Energy Analysis

As an energy analyst, I welcome any attempt by an economist to bridge the gap between us and would agree with Huettner (9 Apr. 1976, p. 101) that energy analysis is plagued by many of the problems that confront economists. One of these is the great difficulty each profession has in understanding the other's methods. Huettner does not, for example, differentiate between energy analysis and net energy analysis, and thereby he leads himself into some awkward corners. Net energy analysis does not use "net energy accounting to value inputs and outputs"; it uses gross energy accounting. Nor does Huettner distinguish between the two quite distinct schools of energy analysis: that of Odum, to which Gilliland (*1*) appears to be an adherent, and that which, broadly speaking, supports the conventions from the workshop on energy analysis methodology convened by the International Federation of Institutes for Advanced Study (IFIAS) in Sweden in 1974 (*2*). The former school places an energy value on the sun and on labor. The latter group regards the sun as a free good and argues that, since the objective of the economy is to furnish people with their needs, to count the energy for life support of labor is to double-count. This group treats energy analysis as the "determination of the energy [resource] sequestered in the process of making a good or service within the framework of an agreed set of conventions" (*2*), for example, establishing the amount of energy resource or resources that had to be extracted from the earth in order to deliver one can of beer to Huettner's house on 9 April 1976. The answer is specific with respect to technology, location, and time. The IFIAS workshop method enables numbers to be compared, no more. If I inform an expectant world that the energy resource requirement of single cell protein made in Japan in 1973 is 187 megajoules per kilogram, assuming the use of a particular technology and energy substrate, I can hardly expect resounding cheers. The number by itself is of little value, no more than if I had informed someone who had no knowledge of the rate of exchange between the yen and the dollar that its cost in Japan was 2300 yen per kilogram. The point is that we do not yet completely understand the relation between money (a market measure of all resources) and energy. Energy analysis has made some progress, which can be identified by comments on Huettner's article.

First I take exception to the article's title, "Net energy analysis: An economic assessment." One cannot make an economic assessment of energy analysis, which is a method of study not an input, any more than one can make an energy analysis of economics. But, as Huettner notes, one can compare the conclusions reached by both. Take the case of shale: a 1972 report by the National Petroleum Council (*3*) concluded that shale would be economically viable when the price of crude oil reached $6 per barrel. Since then, the price of crude oil has doubled, and shale is still not "economic." Even the most neutral observer would probably conclude that something was lacking in the methods of economic analysis used. Huettner has alluded to these lacks when he comments, "economists have generally made various adjustments to market values and even estimated market values when no markets exist." An energy. analyst offers a more precise alternative. He would compare the net energy of refined oil from crude and shale and conclude that in a free market shale oil would never be economic until oil from crude rises to a gross energy requirement per barrel close to that of shale oil. Such an event may be 30 or more years away. Of course, the government may distort the market by taxes and subsidies and make the production of oil from shale a worthwhile activity in the national interest, but that is the politics of energy independence.

Huettner asserts that energy analysts argue that energy requirements remain fixed, and quite rightly scorns this. In fact, what energy analysts argue is that, given the extent of the data base, knowledge of technology, and the ineluctable fact that any transition requires a minimum energy requirement dictated by the laws of thermodynamics, one can more precisely estimate the future energy requirement to manufacture a good than one can estimate its future price. Price estimation is bedeviled by the uncertainty of what discount rate to apply and how to forecast inflation.

Huettner at one point postulates a parameter α_i, the "competitive, market-determined kilocalories of energy used directly and indirectly to produce one unit of input *i*." I cannot recall a single case of the market determining the energy inputs. These inputs are a reasonably close function of the technology of production and location of plant. Although Huettner goes on to argue that his analysis proves that energy analysts are embracing an energy theory of value, outside the Odum school I know of no one who does so. Perhaps this lopsided view of energy analysis accounts for his conviction that energy content pricing is a logical consequence of energy analysis. The only justifiable circumstances would be if a government wished to ration energy use.

Oddly enough, it is on the question of time lags that energy analysts feel their approach has most to offer. While I agree that, given a perfect market, economic analysis and energy analysis would yield the same perception of the future, the market is scarcely ever perfect. Because of a better handle on the future energy requirements for production, as opposed to discounted money costs of production, energy analysis gives a faster signal of impending change. Where energy analysis can be of immense value is in normative forecasting, hence its value to technology assessment and demand forecasting.

Huettner asks whether the public law requiring net energy analysis of new energy R & D proposals should be rescinded. It is worth noting, however, that, in conjunction with the National Science Foundation, Stanford University held a workshop on net energy analysis in August 1975 with the purpose of defining net energy analysis, but in the end it declined to formulate any algorithm for net energy. I have yet to see a rigorous definition of net energy in the scientific literature, although in our own group we have a precise convention.

