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# THE USE OF MICROCOMPUTERS IN ENERGY PLANNING FOR DEVELOPING COUNTRIES

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# THE USE OF MICROCOMPUTERS IN ENERGY PLANNING FOR DEVELOPING COUNTRIES

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# EXECUTIVE SUMMARY

Beneficial changes in energy supply and demand conditions in developing countries will result from a variety of factors. Predominant among these factors will be the ability of developing country governments to build institutions and staff capable of evaluating the complex, highly integrated nature of the energy system; developing sound energy policies; and then assembling, analyzing and implementing projects based on these policies.

This study evaluates the potential roles that a major information technology, microcomputers, might play in developing these institutional capabilities. The potential application of microcomputers for energy and related planning purposes are examined from several viewpoints. First is the viewpoint of existing planning needs in developing countries and the current and potential applications of microcomputers as they relate to these needs. The second viewpoint evaluates past and current experience with microcomputers with particular regard to how hardware and software problems affect use of these tools. Finally, the study evaluates how potential applications of microcomputers might affect the programs and policies of AID.

The study concludes that microcomputers can and will play an important role in expanding and enhancing national energy planning and development capabilities. Major benefits will include staff upgrading, almost instantaneous access to technical planning methods currently used in national energy planning in developed countries and the ability to extend current planning efforts into areas that were previously impossible because of data handling requirements.

Among the specific recommendations from the study are the following:

1. Within AID, computer technology should be regarded from a broad perspective of technology transfer and development as well as from the perspective of sectoral applications.

2. AID should continue to carry out policy-oriented research on the opportunities and institutional conditions for the most effective uses for computers in the development process.

3. A broader set of training programs, for example in programming and servicing of hardware, should be considered as an accompaniment to applications-oriented technical assistance programs.

4. AID should establish clear policies regarding the effective availability of software used in its energy projects.

5. AID should consider mechanisms to provide software support after the end of a project in which software has been installed in a country.

6. AID should investigate the possibility of commissioning the development of advanced software for energy applications in developing countries.

7. AID should assign responsibility for monitoring and supporting programs where computers play an important role to a single office.

# I INTRODUCTION

## A. BACKGROUND

Perhaps the most common adjective used to describe the rapid development and use of the computer is "revolutionary". Several authors liken the effects of computerization on societies and economies to those of the industrial revolution(1). As Stehling has pointed out this "second industrial revolution" is less obvious since it is characterized by miniaturization rather than largeness; by tiny silicon chips hidden inside devices and products rather than billowing smokestacks. More subtle, perhaps, than its predecessor, this revolution may be more profound since it extends man's intelligence rather than his physical abilities(2).

Those concerned with social and economic growth in developing countries must start to deal seriously with the implications of the computer revolution on those countries. Computerization is proceeding at an extraordinary pace and with remarkable pervasiveness throughout industrialized economies. If, as many expect, computers have significant economic value, they may add another critical possession to the "haves", distancing them even further from the "have not" nations.

While this broad issue is worth serious attention by the development community, it can be addressed, at least in part, by examining applications of computers to specific problems of development and development planning. In this paper we consider the applications of microcomputers to the development of the energy sector

in developing countries and, in particular, in the process of planning and implementing national energy programs. We examine this issue from two perspectives: that of the developing countries and their need for cogent, integrated planning; and that of USAID and its desire to make the most effective use of its budget for technical assistance.

As we shall see, applications of microcomputers in the energy sector can be taken as representative of the more general issues of the role of computers in the development process. Particularly in this context the term "computers" as used in this paper should be interpreted broadly to include software, robotics and data base and information systems, what in French is referred to as "informatique".

## B. THE PLANNING CONTEXT

In the body of this report we discuss applications of microcomputers to energy planning and associated analytical activities. It would be well to set the stage for that discussion by providing background both on the general situation with regard to energy planning in developing countries and to the technical development of microcomputers and associated software. Linking these two developments provides the basic rationale for this paper.

Assistance in planning has been a prominent element in the U.S. foreign assistance program in energy from its beginning. Although there had been isolated cases of technology demonstrations and work in villages, the first concerted assistance activity, recognized as an integrated energy program was the inter-agency "LDC Energy Program" initiated in 1977 and codified in the 1978 Nuclear Non-Proliferation



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Act of 1978 (Title V). AID's policy planning for energy assistance during that period emphasized the benefits of energy planning relative to and as a guide to other technical assistance activities[3].

The first two developing country energy assessments were carried out in 1976 and 1977 in Egypt and Peru as cooperative bilateral exercises, managed by the Department of Energy. Those rather detailed and elaborate assessments were continued in Argentina, Portugal and Korea. At the same time AID initiated a somewhat more focused series of country energy planning and assessment activities in Central America, the Dominican Republic, Morocco, Indonesia, the Sudan and Tunisia. The UNDP and the World Bank also undertook brief energy assessments in a large number of countries as well as more extensive policy studies (for example in Somalia). The European Economic Community and other national assistance programs also have supported national energy planning in developing countries.

This is not to say that energy planning assistance has been accomplished and most developing countries "checked off". The UNDP-World Bank assessments, for example, have covered many countries but they have not initiated an indigenous, continuing energy planning activity. Even as extensive a project as the DOE-Egypt assessment was only a start on an adequate planning activity and a major cooperative planning assistance project is now being planned. Virtually all of AID's planning projects have led to follow-on projects. It is generally recognized that, given the total job to be done, the energy planning assistance effort has just begun. Energy planning assistance and its extensions into energy conservation planning, energy pricing

and investment analysis remain high priority areas for technical assistance to developing countries.

One reason for the extended time scale for responsible energy planning assistance is the high priority need to develop local planning and analytic capabilities. Thus, training, broadly defined, is an important and integral part of AID's energy planning assistance program, both in a broad programmatic sense and in individual country projects.

## C. THE COMPUTER CONTEXT

There are many ways of characterizing technical progress in computers: for example, the amount of information on a single silicon chip, circuit complexity per unit, and cost per unit operation per second. Whatever criterion is used, however, technical progress has been exponential over the last decade with extraordinary rates of change from 20 to 30 percent per year[4]. There is every expectation that such growth in capability will continue for some time into the future[5]. Accordingly, a question which often arises when considering the application of microcomputers to energy planning in developing countries is whether next year's technical development will make this year's application obsolete.

