THE ENERGY MODELING FORUM: PAST, PRESENT AND FUTURE

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Chapter Thirteen

The Energy Modeling Forum: Past, Present, and Future

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INTRODUCTION

In recent years, especially since the oil embargo of 1973, there has been widespread development of energy models in the executive and legislative branches of government, universities, industry, research institutes, consulting companies, and commercial establishments. Unfortunately, our ability to utilize the models effectively for energy policy making and planning has not kept pace with this development. The gap between modellers and potential users of models is large and pervasive. Heightened concern about energy problems coupled with the proliferation of analytical tools for addressing these problems has created both the need and the opportunity for bridging the gap. Finding ways to improve communication between model developers and model users has become an active area of investigation and innovation (Greenberger, 1977).

The Energy Modeling Forum (EMF) has been one response to this situation. The EMF seeks to improve the use and usefulness of energy models in the study of important energy issues. Sponsored by the Electric Power Research Institute (EPRI) and administered by the Stanford University Institute for Energy Studies (SUIES), the EMF, within the Departments of Engineering-Economic Systems and Operations Research, operates through a series of *ad hoc* working groups consisting of roughly equal numbers of energy modellers and potential energy model users. Each working group focuses on an issue or set of closely related issues important to energy policy making or planning to which existing energy models can be applied. The

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The Energy Modeling Forum is sponsored by the Electric Power Research Institute.

group designs, implements, interprets, and communicates a set of tests designed to illuminate the basic structure and behaviour of the models. The issues addressed by the group thus provide a forum to compare and contrast the various models, identifying their capabilities and limitations. At the same time, the issue focus assures that the policy relevant implications of the various models are developed and communicated.

This paper on the EMF is organized in six additional sections:

1. A summary of the five EMF studies initiated to date
2. A description of the Energy Modeling Forum as it exists today (February 1979), its basic goals, organizational structure, and the conduct of its studies
3. The history and evolution of the EMF over the two and one-half years of its existence
4. Several new activities closely related to—and partly motivated by—the EMF, which are performing different, and complementary functions
5. Issues fundamental to the future evolution of the Forum
6. A summary and conclusion.

EMF STUDIES: A SUMMARY

The products of the Forum[1]—comparative studies of significant energy issues—include two completed studies, "Energy and the Economy" and "Coal in Transition: 1980-2000," two more studies well under way, "Electric Load Forecasting: Probing the Issues with Models" and "Aggregate Energy Demand Elasticities," and a fifth study just beginning, "U.S. Oil and Gas Supply."

EMF 1: Energy and the Economy

The Forum project was initiated in 1976 with a study designed to demonstrate the research concept. The working group compared six models of the link between energy and the economy to isolate the key factors determining the effect of energy system changes on the long-run growth of the U.S. economy. The results demonstrate the importance of the value share of energy in the economy, the flexibility in substituting other inputs for energy use, and the link between productivity and capital formation in explaining the behaviour of the models (EMF, 1977).

EMF 2: Coal in Transition: 1980-2000

A second EMF working group, organized in July 1977, compared ten different models in the analysis of coal production, distribution, and

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[1] More complete discussions appear in Hogan (1978a) and in the EMF reports and working papers referenced below.

utilization. The report documents the greater importance of coal demand issues relative to supply issues and describes various insights into the level and composition of future coal output gleaned from the models' results. Emphasis is placed upon the sensitivity of patterns of future coal use to changes in regional economic conditions and standards on allowable emissions (EMF, 1978a).

EMF 3: Electric Load Forecasting: Probing the Issues with Models

The third working group examined the use of ten current models in forecasting electric loads. The experiments identified and illuminated prominent load forecasting issues and improved the understanding of the models' capabilities and limitations. An issue identified, but not resolved, was the degree to which combined historical data from many utility regions could be used to estimate relevant parameters in a demand model for a single utility region (EMF, 1978b).

EMF 4: Aggregate Energy Demand Elasticities

A fourth working group conducted a specialized test of the aggregate price elasticity of demand implicit in the participating energy models. Eighteen models were run under nine scenarios testing the models' responses to variations in the prices of oil and gas, coal, and other energy sources. Interpretations of model runs and conclusions are still under heated debate (EMF, 1978c).

EMF 5: U.S. Oil and Gas Supply

A fifth working group held its first meeting in January 1979. The group intends to examine the effects on domestically produced oil and gas of alternative world prices for oil, domestic prices for natural gas, oil price controls, alternative federal leasing rates, price controls, surprises in price trajectories, changes in the tax structure, and alternative assumptions about the geological resource base.

THE ENERGY MODELING FORUM TODAY

Goals and Design Principles

The basic goal of the Energy Modeling Forum—to improve the use and usefulness of energy models in the study of important energy issues—entails a number of subgoals, some competing, some complementary.

The first set of goals relates to comparison of models to improve understanding of their limitations and capabilities:

- To identify and compare critical elements of existing energy models and to illuminate their major strengths and weaknesses;

- To cast light on key modelling issues so as to afford a greater understanding of alternative modelling approaches; and
- To provide guidance for the improvement, linkage, and extension of energy models and to establish priorities for new modelling research.

The second set of goals is related to the development of better information relevant to energy policy making and planning, and available through the use of energy models:

- To use major energy models to sharpen insights, improve understanding, and explore the implications of selected energy decisions and scenarios; and
- To broadly disseminate information about possible energy futures and the impacts of various energy actions on those futures.

