MODELLING ENERGY AND SOCIETY:

THEORY AND METHOD IN ASSESSING THE SOCIAL EFFECTS OF ENERGY POLICIES.

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EXECUTIVE SUMMARY.

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ABSTRACT

Common sense suggests that when more people are employed, more energy is consumed. However, this study of the social effects of energy policy finds a positive correlation between unemployment and per capita energy use. The social theory upon which the study model is based anticipates this otherwise counter-intuitive finding. It is not the number of men or machines at work but the number of social roles and the intensity of activity in those roles which determine the level of energy consumption.

This study assesses the feasibility of a society/energy model which, when completed, may be used to monitor and to forecast the social effects of energy policies. We find that such a model is feasible. An introductory chapter provides a philosophical grounding for relating social scientific concepts to social policy, in general. This chapter establishes a logical basis for the feasibility of the model. The report then consists of two parts. The first provides guidelines for the interpretation of social activities and rules for conceptualizing those activities in several institutional contexts, religious, political and economic, and in the energy social system itself. The second part is a mathematical statement of typical equations expressing "causal" relations between measures of physical energy consumption and both the attributes of various social institutions and the behavior of actors in those institutions.

The concluding pages of the report demonstrate a way of testing the proposed model with empirical data. National, annualized time series data from published sources for the period from 1960 to 1974 are used and empirical tests of the model were limited to three strategic types of energy policies: those involving fuel price controls, changes in employment rates, and changes in economic output. For the moment, we did not consider such issues as interfuel substitutions or comparisons of different price elasticities for different fuels in different geographic or institutional contexts.

The success of the selection of social indicators for the model, as expressed in a system of nested structural equations, is verified in the documentation supporting the technical report.

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EXECUTIVE SUMMARY

Recommendations

1. The social indicator model presented in this report should be refined and then coordinated with a model of physical energy systems and a pure economic model.

2. The model should be disaggregated according to institutions, fuel types, geographic areas, consumer subsectors and the social characteristics of each. The use of cross-sectional along with time series data should contribute to the further validation of the model.

3. More indicators should be developed and validated, especially those which, by providing quarterly data, would increse the number of observations and facilitate the use of economic data.

4. The study's "unobtrusive" indicators taken from public sources should be combined with survey data on energy consumption behavior and attitudes. This will sharpen the model's attitudinal component of social effects.

The Model and the Indicators

Our approach to modelling social behavior was to merge an econometric methodology for stating the relations among variables with that of a social indicator methodology for defining the variables. The underlying model demonstrated, consists of three interrelated components: an exogenous sector (including public policy instruments), a social behavior sector, and an energy usage sector. The separation of the last two is artificial, but is done for the convenience of the analysis. According to this view of the world, government policy and other exogenous variables (the first sector) allegedly affect social behavior (the second sector), which, in turn, results in measurable patterns of energy use. Simultaneously, the model permits, as should be expected, energy usage to feed back into the social behavioral component of the model as well as the government sector.

For this study, the principal concern has been with the modelling of the "social" sector by utilizing a social indicator approach. Economists, for example, usually "assume away" the social sector for explicit modelling purposes, linking changes in, say, policy directly to changes in energy usage. This short circuiting approach, while frequently convenient, is likely to miss feedback effects, or over simplify interactive effects, and so forth. Put somewhat differently, policy changes affect energy usage through a "black box," the contents of which are usually not explored in detail. The theory, the modelling and the empirical analysis of this study are attempts to shed light upon the working nature of this "black box" which, in reality, consists of all of those social activities not directly economic. These include activities which derive their meaning from considerations of family, community, political and religious life, health and education, art, and leisure, among others.

Obtained from published sources, the model's "unobtrusive" social indicators tend to be rates or ratios, such as the proportion of manufacturing employment to total employment or the amount of energy consumed per social unit. They become variables in structural equations which can be read in two directions: first, as the social effects of changing energy levels and allocations, and second, as the effects on energy consumption of various social arrangements.