There are basically two issues here. The first issue is simply one of capability. Is the current generation of microcomputers adequate in terms of memory size and speed for energy planning purposes? Although one could certainly find examples of programs used for energy analysis in industrialized countries that would not fit on

a microcomputer one can also argue that such models (which may involve extensive time series in highly disaggregated regions and the resultant manipulation of large matrices) are inappropriate for the vast majority of developing countries. Neither the quality of existing data nor the immediate planning needs warrant such modeling. In our judgement, and this is confirmed by a consensus of those working in this area, current microcomputers have quite adequate capability for the kinds of applications discussed in the chapters to follow. (Appendix A illustrates these capabilities as they apply to planning needs.)

What about cost? The retail cost in the U.S. of what could be considered a fully configured microcomputer with sufficient capability for energy planning should be under $10,000. This is based on the example of an IBM Personal Computer with 256K of internal memory, a 5MB hard disk drive, monochromatic display and a dot matrix printer. Although this price includes the cost of systems software (compilers) it does not include applications software. It does, however include the cost of an uninterruptible power supply which would normally be advisable. Configurations using other equipment costing around $3,000 could be quite adequate for some applications. The important point is that the cost of the microcomputer is small (usually much less than 10 percent) compared to the total cost of an initial national energy planning effort, particularly if that effort involves foreign consultants. The costs of those planning efforts (in national energy, the electric sector or industrial conservation) are themselves small compared to the investments which they are intended to guide.

As long as current machines are adequate with respect to the tasks to be accomplished, and as long as their costs are small compared to total program costs, it is not very important that the technology may become 60 percent less expensive per unit operation, or 60 percent more powerful per unit cost, in the next three years.

More important perhaps are a series of issues that result from the use of computers in developing countries over sustained periods. Such issues would include lack of access to hardware service and parts; insufficient numbers of trained technicians and programmers; inadequate electric and telephone service; and the like. Such problems, for example, have caused the UN Statistical Office to use a variety of microcomputer systems for its census projects. It prefers to select those manufacturers with the closest or best service arrangement in the specific country involved, then backstop the system with a combination of redundancy, hardware support equipment, and full-time resident expert staff knowledgeable about hardware and applications.

While such issues are serious and pervasive they may in fact provide advantages for microcomputers over mini computer and main frame options. For example, in some countries there may be a need to select between a main frame servicing 10-20 remote workstations in several disbursed agencies or individual groups of 3-5 microcomputers in each agency. In this case the microcomputer option has a decided advantage in reliability through redundancy. It must also be said that in many countries the control of a central computer facility by a single government agency has created a situation in which use of the facility by other agencies has been difficult and/or inefficient.

Complete tailored microcomputer systems can be provided to individual agencies without creating the friction that results from the development of a central computing facility serving several, or many organizations.

A final, and considerable, advantage of microcomputers in a developing country environment is that they are compatible with the rapid growth of computer use and applications. One should distinguish two kinds of growth of computer use: growth in the complexity of programs run by individual users and growth in the number of users. In the developing country environment it is the latter type of growth that is apt to predominate, at least in the early stages of computerization. The microcomputer approach allows the investment in hardware and software at any particular time to match the need at that time. There need not be excessive, unused capacity, as might well be the case for centralized systems, and the system can grow in small units to match demand growth. Even growth in applications complexity beyond the microcomputer capacity can be accommodated by a system initially based on micros. As demand and capabilities increase they can be integrated into larger networks while retaining the ability to function autonomously.

# II APPLICATIONS

The range of potential applications of microcomputers for energy planning and analysis is extremely large. Since the objective of this paper is not to catalogue all possible uses but rather to arrive at useful policy conclusions, we have elected to examine some representative applications of microcomputers. Initially, the discussion will focus on integrated national energy planning, then will move to potential applications of microcomputers in one major energy sector (the electric sector); then to a discussion of the applications in an area of major policy and technical intervention in the energy system, energy conservation. These applications were selected because they are representative of planning activities and are crucial to balanced planning and development efforts. A discussion of the use of microcomputers in training in energy planning will reveal a possibility for important applications in other energy areas. Further, the range and type of microcomputer applications in these areas provides an indication of typical applications in other non-energy, planning areas.

## A. NATIONAL ENERGY PLANNING.

### 1. Major Elements of National Planning

A common error made in initiating national energy planning is to start by collecting information and building analytic and planning models before a clear idea is developed of the objectives of analysis.(6) The first step in energy policy analysis should always

be to determine the questions to be resolved and then to allow those needs to determine the information, criteria and methods to be applied. Even a cursory review of energy planning in developing countries shows that each country has a different mix of problems; each has defined its planning needs differently. Each has reached a different stage in the development and operations of an energy planning system. These differences suggest that no unique off-the-shelf analytic system can be applied uniformly to every problem in all countries or at all stages of the planning process.

On the other hand, there are specific needs that are common and common planning and analysis frameworks which are broadly applicable to developing countries. Generally these systems are of varying levels of complexity and specificity and parallel different stages of national planning: these might best be described as the initial analytical stage and the planning and development stage. In the analytical stage (Table 1, column 1) national efforts are oriented towards characterizing the national energy system and defining broad national strategies. This includes gathering existing energy information; supplementing these data with survey information; projecting energy supply-demand into the future; analyzing this information to determine the strengths and weaknesses of the energy system; and, finally using these analyses to define future supply-demand strategies. (This is also the stage where the physical and functional structure of a national planning system is established, including the roles and responsibilities of government ministries and para-statels.)

TABLE 1

Components of National Energy Planning

Analytical

A. Energy Information Systems: embraces two distinct concepts. First development of a national energy data base. Second, development and operations of a system for collecting, storing and sharing energy planning information normally. The responsibility of an existing organization.

B. National Energy Surveys: provision for collecting, storing and sharing information that is not normally the responsibility of an existing organization.

C. Energy Supply and Demand Balances: characterization of the national energy system from resource production through final consumption. Presents information by fuel type, by use/process, by demand sector, may be regionalized also.

D. Analyses and Evaluation: uses the information available to define energy supply and demand trends, energy/economic relationships, substitution possibilities and the like.

E. Preliminary Economic and Pricing Studies: analyses of the affect of energy consumption on the balance of payments, as well as evaluations of whether consumer prices reflect the full costs of providing energy.

F. National Projections: extension of C-E with qualitative information to assess future energy supply and demand patterns, and the impacts thereof.

Development and Decision

G. Sector Specific Surveys, Models, and Studies: disaggrates national data to present detailed sectoral and sub-sectoral resource, technology, supply and demand characterizations and projections.