A set of design principles guide Energy Modeling Forum activities in pursuit of these goals (SUIES, 1977):

- *User Orientation*. The EMF should work to improve the use and usefulness of energy models, approaching the studies from the user perspective and maintaining an active user involvement.
- *Model Comparison*. The EMF studies should compare the capabilities and limitations of many models, and these comparisons should be descriptive rather than normative. This is a unique contribution that the EMF can make, and it avoids the difficult problem of model validation.
- *Issue Focus*. For the general model user, abstract model comparison should be conducted in the context of the application to an important energy issue. This will provide a direction and a discipline for the model tests.
- *Broad Participation*. The communication objectives of the EMF are best served if there is a wide participation in the selection of study topics, the formation of the working groups, and the dissemination of the study results.
- *Decentralized Analysis*. Existing energy models are often complex and require skillful application by the model developer. Despite the inherent advantages of third-party analysis, the EMF must rely on model tests as reported by the individual research group (SUIES, 1977).

In general, the studies have conformed well to the design principles and guidelines. All but, perhaps, EMF 4 have maintained an active user involvement, including users from government agencies, private sector corporations, research institutes, and universities. Each of the studies has included model comparisons, using between six and eighteen models with ten being the median number addressed in any one study. Each had a strong issue focus although the immediacy of the issues varied significantly among the studies. The two final design principles, broad participation and decentralized analysis, have been fully met in each of the studies.

Organizational Structure

The current organizational structure of the EMF is illustrated in figure 1. The Senior Advisory Panel, the working groups, the EPRI staff, and the EMF staff interact with one another and with the broad community of energy modellers and potential model users.

The heart of the EMF consists of the *ad hoc* working groups of about thirty-five members each. The working group chairman and the issue to be studied are selected before the formation of the working group. Each working group, composed of volunteer participants, with a balanced representation of model users and model developers, is organized around a specific energy issue to ensure both the proper representation of relevant models and participant interest in the policy or planning issues addressed. The chairman selects members with the goal of obtaining a working group which is diversified geographically, institutionally, and philosophically. With observers and others who closely follow the working groups, and rotation of the working groups as new issues are selected, over two hundred and fifty people have been involved in the five studies to date, and more than one hundred might be active in any year.

At each stage in this process, the EMF is assisted by the Senior Advisory Panel. This group, chaired by Charles Hitch of Resources for the Future, Inc., is composed of senior energy decision makers (see Appendix for a list of the membership) who represent the ideal target audience for the EMF studies. The Panel helps maintain the necessary broad participation and user orientation to assure the value and immediate relevance of the working group topics. The Panel meets annually, and provides necessary advice throughout the year. Its functions are primarily fourfold:

- To suggest appropriate study topics and to critique prominent study proposals so as to provide a sense of priority;
- To suggest and possibly assist in recruiting appropriate working group chairmen and members;
- To critique the working group's final report in draft form both for substance and presentation;
- To help disseminate the results of the studies.

The overall planning, co-ordination of daily operations, and administration of the Energy Modeling Forum are handled by the EMF staff, supervised by an executive director. Located at Stanford University, the EMF staff is affiliated with the Stanford Institute for Energy Studies, and Departments of Engineering-Economic Systems and Operations Research. The staff (see Appendix for a listing of staff members) provides support for the Senior Advisory Panel in the development and selection of issues for future topics, recruits the working group chairman, assists the working group chairman in organizing a study, participates both as members of the working group and staff to this group, and publishes the final working group reports.

