assume that the boundary problem will be solved* and still criticize the resultant calculations as irrelevant for two reasons. First, as has been shown above, these calculations have no information content as to the ultimate limits to human activity (long run policy). Second, if short run rather than long run policy is of concern, then of what use are these calculations? Should decision makers pay attention to them and in effect allocate resources according to net energy value weights?

As Huettner (9) has shown, even if we could synthesize perfect substitutes for any input from energy, efficient allocation of resources would require deviations from energy content pricing. Energy is not the only relevant resource constraint and is, and will probably remain, a small portion of the total costs of producing most inputs and outputs. The value weights with which net energy analysis aggregates apples and oranges are far different from those entering an economic analysis. To revalue all inputs and outputs according to net energy weights would certainly cause massive short-term and long-term changes and dislocations within a society. While no one is suggesting that this be done, one might ask why decision makers should be guided by net energy analysis and allocate resources as if it had been done. Gross national product is certainly a poor indicator of social well-being (and was never intended to be one), yet net energy may be far worse. Allocating resources to maximize net energy may reduce our dependence on the Arab States, but it would be worth knowing the corresponding reduction in gross national product.

3.3 Valuation of Environmental Services

The above paragraphs have argued that net energy value weights contain virtually no information of use to decision makers. There still remains, however, the question of whether it can improve the valuation of services provided mankind by the environment. At one end of the spectrum are many economists who argue that no energy or economic value should be placed on nature's services as long as quantity supplied exceeds quantity demanded.**

At the other end of the spectrum are many*** who argue that the value of environmental services can be measured, in order of increasing preference, as:

(1) the energy value of the products and services provided by the environment;

(2) the solar energy used by the ecosystem in providing these products and services;

(3) the energy that would be required to provide these services by alternate means.

Both of these polar positions have sufficient strengths and weaknesses to suggest that each should be rejected in favor of a synthesis of the two. One synthesis worth considering is based on the fact that

*Some of the boundary problem may be solved by eliminating much of the double counting implicit in the "Odum" approach. For example, much of the infrastructure (such as schools) for a new energy development would have been needed anyway assuming that children would require schooling wherever they lived and that the new schools associated with the energy development are offset by school construction postponements in other cities.

**For example, see (10).

***For example, see (6) and (13).

man's demand for services provided by the environment will grow through time and ultimately exceed nature's supply. Beyond that point in time, the value of these services is the cost of providing them by alternate means. Discounting this future stream of costs back to the present yields the present value of future environmental services.

Yet the cost of providing environmental services in the future (and the timing of when they must be provided by man rather than nature) is dependent on how well man protects his environment today. In effect, the ecosystem may be regarded as a complicated machine that provides mankind services through time. By keeping that machine properly maintained in the present, mankind can avoid higher maintenance costs in the future. Today's environmental services should not be valued at zero simply because today's supply provided by nature exceeds today's demand. Rather, today's services should be valued at zero only if it is the optimal solution, i.e., it minimizes the discounted present value of the costs of providing a flow of environmental services through time.*

While the above synthesis establishes a rationale for valuing today's environmental services at more than zero (even if the current supply provided by nature exceeds current demand), it does not provide guidelines for placing actual values on these services. Given the difficulties of forecasting man's demand preferences and supply capabilities far into the future, one must conclude that both economic analysis and net energy analysis cannot achieve reliable answers. Yet it should also be clear that, even if accurate forecasts were available, net energy analysis would not provide mankind the answers it seeks.

4. SUMMARY AND CONCLUSIONS

The above sections have argued that net energy analysis cannot achieve its primary objective of defining ultimate, sustainable limits to man's activities. In addition, net energy value weights were shown to be inappropriate for short run decision making such as resource allocation. Finally, a review of various methodological problems indicated that the actual value weights calculated by net energy analysis are arbitrarily inconsistent and highly variable.

The above criticisms are not meant to downgrade the importance of questions regarding ultimate limits nor the vital insights of net energy advocates. On the contrary, it is clear that the insights and expertise of ecologists, environmentalists and others must be integrated into traditional economic analysis if appropriate values for environmental services and energy resources are to be obtained. The basic purpose of this paper is to indicate that net energy analysis is, for various theoretical and methodological reasons, an inappropriate framework for addressing the questions it seeks to answer. Maximization of net energy is a poor surrogate for the objectives of humanity particularly if one believes that BTUs and kilocalories are inadequate measures of pleasure, or pain, or most human desires and capabilities. While market values are far from perfect, they at least contain some information on society's relative values and how they are changing through time.

*One would, of course, have to project future demand for and supply of these services to obtain these future cost estimates.

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BIOGRAPHY

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Although born in Gary, Indiana, Dr. Huettner lived most of his life in Cleveland, Ohio. His education includes a B.S. (1965) from Case Institute of Technology, an M.A. (1969) and Ph.D. (1972) in Economics from Case Western Reserve University, and two years of Law School. In 1970 he was awarded an American Iron and Steel Institute Dissertation Fellowship.

His industrial experience includes employment with the Bell System and Marathon Oil Company. In addition, he has been a consultant to various state and federal agencies, corporations, law firms and public interest organizations. From 1971 to 1974 he was an Assistant Professor at Wayne State University in Detroit. In 1974 he joined the faculty at the University of Oklahoma as Associate Professor of Economics and a research fellow in the Science and Public Policy Program. In 1975 he became Director of Energy Programs, Center for Economic and Management Research, College of Business Administration, University of Oklahoma.

His teaching and research interests include Public Utility Economics, Industrial Organization, Energy Economics and Econometrics. His publications include numerous books, articles and monographs. Dr. Huettner is also a research associate in the Research Program in Industrial Economics at Case Western Reserve University.