H. Energy Conservation Analyses: uses previous national work and generic operating and technology information to evaluate the national opportunities for energy and economic savings through increased process efficiency.

I. Macro-Economic Studies: evaluates the affect of global market changes on the national energy and economic systems.

J. Portfolio and Optimization Analyses: provide for the selection of one or more optimal projects from amongst a portfolio of projects given a specific set of financial and other criteria. Also selection of optional supply and demand patterns given specific system characteristics.

K. National Investment and Financial Planning: allows for the selection of a mix of development projects given national cash flow, balance of payment and other criteria.

L. Input-Output Models: relate structural shifts in national and regional economic activities to changes in energy supply, consumption and price (and vice-versa).

The planning and development stage (Table 1, column 2) of national energy planning is characterized by increased complexity, specificity and depth. In this stage emphasis is placed on specific technologies and the supply of energy to specific uses in specific sectors. The information and development priorities from these studies are then integrated into "national energy development priorities", and/or implementation plans, and/or economic development plans using multi-sector analyses. Information developed during this phase is also fed back to the national energy characterization to create a dynamic planning system allowing increasingly detailed characterization. This stage is further distinguished from the analytical stage by four major characteristics. First, the information developed is highly specific and focused, whereas in the first stage it is general and highly aggregated. Second, national energy planning efforts at this stage focus on integrating sectoral information and development plans, rather than on constructing the national energy overview. Third, the efforts are decision oriented, they focus not on development of, but implementation of national energy policies and the evaluation, selection and development of specific projects and opportunities. And fourth, the basic information is developed by a variety of organizations with distinct functional responsibilities. Only the aggregate information and results are fed back to a national planning agency.

In many instances the analytical stage and the planning and development stage are not strictly and simply sequential. Often detailed sectoral work goes on in parallel with or even, for example in the electric sector, may precede national integrative analysis.

Surveys, normally characteristic of the analytical stage, are often identified or carried out as part of the planning and development stage. An iterative relationship between the two stages is, in fact, to be encouraged. Results of sectoral planning and development should be returned to the integrative modeling process to extend and deepen national analysis.

## 2. The Role of Microcomputers

In the rush to perform complicated decision-oriented work the generic uses of microcomputers are often overlooked, yet it is these applications that provide the most immediate benefits at both stages of planning. What are these uses? They include data storage and processing; quantitative and statistical analyses, graphics preparation, word processing, comparisons with generic technical information, and the like. Such needs account for much of the effort in national planning. And, one or more such generic applications can be used directly in each of the elements of planning shown in Table 1.

Beyond these generic needs are extensive applications which form the core of current arguments for using microcomputers in energy planning. The arguments run thus: given appropriate information and technical skills an analyst can create a model of a physical system or decision framework which provides sufficient information for decisions, policies and plans. One such model might portray the national energy balance (Figure 1); another might show the flow of national energy revenues and costs (Figure 2), for example. The usual way of using such models is in three stages. The first stage involves the development or modification of the model structure to correspond to local conditions. The second stage involves the development of

FIGURE 1

ENERGY BALANCE DOMINICAN REPUBLIC (KBOE)