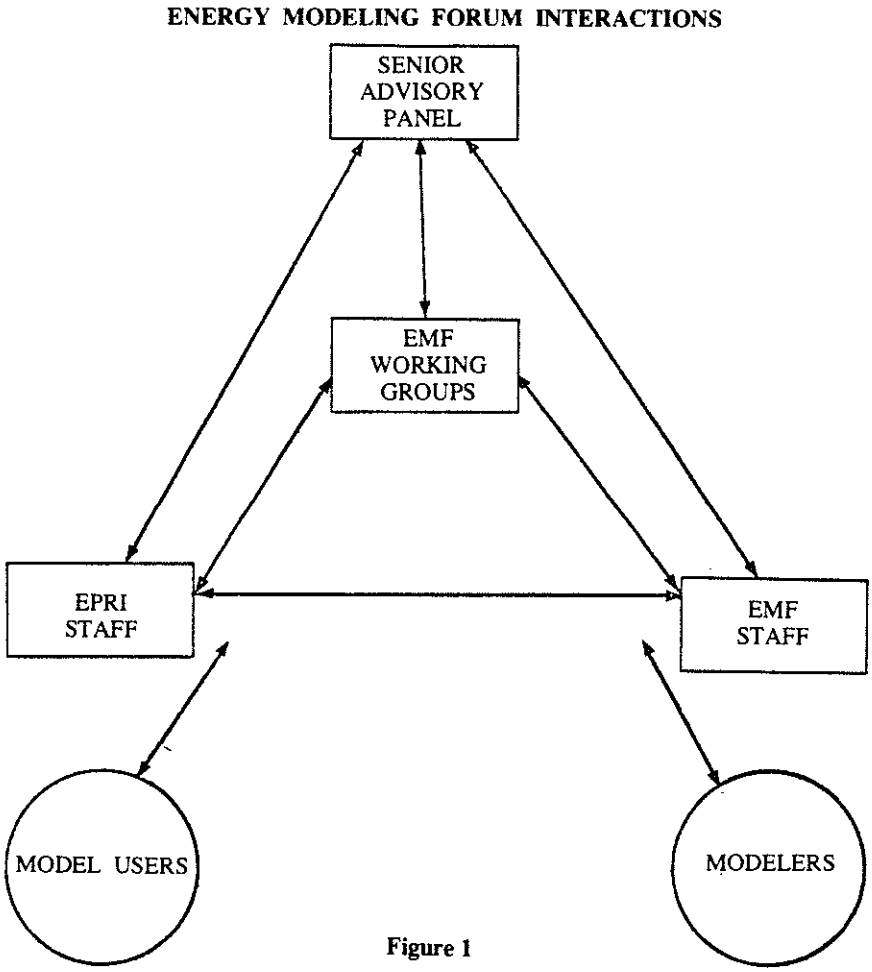

Figure 1

The communication function of the EMF is enhanced by close ties maintained among the various participants in the Forum. The Senior Advisory Panel includes EPRI representation. Meetings of the Senior Advisory Panel are normally attended by the executive director of the EMF, at least one working group chairman, and by several EPRI staff members. Energy Modeling Forum working groups include EMF staff members as well as EPRI staff members particularly knowledgeable in the area being addressed. Close co-ordination between the EMF staff and the EPRI staff is maintained throughout all phases of the Forum. Some of the working group members or chairmen were initially proposed by Senior Advisory Panel members. The community of energy modellers and potential energy model users interacts broadly with the entire process, by participating directly in working groups as members or observers, by membership on the Senior

Advisory Panel, or by a one to three-year position with the EMF staff. This community also suggests appropriate study topics, models to be considered, issues to be addressed, and maintains informal communication with EMF groups.

The EMF Process

A typical study cycle begins with a broad call to modellers and potential model users to assist in identifying potential study areas, moves through phases of working group organization, intense modelling activities, and result interpretation, and the writing and publication of the report. The complete process may take as long as a year and a half, involving typically three to four working group meetings, spaced about three months apart. Publication is normally followed by an indefinite period of publicizing the study and the development of applications for the work. Table 1 illustrates the various phases of a study and indicates which groups typically are actively involved in various phases of a study.

The process of selecting a study topic involves a wide range of participants. Initial identification of potential topics is accomplished by collecting ideas offered by many people. These suggestions are distilled to a dozen or so major potential study areas to be considered by the Senior Advisory Panel. The Panel in discussing the issues provides a sense of priority from a user perspective as well as providing suggestions for specific issues within the general areas. Additional preliminary exploration and issue identification of high priority topic areas follow. This activity is co-ordinated by the EMF staff, but involves participation by the community of energy modellers and model users.

This process results in the selection of a topic and a chairman to direct the working group. Virtually concurrently, the chairman in co-ordination with the EMF staff selects the specific project to be undertaken. This simultaneity assures that the chairman is not only directing a study on a topic within his area of expertise and interest, but also one which seems feasible in light of the existing energy models and the limitations on the current state of the art.

A working group is recruited primarily by the chairman and the EMF staff, with the working group chairman guiding the selection process. This phase, along with the first step of selecting the working group chairman, is critical to the study's success. The value of the process and the final report is dependent upon a strong, knowledgeable, diverse working group whose members are familiar with the nuances of policy issues and policy models and devoted to improving the application of the models to policy and planning issues.

Once the working group is organized and holds its first meeting, complete responsibility for the conduct of the study is vested in the group.

Table 1
Participation in Phases of EMF Studies

Study Phases	Senior Advisory Panel	EPRI	Working Group Chairman	Working Group Group	EMF Staff	Others
Identification of Potential Area	X	X			X	X
Consideration by Senior Advisory Panel	X	X			X	X
Preliminary Exploration and Issue Definition	X	X			X	X
General Topic Area Selection	X				X	
Working Group Chairman Recruiting	X	X			X	X
Specific Topic Selection			X		X	
Working Group Recruiting	X	X	X		X	X
Model Selection			X	X	X	
Issues Identification			X	X		
Scenario Specification			X	X	X	
Selection of Output Variables			X	X	X	
Running of Models				X		
Displays of Results				X	X	
Model Comparisons			X	X	X	
Critique and Interpretation of Runs			X	X	X	
Write Executive Summary			X	X		
Write Summary Report			X	X	X	
Write Appendixes			X	X	X	
Critique Report	X		X	X		
Publication of Report		X			X	
Publicizing Study and Applications	X	X	X	X	X	X

The working group selects the models to be run. Normally, there is agreement that each existing current model represented by a working group member can participate. However, the working group may identify and recruit additional modellers.

During the first meeting, group members identify the most important energy policy or planning issues to be addressed and those that cannot be addressed. The participation of modellers and model users is critical at this point. The capabilities and limitations of the various models, along with priorities for further model development, soon become apparent. In general, the goal here is to focus upon the most important issues and to test the capabilities of the various models to address those issues. This is to be contrasted with what can easily happen in practice: the issues to be dealt with are determined by the particular strengths of the individual models, with secondary consideration given to the importance of the issue for policy and planning purposes.

Study issues normally relate to informational questions significant to energy policy and planning. For example, the second study asks to what extent alternative environmental restrictions influence both the rate of the transition back to coal and the regional distribution of the growth. The fifth study asks how the U.S. supply of oil or natural gas will be influenced by domestic price controls.

Alternatively, the study question may be a modelling or forecasting issue. The third study asks how significant changes in the price of electricity will influence consumption. Differences in the answers among models seem to depend upon the geographic scope of the data base used with the models. Thus, the issue becomes: to what extent could combined historical data from many regions be used to improve the estimation of parameters for a model applicable to a single utility service area?

Once the issues are identified, scenarios are generated to capture the essential features of the issue being considered. The scenario specification includes a set of standardized input assumptions, some of which are changed systematically among the scenarios to test the models and to provide information potentially useful for policy and planning purposes. In general, each modeller is asked to run each of the scenarios with the standardizing assumptions.

Differences in the models become apparent. The input data for one model may be the output of another. Some input variables may not be included in a model, even though they are believed by working group members to be particularly significant in influencing the projections. Some scenarios simply cannot be addressed with a particular model except in the most *ad hoc* way, requiring extensive off-line manipulation by the analyst. Documentation of these differences is important when comparing the results of the various models and the models themselves.