Finally, let us not fall out. The study of economics represents a valuable contribution to the management of our affairs. It is, however, as yet a strictly behavioral science. It has virtually no normative potential, and no one has yet succeeded in making a dynamic econometric model with feedback. Energy analysis is simply a means of examining the energy resource consequences of man's activities. Economics and energy analysis can usefully complement one other to the advantage of both.

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References

1. M. Gilliland, *Science* **189**, 1051 (1975).
2. *Energy Analysis* (Report No. 6, International Federation of Institutes for Advanced Study, Stockholm, 1974).
3. *U.S. Energy Outlook* (National Petroleum Council, Washington, D.C., December 1972).

Letters (2 Apr. 1976, p. 8) and an article by Huettner challenge the utility of net energy analysis in making decisions about energy, environment, and public policy. These incorrectly represent what energy analysis and net energy calculations are; for example, the authors confuse energy and entropy, state that economic analysis does the same thing as net energy analysis, and doubt that energy is a basis for economic vitality.

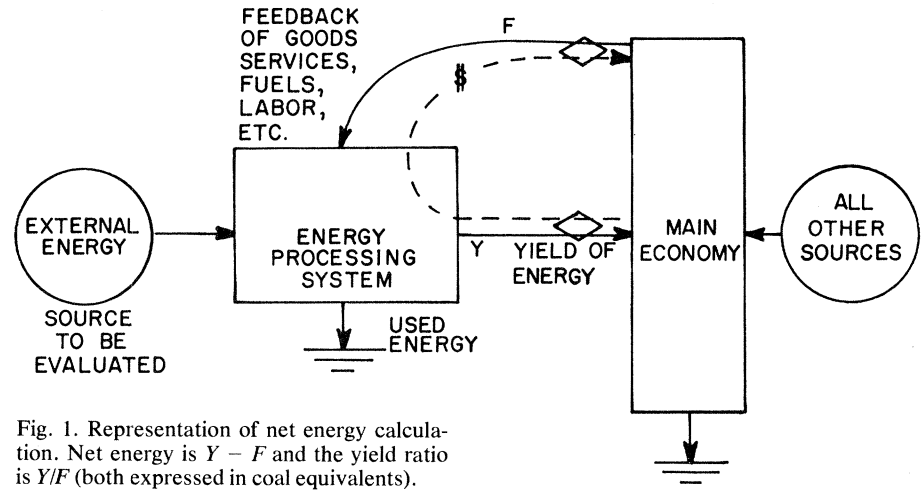

Fig. 1. Representation of net energy calculation. Net energy is $Y - F$ and the yield ratio is Y/F (both expressed in coal equivalents).

Net energy calculations are one of the by-products of doing general energy analysis, in which all flows believed to be important—including flows of money—are diagramed. Each is then evaluated in energy terms, first in degraded heat equivalents, then in coal equivalents. Net energy is calculated to evaluate the contribution to the economy of an externality, such as fuel, minerals, environmental interaction, sun, wind, land, and so forth. Since money flows only within closed loops of the economy, one cannot evaluate in dollars whether an inflow from an external energy source or an environmental interaction is economic. The value of money overall is proportional to the energy inflows from outside.

The requirement for net energy calculation was represented by us to those writing Public Law 93-577 (the Non-Nuclear Energy Research and Development Act of 1974) with the simple diagram in Fig. 1. Net energy was defined as the difference between the energy yield Y and the feedback F, where both are expressed in equivalent energy units (of the same quality and energy cost). Calculating the yield ratio (Y/F) helps to estimate the fraction of the economy that must be returned to the processing of the energy. For example, a yield of 6 for 1 returned seems to be characteristic of the main primary energy sources available to the United States with the price of foreign oil at $12 per barrel. The yield from nuclear plants is not as high. Proposed alternative energy technologies, such as solar heating, oil shale, solar cells, and low-velocity windmill generators have very poor yields. Net energy calculations cut through confusion in showing which proposed primary energy sources are poor.

Secondary energy sources are subsidized by primary sources feeding back through the economy and need not have net energy. However, to be economic they must yield as much energy from outside the economy per unit of energy invested as their competitors. An example is industrial agriculture. Tertiary treatment, cooling towers, and solar technology are poor secondary sources. More on these concepts and energy analysis can be found in (*1*).