1978

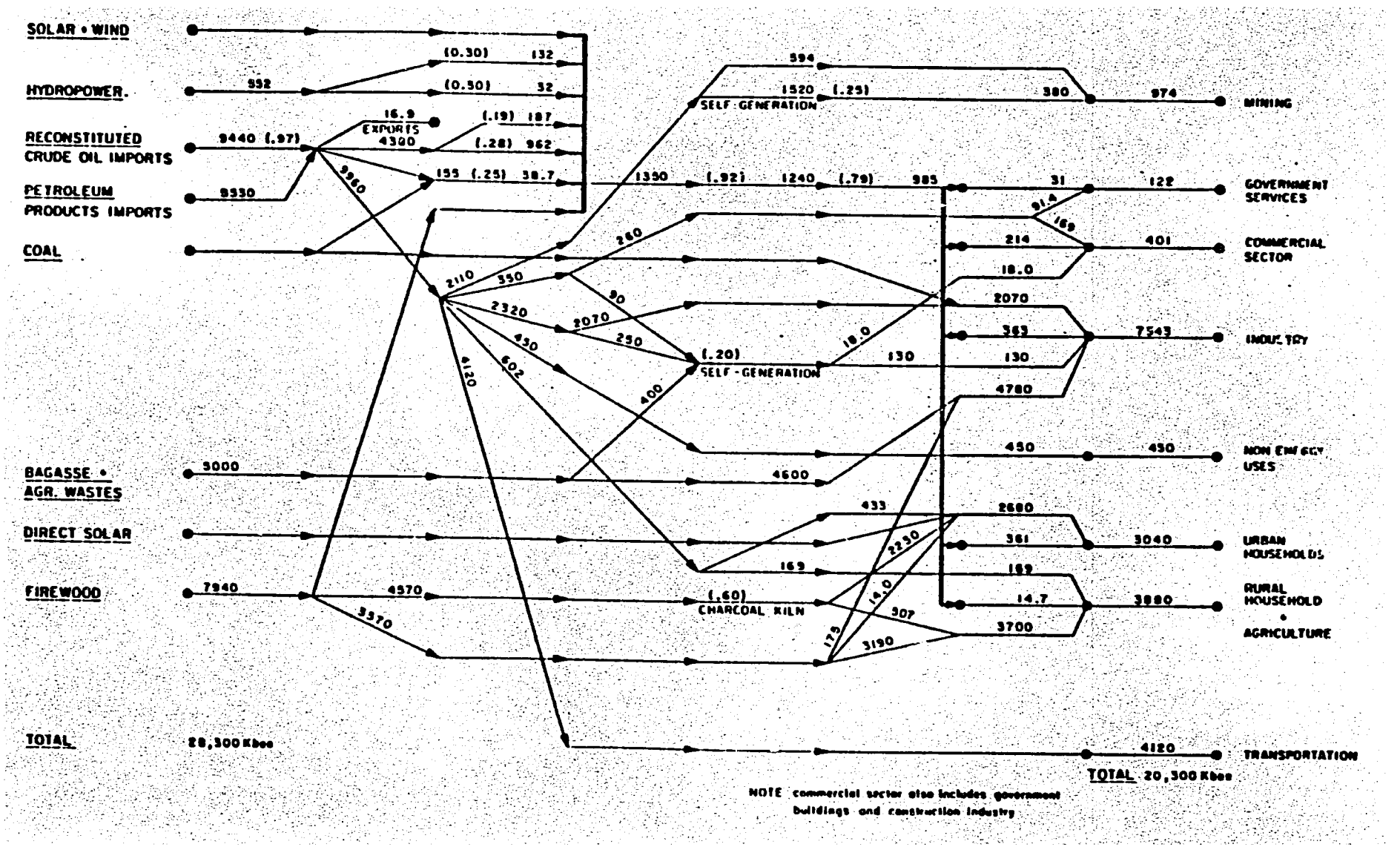




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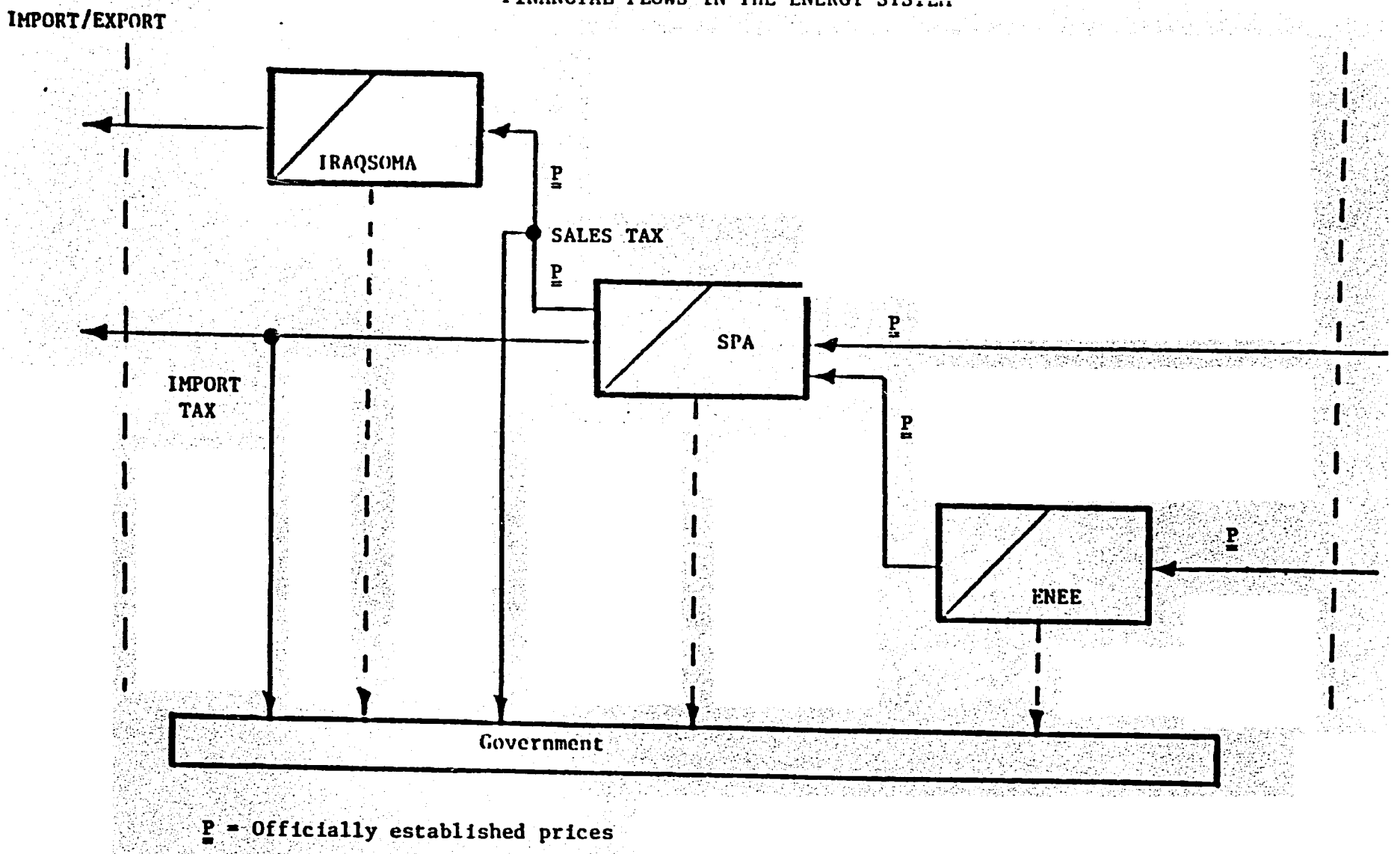
FIGURE 2

FINANCIAL FLOWS IN THE ENERGY SYSTEM



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adequate data to quantify the model. The third stage includes the manipulation of the model to analyze issues of importance. These issues might include a change in supplier oil prices, renewable energy development, conservation programs or new pricing structures.

The beauty of using computers for such applications lies in five basic factors. First, the rigor of a mathematical model imposes a quantitative discipline on the analysis of policy issues. Second, many of the applications are complex and require extensive manipulation of large bodies of data: by constructing a formal machine model repetitive procedures are moved to a faster, less error-prone environment. Third, the systems modeled are themselves slow to change, thus, a mathematical representation provides a relatively long term tool for analyzing a range of problems. Fourth, the initial characterization often provides information about how the system works which was not recognized previously: if done appropriately this characterization is an excellent learning experience. And finally, while the initial system characterization must be difficult, subsequent use and manipulation of the models can be relatively simple.

In these applications microcomputers would seem, on the face of it, to have at least two distinct advantages. First, they are easily used by the analyst. A tradition of "user-friendliness" has evolved in the microcomputer field which breaks down the barriers between the analyst and the machine. Second, they have low unit cost which allows redundancy and also allows them to be distributed where they are needed and used in a policy context.



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As we consider some recent examples of the applications of microcomputers in energy planning in developing countries, other less obvious advantages will be come apparent.

At the national energy planning level in most developed countries many models and techniques are used. For example, the U.S. Department of Energy maintains a model catalogue listing well over 100 energy and related planning models.(7) Most of these models are inappropriate to developing countries because they require detailed historical or current information not normally available, are extremely complex, and often focus on actions that are of low priority in developing countries. Indeed, an extensive model survey done in 1981 by MITRE yielded only 20 planning models which might be applied in developing countries, most of which still suffered from the problems noted above.(8)

Two years after the MITRE survey the state of energy modeling for developing countries has changed only slightly and any listing of available, microcomputer based, national energy planning models would still be brief. Table 2 provides a list of such models matched to the planning elements and <u>some</u> of the large planning models they match. It should be noted that, with several exceptions, most of the microcomputer models shown are still under development and have not been widely used. Further, the majority of models used have focused on economic and financial decision analyses with far fewer applied in supporting the initial structural planning effort(9).