The definition of scenarios is accompanied by a selection of output variables to be reported by each modeller. These are normally selected by the working group in order to provide projections of those variables that are most meaningful for policy and planning purposes and to give the working group members an opportunity to observe the inner workings of a model at several critical points. For example, in the fifth study, output variables to be reported will include measures of drilling activity, quantities of oil and gas discovered, reserves of oil and gas, and production rates for a selected set of years. Whether or not individual models can calculate these intermediate variables is often important in communicating capabilities, limitations, and dependability. Comparisons of model behaviour at several observation points provide the raw material for group discussions and report writing.

Each model is run by its key developer or a close colleague. Third-party model operation is not routine.There would be advantages in third-party model operation, but these are outweighed by the practical advantages of the modellers running their own systems. The developer may best understand the limits of applicability of the model. Moreover, the modeller knows which sets of equations or data within the model must be modified to examine specific scenarios. Having worked extensively with a given system, (s)he can make runs without undertaking the enormous learning cost required for third-party analysis.

Displays of model outputs are designed so as to facilitate interpretation and comparison. Graphic comparisons are prepared by the EMF staff for use by the working group. The displays of the outputs, if done creatively, can help in interpreting the comparative behaviour of the individual models.

A large portion of working group time is devoted to critique and interpretation of the runs. Differences among models provide an opportunity and a motivation for explaining why the different results occur. Discrepancies in results may point to fundamental differences in model structure, model parameters, basic data utilized, or perceptions about the direct implications of scenario assumptions. Divergence in model results normally leads to creative tensions among the modellers with each trying to understand why his model differs from the others. One motivation is to improve the model if appropriate. Another is to show why one model's answers may be more dependable than those developed by some other modeller. This dialogue is a strong motivating force which leads to important understandings about the fundamental model differences relevant for policy or planning purposes, the areas of uncertainty in knowledge about the world, and the significant areas of research potential. The process can result in the revision of a model during the study to account for implementation problems not initially perceived by the model's developer.

These working group discussions enhance the model users' insights about the policy issues and suggest distinctions among policy options that may not be apparent on the surface. For example, many policy options may

increase the cost of producing a given amount of energy, e.g., restrictions on types of coal that can be used for electricity generation or restrictions against the use of nuclear energy. Others, however, may simply influence the price of energy without influencing its cost, e.g., an energy tax that is redistributed through the U.S. Treasury. The first class will have a far greater impact on economic growth than will the second class of options (Sweeney, 1978). What may seem to be a subtle distinction in policy options may have a profound impact on the effects of the various options on economic growth.

The working group report is characteristically written and published in two separate components: a relatively short summary, approximately thirty pages long, directed at a broad audience, and a much longer series of supporting documents aimed at a smaller, more technical audience.

The summary explains the major commonalities and differences in the models, provides answers (to the extent possible) to the issues raised, identifies limitations of the analysis, and presents recommendations developed by the group. In writing this report, communication is emphasized; the report is intended to be jargon-free and accessible to non-technical readers. A two to three-page executive summary encapsulates the key conclusions of the report.

The series of supporting documents varies significantly from study to study. Generally included, however, are descriptions of the individual models, comparisons of the models, a simplified framework for both comparing the models and communicating an intuitive understanding of the results, a detailed description of the scenarios, detailed results from each model with comparative graphics, and a set of technical papers discussing more deeply any modelling and analysis issues that may have surfaced during the study.

The working group report provides one communication vehicle for disseminating the results of individual studies. Other mechanisms also are used. The Senior Advisory Panel is briefed on the report and members have played significant roles in communicating the results. Working group observers bring insights back to their respective organizations and help to disseminate the study's findings more broadly. Working group members typically make seminar or conference presentations based upon the study. EPRI, as well as the EMF, publishes the report and facilitates its distribution. Thus, many people help publicize the study. The study belongs fundamentally to the working group and the communication of results relies heavily on study group members actively publicizing the results.

Although the EMF reports, individual participant presentations, and other vehicles are used to communicate the results of the study, much of its benefit is not easily transferred to non-participants. A major EMF focus is on how people can use models more effectively, but effective use is a skill, learned like any other skill. While an EMF study can help modellers and

model users alike in the difficult, artistic process of utilizing models for addressing real, complex issues, the skills and insights gained often cannot be fully transferred beyond the participants, except at extremely high cost. Hence, formal communication of results beyond the working group is an important product of EMF studies, but clearly not the only product.

EMF HISTORY AND EVOLUTION

Several forces provided the impetus behind the creation of the Energy Modeling Forum and its location at Stanford University.

Professor Martin Greenberger of Johns Hopkins University was intensely interested in the relationship between modelling and the policy process (Greenberger *et al.*, 1976). He was concerned that models, on the whole, had not been used as effectively as possible for policy making and planning, partly because of the insufficient linkage between model development and the policy process. In early 1976, while on leave from Johns Hopkins University as manager of the Systems Program of the Electric Power Research Institute (EPRI), Greenberger developed the idea of establishing an institution designed to improve the use of energy models in the policy process.

At Stanford University, the Institute for Energy Studies (SUIES) had developed a very productive program in energy research. This research, however, was focused fundamentally in technology areas with relatively little attention to energy policy or analysis considerations. Partially to change this focus, Professor Thomas Connolly initiated an energy policy seminar which brought together policy makers and planners with analysts. The interchanges proved productive. Some seminar members, including Professor George Dantzig, felt the introduction of formal models useful for policy purposes could improve the seminar activities. Dantzig initiated the PILOT energy modelling project to meet this need, and, in a SUIES seminar, advocated the development of an institution to bring together energy modellers and potential users of energy models.