Empirical Testing of the Model

The model was successfully tested at three strategic points, each representing a sybsystem of social behavior and energy use: (1) the interrelationship between "exogenous" socioeconomic variables and the "endogenous" variables of automobile purchase and use; (2) the well known GNP-unemployment-energy use triangle; and (3) a composite which merged as endogenous variables the GNP-unemployment-energy use triangle with automobile purchases and miles driven. In general, the findings were statistically significant for individual social indicators combined with a high overall fit.

Some of the results of the analysis are interesting, although they function only as heuristic examples. For instance, total energy usage per capita is positively related to GNP lagged one period. Thus, a one percent increase in 1974 per capita GNP would be expected to increase per capita energy consumption for 1975 by about 0.58 percent, or 2.04 million B.T.U.'s per capita. Also, because of a lagged effect, an increase in the 1974 average unemployment rate from 6.7 to 7.7 percent would have reduced per capita energy consumption in 1975 by about 0.8 percent or 2.8 million B.T.U.'s per capita.

Consistent with the study's social theory, these results are attributable to social activity as a "feedback mechanism."

The purchase of small automobiles also, as expected, would significantly impact energy usage. For instance, if in 1974 small automobile purchase patterns had shifted from 62.9 percent to 63.6 percent of all new automobile sales, total per capita energy consumption would have declined by 1.35 million B.T.U.'s. This savings is not generated solely from the machinery; rather, the purchase of small automobiles is a declaration by owners that certain appurtenances of travel, if not the trip decision itself, plays a smaller part in their lives. A critique of our results by Mathtech presents an illustrative policy impact analysis. The exercise, based on only a small sector of the model, is a demonstration of how the model may be used to forecast policy outcomes, rather than a realistic policy guide.

The model was tested for three types of energy policies:

(1) A direct energy policy, in which the price of fuel was allowed to increase more rapidly than CPI.

(2) Employment policies, one of which involved introducing a larger proportion of teenagers into the labor force and another which involved increasing the proportion of non-white labor.

(3) A policy to encourage economic output, measured by one year lagged GNP per capita. This last has a positive effect on current miles driven. Using a three-year lagged GNP per capita we find an increase in current fuel efficiency. Although counter-intuitive in a supply/demand framework, these findings are consistent with the

underlying social theory in which the driving variable is interpreted to reflect more intense social activity.

A Sketch of the Social Theory

The concepts used for analyzing the social impact of energy policies are identical to those used for analyzing any social action which implicates the physical environment. As energy--like any other environmental object--becomes part of the social system, it is used to facilitate or hinder, reward or punish. It acquires, then, social meaning, which may be quite different from the one it has for a physical scientist or engineer.

One significance of energy is as a focus of social conflict. Social actors compete for it as a resource or inflict hardship on one another in the process of its conversion or extraction. This conflict serves to restructure the axes of already existing conflicts in the society. Otherwise conflicting groups become allies and groups not previously opposed to one another are drawn into conflict around territory or resource allocation. As part of the social system, energy functions like surplus labor, permitting a more complex society, more intense social activity and an increased rate of social differentiation. Energy creates the conditions for social and technical division of labor, but does not usually determine the direction of that differentiation. The direction of social development is determined by culture.

The institutional contexts in which energy is used as well as the social purposes it serves define its cultural significances. Although energy continues to have significance in religious and familial contexts, its political and economic meanings are more salient to contemporary society. This is due to its role in "rationalizing" social activity. The derivation of energy from fossil fuels or from nuclear sources has more of a "rationalizing" social effect than does the derivation of energy from agricultural activity, for instance. In this sense, the type of energy we use does influence the direction of social change.

Six socially relevant characteristics of energy from mineral resources, as contrasted with that more directly dependant on animal and human labor, promote its socially "rationalizing" effect. The uses of energy from mineral resources: (1) is free of biological and psychological restraints; (2) has no inherent social location, may be used indifferently by prince and pauper (An economic location, a price, is a culturally imposed constraint controlling allocation to assure its social availability.); (3) it is divisible into units of almost any size; (4) is continuously deliverable at any desired rate; (5) is usually storable and, thus, free of many temporal constraints; and (6) is generally transportable, thus free of many spatial constraints.