## 3. Experience in Developing Countries

To our knowledge most applications of microcomputer energy planning techniques in developing countries have been closely linked

TABLE 2 NATIONAL ENERGY MODELS

| Structural | Main Frame Models | Microcomputer Models | Used In: |
|---|---|---|---|
| Energy Data Bases | (1) Energy Modeling Data Base (EMDB), Brookhaven National Laboratory, (2) Energy Supply Planning Model, Bechtel Corp. (3) Energy Balance Data Base (EBDB), Argonne National Laboratory. | no comparable data base structures available. | Tunisia, Sudan, Argentina, Egypt, Peru, and the DR |
| Energy Supply and Demand Balances | (1) Argonne Energy Model, ANL.<br>(2) Reference Energy System, BNL.<br>(3) LEAP, ESRG/Beijer (Kenya) | (1) Argonne Energy Model, ANL.<br>(2) Energy Systems Planning Model, DSI, under development<br>(3) RESGEN; IDEA<br>(4) Enerstat, under development, proprietary.<br>(5) LEAP being adapted<br>(6) RMA model. | (1) RES used in Tunisia and Sudan<br>(2) Morocco<br>(4) no data<br>(5) Kenya<br>(6) Tunisia, Indonesia |
| Economic and Pricing Studies | various | (1) E/DI Energy Pricing Analysis Model (EEPAM), E/DI<br>(2) Energy Finance Assessment Model (EFAM), IDEA | (1) Somalia and Liberia<br>(2) Tunisia |
| National Energy/ Economic Analysis | (1) Midterm Energy Forecasting Systems (MEFS), USDOE.<br>(2) A Macro Economic Model of Inflation and Growth in Korea, Korea Development Inst.<br>(3) BEEAM, BNL | no comparable micromodels | none<br>Korea<br>Portugal, Korea |

TABLE 2 NATIONAL ENERGY MODELS
continued

| Structural | Main Frame Models | Microcomputer Models | Used In: |
|---|---|---|---|
| Sector Specific | Several, e.g.: National Coal Model; On-shore Oil and Gas Supply Model; Aggregate Refinery Model; Solar Heating and Cooling Model; Residential Energy Use Model; OR Industrial Model (ORNL); Electric Power System Development Model; Technology Assessment Model (SRI); Oil Market Simulation Model | no comparable public micro models | none |
| | | (1)Fuelwood/Forestry Model, The Futures Group | Several African countries |
| | | (2) Various proprietary oil and gas systems models | no data |
| Energy Conservation Analysis & Models | discussed in Section II-C | various models and data bases | Tunisia, Togo |
| Optimization Models | (1) Brookhaven Energy System Optimization Model, BNL; | | (1)Energy Management Training Program, Dominican Republic |
| | (2) Regional Industrial Supply Model, DRI; | | |
| | (3) Project Independence Evaluation System, DOE | | |
| | (4) Systems Europe Optimization Model | | (4) Thailand |
| National Investment and Financing | | (1) Energy System Planning Model, DSI; | (1) Morocco |
| | | (2) Finance and Cash Flow Analysis Model, IDEA; | |
| | | (3) Energy Investment Assessment Model, E/DI | (3) Dominican Republic |
| Input/Output Models | (1) Energy Disaggregated Input-Output Model; | no comparable models | none |
| | (2) Nine-Sector Generalized Equilibrium Model; | | |
| | (3) Wharton Annual Industry Forecasting Model. | | |

to the participation of consultants in national energy planning efforts[10]. In the earliest national planning efforts supported by AID and USDOE (e.g. Egypt, Peru, Portugal and Argentina) information developed in each country was carried back to the U.S. and computerized in existing main frame models. Because these experiences were not readily transferable and built few planning skills in the countries involved subsequent efforts focused on providing long and short-term planning support in-country including enhancement of national planning capabilities. No effort, however, was made to ensure that the development of planning skills was complemented by the development of planning technologies. Consequently, the use of these tools was limited to consultants who applied them as time and labor saving devices and national analysts who applied the formulae and methods by hand.

This situation has changed markedly over the past two years because of a number of factors. First, several countries have passed through the analytical stage and are now concerned with urgent policy and investment decisions. Second, as AID has taken a stronger role in energy assistance the emphasis on developing local capabilities has increased. Finally, development of microcomputer technology itself has facilitated both the process of policy analysis and the process of local participation. Thus, in several countries, including the Dominican Republic, Morocco, Tunisia, Indonesia and Liberia a more participatory approach to computer-based analysis is beginning to flourish.

The results of such cooperative efforts are thus far encouraging. As national staff have more direct input and participation in the

analytic efforts the results are achieving greater support. The speed of the computers allow national staff to play with variations in input, thus allowing development of some idea of the "sensitivity" of analytic results to small variations in assumptions. The use of integrated planning models, even the relatively crude models now being used, have allowed evaluations and analyses that might not have been done under other circumstances.

Three examples of AID supported national planning are illustrative of those conclusions. In the first, Energy/Development International (E/DI) carried out a National Investment Planning Project for the Comision Nacional de Politica Energetica in the Dominican Republic. This work was novel in that it sought to intercompare energy supply projects and conservation efforts to relate macroeconomic and energy investment considerations to energy prices: thus it transcended general national energy planning which proceeds only to the level of broad national energy strategies.

The preliminary results of the initial phase were unexpected in that they generally supported coal import and final-fuel use projects over development of indigenous energy resources such as hydroelectric power.(11) A more general set of conclusions were that this type of work is tractable from an analytic point of view, that national staff could participate effectively in the planning and analysis process, and that microcomputers are tools of sufficient capability and sophistication to carry out complex analyses.

In the second example, Development Sciences Inc. (DSI) developed a software package to enhance the planning capabilities of the Ministry of Energy and Mines (MEM) in Morocco.(12) The system



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developed (Figure 3) links energy supply, demand and other baseline conditions - the national energy system - to planners' expectations about the future - the scenario - and an inventory of development projects - the investment portfolio.

The model then determines the performance of the portfolio over a 20-year period in terms of energy demand/supply balances, and its financial and manpower resource requirements. With this information, the planner can then return to the beginning of the planning cycle and redefine the portfolio. change project characteristics, or modify alternatives such as prices or imports. Thus, an acceptable plan emerges as the result of several iterations, the preferred plan being chosen with an understanding of the consequences of alternative investment strategies.