Chauncey Starr, then President of EPRI, and Martin Greenberger responded favourably. Dantzig and Greenberger pooled their ideas and, with the encouragement of Starr and others at EPRI, jointly developed the concept and initial architecture for the Energy Modeling Forum. A competitive request for proposal was issued by EPRI in the spring of 1976.

During this same time period, William Hogan, then Deputy Assistant Administrator for Data and Analysis at the Federal Energy Administration (FEA), was discussing the possibility of joining the Stanford University Departments of Operations Research and Engineering-Economic Systems. Believing that the use of models for policy and planning could be greatly improved, Hogan was attracted by—and ultimately accepted—Stanford's invitation for him to take the lead role in responding to EPRI's request for

proposal. Stanford proposed that the EMF be established at Stanford with Hogan as Executive Director.

In July 1976 a workshop was held at Stanford University under the auspices of EPRI and the Institute for Energy Studies to explore interest in a forum and to examine ways to create and structure such a project. Greenberger initially intended the workshop as a means of launching the Forum project, but the host institution for the EMF had not yet been chosen, and the workshop was conducted independently. The approximately one hundred people attending the workshop provided a broad representation of model developers and users.

The idea of a forum was received favourably by participants in the workshop and many variants were suggested. Proposals ranging from a clearinghouse for model access to a certification agency for model evaluation and validation were considered. A central theme confirmed by the discussion was that a strong user orientation and broad participation were crucial.

The Stanford Institute for Energy Studies, selected by EPRI as headquarters for implementation of the EMF project, initiated the project in September 1976 as a six-month experimental effort to test the viability of the concept. William Hogan, by then a Stanford faculty member, became the first Executive Director of the EMF and provided leadership in that position for two years.

For its first study, the EMF examined the use of models to study the nature and strength of the feedback from the energy sector to the aggregate economy. An important topic in its own right, this subject was of particular interest because of the closely related work of the Modeling Resources Group of the Committee on Nuclear and Alternative Energy Systems (MRG-CONAES) (Koopmans *et al.*, 1978), which did not fully consider this feedback.

Following the principles developed at the summer workshop, a group of thirty interested model users and developers was organized to conduct the study. Because of the experimental nature of the project, Hogan served as working group chairman as well as EMF Executive Director.

The six models explicitly represented the energy-economic linkage. Each model was for the full U.S. economy, and each was judged appropriate for long-run issues but not for short-run issues. As in the MRG, common scenarios were constructed by standardizing many input variables. The working group then sought to explain the common results or the causes of model differences. This comparison process was facilitated by the high degree of commonality among the various models.

The key comparative results of the study were estimates of the aggregate elasticity of substitution[2] implicit in the participating models. This parameter

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[2] For small changes in energy prices, the aggregate elasticity of substitution closely approximates the aggregate price elasticity of energy demand.

was shown in the report to be one of the key determinants of the strength of the link from energy to the economy.

The first EMF study contributed importantly to the current structure of the EMF process. In particular, the study involved considerable participation by the model-using community, which resulted in careful attention to specifying limitations of the models in studying the energy-economy issue. Additionally, the study had a strong issue focus. Although some questioned the direct applicability of the study's results to the evaluation of the energy policy options available to the federal government, it served to educate many policy makers about the magnitude of the relevant trade-offs.

Despite its positive contributions, the first EMF study suffered from several problems that had plagued previous model comparison studies. The group was often torn between the sometimes conflicting goals of policy analysis and model comparison. The study suffered from a lack of visibility; and it had a distinctly academic flavour.

The issue focus of the study was intended to aid in the model comparison, but this focus seemed to imply that policy recommendations could be drawn from the study's conclusions. A subgroup of study participants, however, contended that they would have conducted a policy study differently from a model comparison study, and therefore argued against the development of policy recommendations.

Despite the active participation of the user community in the study, the study suffered from a lack of visibility at the highest levels of government and industry. Part of the problem was that a professor as a working group chairman and six models developed primarily in universities gave the study an academic aura.

The perceived shortcomings of the first study figured in the decision by Greenberger and Hogan to institute a Senior Advisory Panel of high level energy decision makers to review the Forum studies and suggest new topics for comparative analysis. Charles Hitch, President of Resources for the Future, agreed to chair this panel.

The second EMF study, "Coal in Transition: 1980-2000," differed in several respects from the first. The executive director did not also serve as working group chairman. Rather, Dr. David Sternlight, Chief Economist at the Atlantic-Richfield Company (ARCO), was chairman of the working group. His industrial affiliation, user perspective, and previous energy policy analysis and modelling experiences proved to be invaluable. This choice allowed the complementary talents of the working group chairman and the EMF executive director to be jointly applied in the leadership of the study.

The models in the second study differed in scope from those in the first. Three types of models were employed: energy sector models with significant coal detail; models of coal supply, transport, and demand; and a resource planning model. It was now more difficult to standardize assumptions: for example, the energy sector models took exogenous projections of aggregate

energy demand as inputs, whereas the coal and facilities planning models required exogenous demand projections for electricity consumption and for non-utility coal demand. Model comparisons were conducted not only in the parallel mode as in the previous study, but also in a complementary mode with different information developed by different models. In the complementary mode, the results of one model, for example, a detailed energy sector model, could be scrutinized by use of another, more disaggregated model, for example, a resource planning model.

The conflict between the model comparison and policy analysis goals that surfaced in the first study was again apparent in "Coal in Transition." Once more, a subgroup of modellers resisted the notion that the study would make policy recommendations.