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Reference

1. H. T. Odum and E. C. Odum, *Energy Basis of Man and Nature* (McGraw-Hill, New York, 1976); H. T. Odum, C. Kylstra, J. Alexander, N. Sipe *et al.*, in *U.S. Energy Policy: Trends and Goals*, part 5, *Middle and Long-Term Energy Policies and Alternatives* (Government Printing Office, Washington, D.C., 1976), pp. 254–304; M. Gilliland, *Science* **189**, 1051 (1975).

In my article I argued that energy analyses of the Odum or Slesser variety constitute an energy theory of value and would lead to conclusions generally different from those reached by energy analysis of, say, my own variety. Since the conclusions are likely to be different, ranking of alternatives or allocation of R & D and other resources would also tend to differ. In addition, I argued that the direct allocation of resources (that is, quantities of R & D manpower, and so forth) by net energy principles has the same economic effect as an indirect allocation achieved by setting prices according to net energy principles (the duality of resource allocation achieved by either price or quantity mechanisms was the subject of much of Leontief's Nobel Prize–winning work). Finally, I argued that an economy with decisions guided by net energy analysis would be far different from one guided by economic analysis in terms of level of gross national product and types of outputs produced.

Energy analysts are currently using a variety of concepts to assess energy problems and rank alternatives. These concepts include techniques which might be loosely labeled as net energy analysis, gross energy analysis, entropy analysis, and even economic analysis. While there are various gradations within each of these categories, it is clear that a fundamental conceptual difference exists between analysts using economic measures, such as market prices, to value inputs and outputs, and analysts using physical measures, such as energy content. While it is clear from the comments of Odum and Slesser that their energy analyses differ, my concern is not with their differences but with their similarities.

My point continues to be that energy analysts employing economic principles will generally reach different conclusions from energy analysts using noneconomic principles and that these differences will remain even if all markets are free or perfect. Claims that one method cuts through confusion or forecasts impending change faster or has more normative content could probably not be proved by proponents of any method, since every discipline is rife with examples of poor research to be exploited by the opposition.

Under these conditions, I believe it makes more sense to examine the basic assumptions and logic of a discipline in an effort to determine where it will take us if we let it guide our decisions. It is on this basis that I argue that energy analysis guided by noneconomic principles constitutes an energy theory of value. While there is general agreement that the Odum "school" embraces an energy theory of value, Slesser maintains that his "school" does not. Yet if one "values" inputs and outputs in energy terms, ranks or compares alternatives in energy terms, and then acts on this information, I believe that an old adage applies, "When in Italy, all roads lead to Rome."

But what is wrong with units of energy and right with dollars? Isn't it true that one can select any good or product in the economy as the numeraire? Couldn't the government issue homogeneous, 1-Btu lumps of coal with George Washington's picture on them instead of printing dollar bills? Wouldn't all inputs and outputs then be valued in Btu's and wouldn't profit or welfare maximization be the same as energy maximization—an energy theory of value? How can the answers to these questions be yes except for the last one?

The question is really one of what or how one determines value. If the energy content of a good is 3 Btu's, would it always trade for three lumps of coal or even tend toward a value of three lumps of coal? Would there be coal inflation and what is the appropriate discount rate in terms of Btu's? Would supply and demand forces determine values or would energy content? Would confusion end, impending change be forecasted faster, and normative content be increased?

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Origin of Roman "Royal Purple"

I found George D. Ruggieri's article "Drugs from the sea" (29 Oct. 1976, p. 491) most interesting, especially since I have been working with one drug he mentions (tetrodotoxin) for the past 2 years. However, I believe he errs when he states that ". . . Roman ladies . . . bedecked themselves in beautiful gowns dyed purple with a seaweed extract. . . ." The famous "royal purple" of classical times was actually isolated from mollusks (*Purpura* and *Murex*). Had the Roman ladies known explicitly of its origins and manufacture, they would probably have been repelled even more than by the seaweed. It has been suggested (*1*) that the unenviable reputation that the streets of Tyre possessed for being foul-smelling may have come from the decomposing bodies of the mollusks used in the preparation of royal purple.

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Reference

1. C. Singer, E. J. Holmyard, A. R. Hall, Eds., *A History of Technology* (Oxford Univ. Press, New York, 1954), vol. 1, pp. 247–248.

There is certainly no doubt that the "royal purple" of classical times was of molluscan origin. The original reference, "as wool dyed in seaweed pleases one almost as much as purple" ("ut lana tincta fuco citra purpuras placet"), is from Pliny the Elder's *Natural History*. I'm convinced from the above quote that Pliny, too, was aware of "royal purple" (from Mollusca). But as I indicated elsewhere in my article, some of Pliny's remarks were often fanciful and this perhaps may be another example.

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