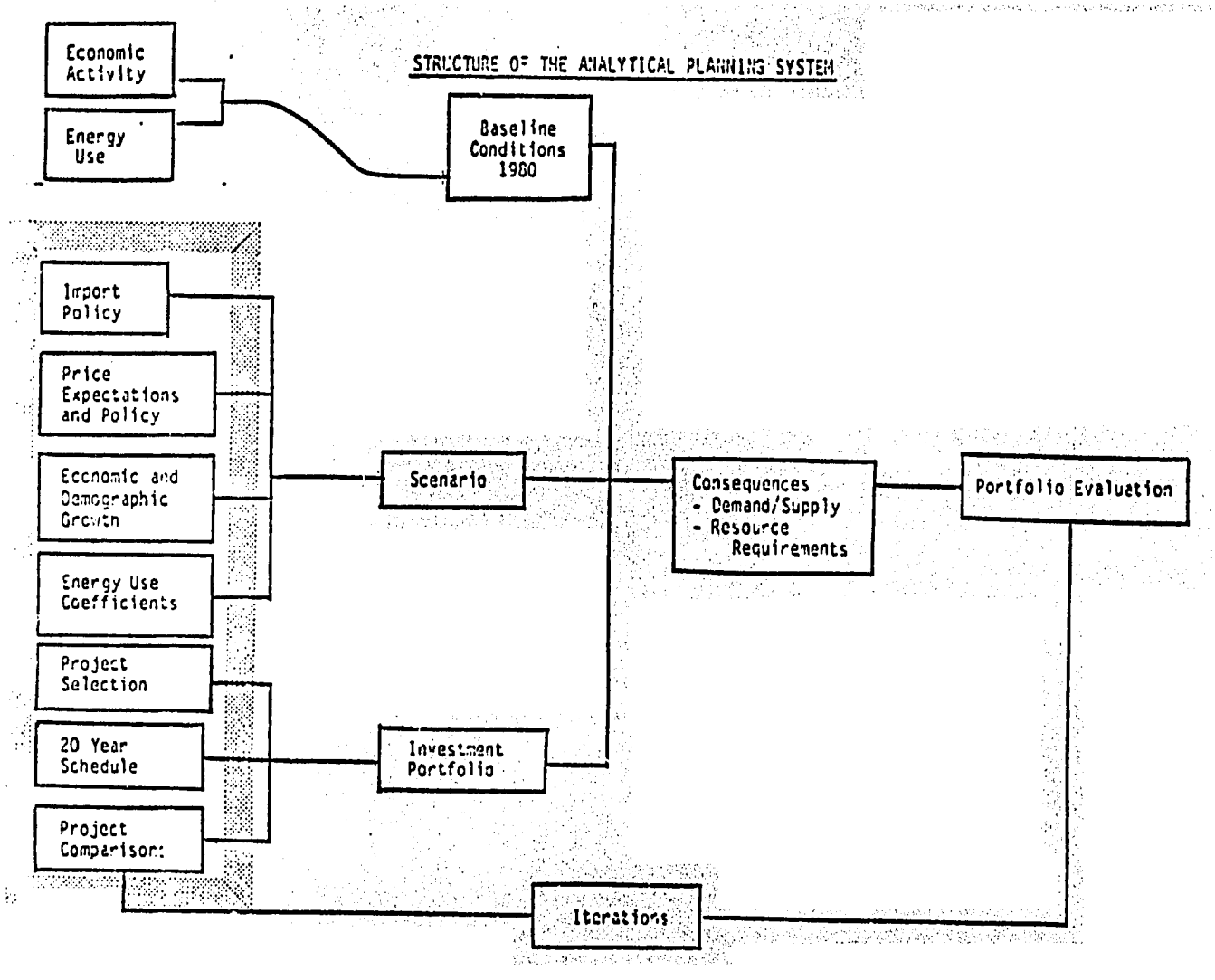
As this project nears completion, preliminary impressions are strongly supportive of the application of microcomputers as planning tools. For example Ulrich F.W. Ernst of DSI writes that:

> "..the Moroccan decision makers feel very comfortable with the way in which the information on possible decisions is organized and presented.
>
> ..key decision makers in the Ministry of Energy and Mines suggest very strongly that this software package represents the kind of planning tool they <u>can and will use</u>, and
>
> ..the combination of interactive use of the programs and the associated use of graphics also seemed to <u>enhance existing skills</u>."(13)

At the present time, plans are underway to adapt this model for Costa Rican use, stressing alternative pricing scenarios.

Another example of the effectiveness of results presented using microcomputers to decision-makers is the RAPID project of the Futures Group. Using Apple computers the RAPID program graphically displays

FIGURE 3


STRUCTURE OF THE ANALYTICAL PLANNING SYSTEM
Economic Activity
Energy Use
Baseline Conditions 1980
Import Policy
Price Expectations and Policy
Economic and Demographic Growth
Energy Use Coefficients
Project Selection
20 Year Schedule
Project Comparison
Scenario
Investment Portfolio
Consequences
- Demand/Supply
- Resource Requirements
Portfolio Evaluation
Iterations



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the implications of alternative population policies and growth assumptions. The portability of the microcomputer has been an important element in communicating their policy conclusions directly and forcefully to senior government officials.

Nevertheless, despite similar positive responses to microcomputer based planning in other developing countries, few hard conclusions are possible. Actual experience to date is too limited to suggest more than (1) that institutional demand for such tools is large, (2) that basic skills are available in most institutions, (3) that such tools can be usefully applied, (4) where applied can provide markedly better information and analyses, and (5) where applied have significant educational value.

## B. THE ELECTRIC SECTOR[14]

### 1. Potential Applications

Potential computer applications for electric sector planning in developing countries are large and varied, ranging from general systems analysis and financial planning to systems evaluation, quality control and operations. In many cases operating models have been used by consultants and staff engineers for hands on planning in developing countries. Only a few utilities in developing countries, however actually use such models regularly.

Be that as it may, in electric utilities the use of computers is expanding rapidly. In the past decade high speed computers have been successfully employed in carrying out engineering and economic studies, power system operating performance evaluations and

forecasting, planning, operating control, and business and operations data processing. In addition, computers provide the capability to perform more advanced engineering and scientific analysis computations that were possible previously. Today the computer is an indispensable tool in all phases of power system planning, design and operation and provides the following advantages to small electric companies:

- More efficient and economic performance of routine engineering calculations required in the planning, design and operation of a power system.
- Better utilization of engineering talent by relieving the engineer from tedious hand calculations and permitting him/her to spend more time in technical analysis.
- Increased ability to perform more effective engineering studies by applying calculating procedures to obtain alternate solutions providing a broad base for engineering decisions.
- Increased capability to perform studies which heretofore were not possible because of the volume of calculations involved.