The third study group was designed to help electric utilities deal with the new complexities and uncertainties of electric load forecasting. Bernard Cherry, Vice President of Corporate Planning at the General Public Utilities Service Corporation accepted the position of working group chairman, thus repeating the second study's successful practice of having a working group chairman from the relevant industry. Again the chairman's problem orientation provided critical guidance and discipline for the study.

The study contrasted with the previous two because it involved models with differing geographical coverages. Most of the models were used for a particular utility's load forecasting, considering only that utility's region. This was a critical issue in the study because regional differences made it undesirable, if not impossible, to standardize the inputs to the models. The standardization problem was circumvented by allowing each modeller to specify a "best information" base case. Input parameters variations between scenarios were specified in percentage terms and scenario results were examined in terms of percentage differences in values of output variables.

The variance in scope in the models provided observations of differences in model behaviour. In particular, for given percentage changes in electricity prices and in competitive fuel prices, applications of the few nationally oriented models in this study showed a larger proportional impact on electricity consumption than did the utility region models. As the differences were addressed, the striking dissimilarities led to debate among the modellers. The observation led one group to conclude that combined data from many utility service regions could be used to more accurately estimate parameters in the demand models than would be possible by using data from only a single utility region. Another group felt that combining this data would reduce the quality of the estimates because of the great differences among regions. Although consensus was never achieved, the interchanges led some participants to consider the benefits of changing utility forecasting practice by estimating parameters on combined data, and it led other participants to further critical examination of the econometric foundations for pooling data from many regions.

Many participants in the third EMF working group initally questioned the potential value of the study and worried about the possibility of misuse of the results. By the time the study was completed, the participants were calling for continuation and expansion of this type of activity. Strong support by the working group members helped the Electric Power Research Institute launch its Utility Modeling Forum (UMF), a comparative analysis project focusing specifically on the problems of the electric power industry, in the autumn of 1978.

During the summer of 1978, Hogan resigned his position at Stanford University to join the Harvard faculty and was succeeded as Executive Director by Professor James Sweeney, an Engineering-Economic Systems faculty member. John Weyant, an original EMF staff member, was appointed Associate Director to replace Shail Parikh, who had resigned from that position some time previously. Weyant's expanded role in EMF, together with a period of overlap between the outgoing and incoming executive directors, provided some measure of continuity in the operation of the Forum.

The fourth study, "Aggregate Energy Demand Elasticities," is somewhat different from the earlier studies. Motivated partly by the EMF 1 conclusion that the aggregate elasticity of substitution is a critical determinant of the link between energy and the economy, the Senior Advisory Panel recommended that the EMF perform further experiments to improve the precision and level of confidence in the elasticity estimates. They felt, however, that the experiment would be too technical and not tied closely enough to specific policy issues to warrant formation of an EMF working group. Thus, during early 1978, the EMF staff, with the aid of many outside experts, designed an experiment to estimate the aggregate demand elasticity implicit in energy models.

By late 1978, eighteen models had executed the experiment. Interest in the study's results had escalated to the point where a face-to-face meeting of the study participants and interested observers was deemed desirable. Therefore, a working group of approximately forty people, predominantly model builders, was formed. Hogan, by then at Harvard University, became working group chairman, thus providing further continuity in the transition to a new executive director. One meeting of the working group has been held to date, and a second meeting will probably be necessary.

The scope of the models of this fourth working group varied greatly. There were self-standing U.S. models and U.S. models as components of international energy demand models. Some were highly aggregated, others disaggregated by fuel. Some models included the energy sector embedded within the entire economy. Some examined the aggregate of all energy consuming sectors, while others were disaggregated by sector or represented only a single energy-consuming sector.

While it has not yet been completed, the fourth EMF study has raised the question of whether a technical comparison study can be conducted apart from the model-using community. However, we believe that to be valuable the technical comparison must be focused on one or two relationships widely believed to be significant. The ultimate utility of the study will depend upon our ability to widely communicate the results effectively to the model-using community.

At the time of this writing, the fifth EMF study, "U.S. Oil and Gas Supply," is just getting under way with Ben Ball as working group chairman. As was true in most of the previous studies, the chairman, currently an Adjunct Professor of Management and Engineering at the MIT Energy Laboratory and formerly a Vice-President of Gulf Oil Corporation, has fundamentally a user perspective.

It is too early to predict the progress of the study. One difference, however, from past studies, is in the effort placed on model examinations and comparisons. Energy Modeling Forum staff members have drafted and made available to working group members a comparison of major oil and gas supply models. It is hoped that deeper model assessments and comparisons will be possible.

Table 2 summarizes the progress of the various studies as of February 1979.

Two other study topics identified by the Senior Advisory Panel as high priority areas are listed in table 2: "Energy and Inflation" and "World Oil Supply, Demand and Prices." Although at this time we do not know whether either of these two subjects will be chosen for future studies, the EMF staff is currently in the process of preliminary exploration and issue definition. This process will help us decide whether such studies will be feasible and valuable, as well as educate the EMF staff and facilitate the working group deliberations.

RELATED ACTIVITIES

Several recently initiated projects are closely related to the Energy Modeling Forum. The previously mentioned Utility Modeling Forum (UMF) plans to conduct an ambitious series of studies focused entirely within the utility modeling area. Part of the motivation for the UMF was the EMF success and the positive response of EMF 3 working group members. This project, sponsored by EPRI, and administered by Booz, Allen, & Hamilton, Inc., has recently held its first meeting.