The characteristics of detachability, divisibility and transportability facilitate energy exchange via the marketplace. With this in mind, we would hypothesize that energy related activities influence social change through twelve interrelated factors. Several of these hypotheses can be tested directly or further specified according to fuel types and the technologies through which they are consumed.

(1) As special occupational groups develop around the acquisition and processing of each energy resource, distinctive occupational cultures are produced which influence the direction of the political, economic and religious development of society.

(2) Social power shifts from the land-holding aristocracy to the industrial entrepreneur.

(3) As a specialized energy industry emerges, social organizations relinquish control of self produced energy leading to a peculiar form of industrial interdependence.

(4) As tasks become more complex, the working class relinquishes its traditional role as direct producers for that of laborer-administrators.

(5) As increasing control becomes available to each actor, the social and physical space of the actor's activities is extended producing a depopulation of the productive unit.

(6) With the depopulation of the productive unit, personal interactions give way to the management of things. Property law increases in significance relative to personal status law and so changes the character of culture.

(7) As the potency of human acts increases, the problem of social control becomes insistent.

(8) Increasing social and spatial distance between social actors diminishes the role of traditional social groups while strengthening secondary associations, political and economic, formed for instrumental purposes.

(9) The allocation of institutional social power also shifts from solidary social relations, such as kinship and religion, to economic and political relations which, because of the instrumental nature of their social function are more advantaged by energy-based technology.

(10) Social power shifts among geographic regions according to the location of energy supply and among specific industries for the same reason.

(11) Industry, transportation and warfare become especially prominent types of social organization in high energy societies.

(12) Energy depletion causes social contraction, but this contraction does not follow a path reversing that of the social expansion caused by energy increment. As energy becomes less available, social strain radiates to the larger society from those social realtions which had become most energy dependent.

Decisions for Future Development

We are sanguine about the usefulness of the social indicator approach, but wish to emphasize that three types of choices must be made by policy-makers and researchers alike before additional work can proceed.

(1) Forecasting versus structural analysis. If the model is to be used primarily for forecasting rather than for "structural" analysis, it must be "simplified" to engender testable results. For example, in econometric studies forecasting models are frequently

pure reduced form equations, with strictly exogenous independent variables. However, if social structure is the primary concern, the model should use the dependent variable as a function of exogenous and endogenous variables depending upon the behavioral theory. The latter approach is more complex, but yields results pertaining to the internal behavior of the system.

(2) Choice of method. Although this analysis used econometric methods, several methodologies can be considered for forecasting. For example, to study physical energy systems, energy supply or energy cost equations, deterministic programming or probabilistic models might be more useful. This dichotomy is acknowledged by the government energy agency in its development of the PIES and subsequent models for measuring and predicting domestic energy use.

(3) Assessment and evaluation. Three types of errors could impair any social indicators model. Errors in basic data would be likely to vitiate final output. Errors of substance could occur if the analyst fails to choose the proper variables. In the social indicator approach, this is likely to happen when the data surrogate is not characteristic of underlying social behavior. Finally, errors of causal validity could mask cause and effect relations.

APPRECIATION

While this report is a joint product of both authors, primary responsibility for the writing of Volume Two, The Social Meanings of Energy, was taken by Samuel Z. Klausner. Robert H. Edelstrin wrote Volume Three, The Measurement Model, and monitored the work by Mathtech presented as an appendix to that volume.

The impetus and major direct support for the project were provided to the Center by the Federal Energy Administration (under Contract CO-04-60588-00). The level of development of the theory and the model reflected in the report would not, however, have been possible without the supplementary assistance of the Research Fund of the Center for Research on the Acts of Man and a subvention of staff time and computer facilities from the University of Pennsylvania over some years preceding the study.

Supporting the work of the senior authors are the efforts of David Luery, who collected documentation for the indicators and tested the equations, Albert G. Crawford, who continued this task, Gail W. Donner, who administered the sequence of research activities, a task concluded by Julia Robinson, Helen S. Dunham, who typed a significant portion of the draft manuscript and Penny Jeannechild who typed part of the final report, and Joel R. Feidelman, Esq. who helped us work through some contractual complexities. Jeffrey Milstein, Technical Project Officer of FEA perceived the value of a social study for the mission of federal energy agencies.

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