As might be expected from a relatively "advanced" industry there are a wide variety of models that have been developed for electric system and operations planning. Among the models that have priority applications in developing countries are those shown in Table 3. (Appendix B provides a brief description of some of these models and a listing of special purpose utility programs.)

2. Software Availability and Experience

To our knowledge electric utility planning and analysis software is widely used but not widely available: microcomputer software less so. Where assistance in utility planning in developing countries has been provided by foreign consultants this software has been used

TABLE 3

Priority Electric Sector Models

1. Power System Macro Models
   - Generation Planning
   - Production Costing
   - Fuel Estimation
   - Fuel Costing
   - Probabilistic Production Cost
   - Power System Simulation - load flow
   - Economic Despatch

2. Power Generation - Related Models
   - Powerplant Testing
   - Boiler Efficiency
   - Generator Capacity Margins
   - Forced Outage Probabilities
   - Mechanical Design Systems Models (family)
   - Electrical Design Systems Models (family)
   - Civil - Architechnical Design Systems Models (family)

3. Transmission/Distribution and Load Flow Models
   - Transmission Line Parameters
   - Short Circuits
   - Transmit Stability
   - Substation Metering
   - Load Flow
   - Distribution Factors

4. Load Data Accumulation and Reporting Systems

5. Financial Models
   - Rate Structure Analysis
   - Project Investment Analysis
   - Energy System Financial Analysis

6. Energy Conservation and Load Management Models

extensively. We know of very few cases, however, where such software and the requisite training has actually been transferred to utility staff in developing countries.

Speculatively, the reasons behind such a problem are as follow. The development of utility planning models is an expensive, detailed undertaking which requires specific experience and knowledge. Historically, say up until 1975, only sizeable utilities in developed countries, architect/engineering firms, and large multi-program consulting companies had the experience necessary to develop this software. Those companies which did, considered such software proprietary: using it as a cost-cutting and marketing tool for consulting and development work. Additionally, most of the initial software ran on main frame computers and required trained technicians all of which were, and are, not widely available in utilities in developing countries.

To a certain extent these conditions are changing, with the changes driven by the development of microcomputer technology which is in many cases as capable as some old main frames; with the growth of technical software markets which have created an economically attractive outlet for special purpose software and training; and with the advent of single-purpose consulting companies focusing on these specific markets. Equally important, during its visionary period the U.S. Department of Energy sponsored the wholesale development of many models, including non-proprietary electric utility models for general and specific purposes, which are now emerging as market-makers. As a result, more electric utility planning software is becoming available.

Table 4 provides examples of these programs and the vendors which provide them.

## C. INDUSTRIAL ENERGY MANAGEMENT[15]

### 1. Potential Application

The use of computers for calculations in industry has, of course, developed over a period of many years. The oil and petrochemicals industries, for example, use linear programming techniques for planning purposes; most large oil refineries are operated with the help of a linear program model which optimizes the processing of a variety of feedstocks and the blending of intermediates into a wide range of products.

There are many possible applications for microcomputers in industry in developing countries. These may be divided into several broad categories and are discussed below with a few examples of each type of application to illustrate the potential for productive use of microcomputers in energy management.

#### a. Data Management

Within this category are programs for standard mathematical calculations including regression analyses and testing of statistical significance, linear programs, simple curve fitting routines and graphics software. Programs can be written for specific applications but the most common data management needs are met with commercially available software packages.

Another type of program of great utility in all areas of energy work is the "electronic spreadsheet", of which Visicalc is probably

TABLE 4

Examples of Available Electric Utility Planning Programs

| Program | Source/Vendor |
|---|---|
| Wien Automatic Planning System Model (WASP Versions I, II and III) determines optimal national electric generation expansion program using system reliability and cost | International Atomic Energy Agency (IAEA) and Argonne National Laboratory (ANL-mini-computer) |
| Reliability Computation Model (Relcomp), evaluates the reliability and economic performance of alternative generation expansion plans (non-optimizing) | ANL (microcomputer with extended memory) |
| Marginal Cost of Service Computer Model (MARCOST), a production costing and dispatch model that estimates marginal costs as the actual operating costs incurred change. | EBASCO Business Consulting Company, EBCC; (various) |
| SIMPRO III, provides highly detailed short-term estimates of production expenses and reliability indices | EBCC (various) |
| SIMLOAD, models system and individual rate class reliability load shapes to consider weather variations, forecast uncertainty and load management. | EBCC (various) |
| Generation Expansion Planning, various models including Loss of Load Probability (LOLP); Monthly Production Simulation (MPS); Multi-Area Production Simulation (MAPS); DISPATCH, a simulation of the hourly operation of the thermal sector of an electric utility; Optimized Generation Planning (OGP); and LOADS, which forecasts monthly peak and minimum loads and load factors. | General Electric, Electric Utility Systems Engineering Department, (various) |
| Lifecycle Cost Analysis (v.2.1.) provides yearly cash flow and/or present worth cost analysis | Carrier (various micros) |
| Energy Supply Planning Model (ESPM) determines capital and operating cash flow requirements for a given supply system configuration. Also estimates labor and material requirements for the construction and operation of facilities. | ANL (Apple II) |

the most well known. This program is extremely versatile and is readily usable by engineers after only a few minutes practice. In brief, the Visicalc program is amenable to use for any problem that can be expressed in matrix or tabular form. For example, as discussed below, energy planners often have to project energy demands over a period of time for which annual growth rates are specified. The following data are taken from a recent study for the Tunisian industrial sector:[16]

| | 1980 | PCT | PCT GR | 1986 | PCT |
|---|---|---|---|---|---|
| MATCON | 417.1 | 39.82 | 14.5 | 939.88 | 46.72 |
| CHEM | 96.4 | 9.20 | 10.2 | 172.65 | 8.58 |
| MECMET | 166.1 | 15.86 | 14.3 | 370.38 | 18.41 |
| MINING | 178.9 | 17.08 | 4.9 | 238.38 | 11.85 |
| TEXT | 42.9 | 4.10 | 9.3 | 73.14 | 3.64 |
| PAPER | 44.7 | 4.27 | 0.2 | 80.06 | 3.98 |
| FOODPR | 89.3 | 8.53 | 5.0 | 19.67 | 5.95 |
| OTHER | 12.1 | 1.16 | 6.3 | 17.46 | 0.87 |
| TOTAL | 1047.5 | 100.00 | | 2011.62 | 100.00 |

Suppose the annual growth rates are believed to be subject to considerable variation: what would industrial demand become if the construction materials subsector were actually to grow at 10.5 percent per year? By setting up the "matrix" calculation using the Visicalc program, the user can simply amend the subsector growth rate from 14.5 percent to 10.5 percent and the computer will automatically

recalculate the projected demands and other dependent figures within a few seconds. Other key data can be changed by the user and the sensitivity of the projections to these changes can be observed immediately.