An activity complementary to the Energy Modeling Forum is the Energy Policy Analysis Forum under the direction of Kenneth Hoffmann of Brookhaven National Laboratory. This forum involves high-level Department of Energy analysts and outside modellers and analysts. Conducted as a continuing seminar, its goal is to identify analytical capabilities dealing with

Table 2
Phases of EMF Studies[a]

Phases	EMF 1	EMF 2	EMF 3	EMF 4	EMF 5	Energy/ Inflation?	World Oil?
Identification of Potential Area	C	C	C	C	C	C	C
Consideration by Senior Advisory Panel	C	C	C	C	C	C	C
Preliminary Exploration and Issue Definition	C	C	C	C	C	•	•
General Topic Area Selection	C	C	C	C	C		
Working Group Chairman Recruiting	C	C	C	C	C		
Specific Topic Selection	C	C	C	C	C		
Working Group Recruiting	C	C	C	C	C		
Model Selection	C	C	C	C	C		
Issues Identification	C	C	C	C	C		
Scenario Specification	C	C	C	C	C		
Selection of Output Variables	C	C	C	C	C		
Running of Models	C	C	C	C	•		
Graphical Displays of Results	C	C	C	C	•		
Model Comparisons	C	C	C	C	•		
Critique and Interpretation of Runs	C	C	C	•	•		
Write Executive Summary	C	C	C	•	•		
Write Summary Report	C	C	C	•	•		
Write Appendixes	C	C	•	•	•		
Critique Report	C	C	•				
Publication of Report	C	C					
Publicizing Study and Applications	•	•					

C — Completed as of 28 February 1979
• — Ongoing as of 28 February 1979
[a]EMF studies: EMF 1: Energy and the Economy
EMF 2: Coal in Transition: 1980-2000
EMF 3: Electric Load Forecasting: Probing the Issues with Models
EMF 4: Aggregate Demand Elasticities
EMF 5: Oil and Gas Supply Functions

important energy policy issues being considered by the Department of Energy. This seminar is expected to discuss a much larger number of issues than can be addressed within the EMF format. The seminar, however, will be limited to the identification of analytical capabilities, and will not conduct its studies in the depth possible in the EMF. Close co-ordination between the EMF and the Energy Policy Analysis Forum is being maintained.

A third related activity is being contemplated by the Solar Energy Research Institute. This organization may launch an EMF-like comparative model study of alternative new technology diffusion models. This effort would help to identify methodologies that could be employed to model the rates of introduction of solar energy technologies.

A "Model Verification and Assessment" project was established by EPRI at the Massachusetts Institute of Technology in 1977. It complements the EMF by going more deeply into the testing and appraisal of individual models. The assessment project has the dual purposes of: (1) developing procedures and methodologies for in-depth assessment, and (2) applying these assessment procedures to individual energy models (Model Assessment Laboratory, 1978).

While these various activities each perform somewhat different functions, there is enough commonality so that lessons learned in any one can be valuable to the others. It is hoped and anticipated that extensive sharing of information naturally will occur.

ISSUES FOR THE FUTURE

Unresolved issues to be addressed include:

- The appropriate trade-off between model comparisons and policy analyses
- The extent to which the EMF should conduct model assessments and evaluation
- The appropriate role of the EMF in an academic institution such as Standard University
- The extent to which study participants should be compensated for their time and computer expenses.

A tension keenly felt in the first two studies and anticipated in the fifth is the appropriate trade-off between model comparisons and policy analysis. A typical working group includes a mix of people, some primarily concerned with modelling and some primarily with using information for policy and planning purposes. Indeed a major goal of the project is improved communication between these two groups. While these two activities are complementary in many respects, in other respects they conflict. The model comparisons considerably improve the policy analyses by refining the quality and the reliability of the information developed by using models. The policy analysis enhances the relevance of the model comparisons by structuring the comparisons to focus attention on similarities and differences most relevant for policy issues.

The first area of conflict between these two goals comes in the choice of scenarios. Because of limited time and resources, only a small number of scenarios can be structured, implemented, and interpreted by the group. Since some scenarios are most useful for model comparisons while others would be most useful for policy analyses, the selection of scenarios represents implicitly or explicitly a choice between model comparisons and policy analyses. The model users would have little interest in a study devoid of policy implications. But the model developers are anxious to examine the comparative advantages of their systems. While efforts have been made to choose scenarios to satisfy both purposes, the tension has been strongly communicated.

The tension between goals also is felt in subsequent interpretations of the results of the model runs, with conflicts on the allocation of group time for model comparisons versus policy analysis. It has been felt generally that users would see little value in detailed, jargon-ridden debates on the equations and data embedded in the models. On the other hand, without such debates, in-depth model comparisons may be impossible. One proposed solution is to extend one or more working group meetings by a day to allow the modellers (and anyone else desiring to participate) an opportunity for in-depth model-oriented discussions. Another would be for the EMF staff to draft more complete model comparison papers and to allow some of the debate to proceed by mail and telephone, directed toward improving the EMF draft.

In developing the final report, the tension over goals also is apparent. The various goals imply different themes and formats for the report. The solution to date has been to write a summary report which focuses on the policy analysis and on the capabilities and limitations of the models as a class. Individual model comparisons then appear in a longer report. While this compromise gives weight to both goals, it tends to downplay the model comparison objective.

The issue of policy analysis versus model comparison may never be resolved, but this may be a sign of health. The tension between the goals provides opportunities for working group members to concentrate their own efforts primarily on aspects of the study most relevant to them and thereby helps to improve the overall study quality.

A closely related issue concerns the depth to which EMF should conduct model assessments and evaluations as opposed to simply model comparisons. The EMF recently has been criticized, particularly by the academic community, for its lack of critical review of the participating models.

The forum has focused attention on the "ventilation" of models, the simple examination and explanation of their behaviour (Hogan, 1978b). This step, of course, logically must precede evaluation or assessment. This comparative study of the behaviour of a number of models allows consequent work to identify differences stemming from data differences, structural

differences, differences in explicit assumptions, and, often most importantly, differences in implicit assumptions or world view held by the developers. Although evaluation *per se* has not been conducted by the Forum, the differences identified through the comparisons provide an improved basis for individuals to make their own evaluations of the models.

There are several reasons why the Forum up to this point has not conducted in-depth evaluations. First is the question of the extent to which objective comparisons are possible. Of course, some aspects of assessment can be conducted objectively. One could examine whether the computer code was written as the developer intended or could attempt to replicate the underlying econometrics. Activities of this sort are in fact being conducted by the MIT Model Assessment Laboratory (1978). Some assessments, however, cannot yet be objective with the current state of the art but are based upon subjective peer review judgements. Econometric evidence, for example, can be viewed differently by various professionals. Even more difficult is sorting through and assessing the implicit assumptions and the world view incorporated in the model. Evaluating which implicit assumptions and world view are more nearly correct cannot be done objectively. Individuals, however, can make their own judgements on a subjective basis, if the behaviour of the models is clearly communicated. This individual, subjective process is facilitated by the Forum studies.

Furthermore, early experience at the Model Assessment Laboratory has demonstrated that a credible in-depth, hands-on, third-party review of a single model can require resources comparable to a full EMF study. A comparative in-depth assessment of, perhaps, ten models could require an order of magnitude more resources. Faced with a limited budget, even if desirable, such a process is impossible for the Energy Modeling Forum.

Another difficulty with model evaluation is that different models may be particularly useful for different purposes. The type of model useful for forecasting the consumption of gasoline in the presence of new car average efficiency standards may be different from the type desirable for forecasting the market share of station wagons. Different models may be more appropriate for various alternative purposes. For example, for forecasting gasoline prices two months hence, a simple time trend extrapolative model may be far superior to one including a detailed representation of the economic and engineering relationships. Conversely, for evaluating the impacts of oil decontrol on gasoline prices, the time trend extrapolative approach would be useless, while a structural modelling approach could be quite effective: (Sweeney and Flaherty, 1978). Realizing that different models are appropriate for different purposes, the EMF has attempted simply to delineate the capabilities and limitations of various models without undertaking the more difficult task of model evaluation.

Finally, potential working group members must be convinced of the value of the process to them as individuals. Each volunteers time and many

contribute computer costs. If the expected rewards for participating are primarily public criticisms of their models, especially criticisms built on weak foundations, then the voluntary participation could be reduced notably. This may still become an issue. However, if the assessments are objective, and if they recognize strengths along with weaknesses, more telling comparisons probably are possible without discouraging the participation of the modellers. In this way, the Forum may include some elements resembling professional peer review, but without the academic apparatus of manuscript refereeing.

The current movement is towards deeper model comparisons. At the same time, it is crucial that the issue focus not be lost. For the fifth study, the EMF staff devoted to model comparisons has been significantly expanded. Staff members currently are examining methodological differences among oil and gas supply models, to the extent possible without hands-on experience. This examination was started even before the working group convened, with the expectation that the group will encourage and participate in this process. This expectation is being realized. The extent to which the EMF evolves towards deeper model comparisons and evaluations is an open issue. Its resolution depends upon such factors as the future EMF budget, the preferences of working group members, and the willingness of working group members to expose their models to critical review.

Closely related is whether or not third-party model operation should be introduced into the EMF. In the current mode of operation, all model runs are made by the model developer, not the EMF staff. Benefits of changing this mode of operation would be associated with the opportunity for a more scientific, objective, and complete examination of individual models. The costs would be several, and high. First would be the requirement for staff members to learn software that is model-specific. Second, there would be a weaker linkage between the evaluation process and the modellers, possibly resulting in a lesser interchange of information. Finally, model assessment is far more costly than the current EMF procedure. Therefore, it is expected that little if any independent third-party operation will be introduced.

The role of the EMF in an academic institution such as Stanford University, where the educational progress of students is a key concern, raises another issue. In the past, Stanford students have participated in the EMF, but to a relatively limited extent. Currently, eight Stanford graduate students are participating directly in ongoing EMF studies or in preliminary issue identification and exploration for possible future studies. Many of these students are looking into methodological issues or are comparing methods, supporting data, or econometric techniques underlying participating models. This activity contributes simultaneously to the academic goals of Stanford University and toward deeper, more telling model comparisons and evaluations. Thus, responsiveness to the educational goals seems at the same time to allow responsiveness to the call for increased critical evaluation, while maintaining the issue focus.

The final unresolved issue involves costs. Participants in an EMF study volunteer their time and generally computer expenses. Although most feel a sense of professional obligation and perceive a learning experience in participation, which justifies the donation of their time, the expense of running the sometimes quite costly models is not so easily absorbed. However, this policy has in the past excluded some potential participants who simply could not afford to participate without compensation. While the EMF has made an effort to help participants find a way to cover the computer costs of running the models, this policy may have, in the past, and probably will, in the future, exclude some of the models.

Many private and public sector organizations benefit extensively from the studies, but bear none of the costs. Plans therefore are under way to raise money to cover the out-of-pocket expenses of study participants whose organizations cannot bear these costs. What kinds of costs should be covered, to what extent, and by whom are unresolved at present.

SUMMARY AND CONCLUSION

The Energy Modeling Forum, organized almost three years ago as an experiment to improve communication between energy decision makers and energy modellers, has been succeeding although many issues remain unresolved. Future success depends upon continuing co-operation from the broad community of energy modellers, planners, and policy makers. Constructive critiques and suggestions and constant efforts to improve interaction will be important factors in fulfilling the objectives promised in the original design of the Energy Modeling Forum.

APPENDIX

Energy Modeling Forum

Senior Advisory Panel

Mr. Charles J. Hitch (Chairman)	President, Resources for the Future
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