Another major type of data handling activity is the storage and retrieval of large masses of data. An example of this application to energy management is the collection and analysis of plant-level energy data carried out for 60 factories in Tunisia.[17] Visits were made to all the plants in turn and a questionnaire was completed for each by the survey engineers. Data collected included energy consumption figures for each energy form and corresponding production figures. The analyses carried out using these data and Versaform, a product of Applied Software Technology, included a review of consumption for different subsectors and comparisons of energy efficiency with international data for corresponding manufacturing activities. Using the same Versaform software, it was possible to prepare a number of useful reports by searching the data files in different ways. The options for searching files and data retrieval are virtually unlimited with a sophisticated software package such as Versaform, and the user can begin to create forms, store data and make searches after only a minimum amount of practice on the microcomputer.

b. Engineering Calculations

At the plant level, there are many calculations which are performed regularly by energy managers and engineers. Most such calculations are not particularly complex and can often be carried out with electronic calculators in a few minutes. The close user interaction provided by personal microcomputers makes programming for

such calculations worthwhile and, thus, the consistency of the calculation methods used is guaranteed.

Some of the common calculations performed in the course of plant energy audits are:

- furnace efficiency based on stack gas analyses and temperatures, taking into account fuel characteristics.
- boiler efficiency, same as above and also including the effect of blowdown and condensate return.
- heat losses from structures, such as boilers, process vessels, cement and brick kilns.
- heat losses from pipes, and the effect of adding insulation.
- fuel combustion calculations, to calculate stoichiometric air requirements for different fuels, stack gas volumes and calculated compositions from fuel analyses.
- pump, compressor and turbine calculations, such as work output and efficiency.
- pitot tube calculations, for estimating gas flow rates from instrument readings.
- heat exchanger calculations and sizing of heat recovery systems.
- estimation of steam and compressed air losses from leaks.
- heating, ventilation and cooling loads for offices and commercial buildings.

Few software packages are available commercially for these types of engineering calculations, with the possible exception of HVAC programs based on standard calculational procedures such as ASHRAE methods.

c. Financial Analyses

Much energy management work leads to the identification of conservation opportunities requiring capital investment. The evaluation of these involves using simple payback techniques or,

preferably, discounted cash flow methods. A typical DCF rate of return calculation can be made using the Visicalc,which includes a facility to calculate net present values of a series of annual cash flows for a given discount rate. This allows the user to estimate the discounted cash flow rate of return for a capital investment.

Other types of financial analyses which could be applied to microcomputers and which are related to energy conservation work include those which provide estimates of the impact of investments on company cash flows and balance sheets. Standard accounting packages could be used for this work.

d. Special Applications

There are a variety of special applications for microcomputer programs which can be used in specific industries. Examples are:

- linear program models for optimizing oil refinery and petrochemical plant operations.
- fuel blending calculations (e.g. gasoline blending by octane number, fuel oil blending to viscosity and sulfur specifications).
- transportation models for optimizing the operation of distribution depots and delivery fleets.
- Monte Carlo simulation models (e.g. for estimating the capacity of storage tanks or inventory levels).
- electricity and gas tariff analyses.

2. Software Availability and Experience

Until recently industrial energy conservation programs were the focus more of talk than action. This was, perhaps, reasonable given that relatively little was known about the relative efficiency of industrial processes in developing countries. Following initial national energy assessments and planning efforts, however, it became apparent that potential savings from energy conservation are

significant.[18] Numerous assistance efforts are now targeted on achieving energy savings and economic gains through industrial conservation in developing countries.[19]

The focus of current industrial energy conservation programs is threefold: evaluating explicit energy conservation opportunities through data collection, audits and analysis; creating the institutional capacity to support self-sustaining conservation programs through training of nationals and financial support; and integrating energy conservation as a major policy area in national energy and economic plans.

The pattern of application of computers for energy conservation analysis and planning parallels that of other assistance programs. There were few - if any - applications in developing countries (except in cases of major international corporations) prior to 1980; between 1980 and the present the primary users were consultants; and, some of the current assistance efforts include provisions for computer applications and training in some cases. To date, however, such software systems are rarely used by plant managers and planners in developing countries.

The availability of software, however is a different matter. There are currently many energy conservation packages available commercially or at cost through non-profit organizations. These packages provide many of the primary needs of industrial energy conservation managers. Previous examples of the multiple uses of Visicalc and Versaform were given. Table 5 below, shows a number of other programs useful for specific and general energy conservation applications.

TABLE 5

Examples of Software Used in
Energy Conservation Analysis and Planning

| Programs | Vendor (Machine) |
|---|---|
| STEAMPROP, Thermodynamic properties of stream; HEATLESS, computes the heatloss from pipes and flat surfaces; CURVFIT; DFCECA, discounted cash flow analysis for energy conservation alternatives; PIPELOSS, calculates head loss and power consumption. | Center for Energy Studies University of Texas at Austin (Apple II) |
| HVAC Energy Consumption and System Simulation; Lighting Design; Residential Cooling and Heating; Heating Fuel Cost; Commercial and Residential A/C Group; Commercial Cooling and Heating Load - ASHRAE. | McClintock Corporation MC2 Programs (Various micros). |
| ENERCOM provides utility companies with a system to evaluate residential energy efficiency. | Enercom, Inc. |
| PROCESS, general purpose flowsheet for the calculation of mass and energy balances. | Simulation Sciences, Inc. (various) |
| TRACE, assists building and systems designers in comparing operating efficiencies and costs of alternative A/C systems. | Trane Air Conditioning Economics (various) |
| EFACT, analysis of the potential savings obtained by implementing alternative control strategies. | Johnson Controls, Inc. (various) |
| ECD, energy conservation design; WONDER-2, estimates yearly energy consumption; EMCS, determines energy and cost savings from alternative HVAC control strategies; EFFUFAC, models heat gain/loss through a roof or wall. | Bickle Group computer programs (various) |
| Boiler Plant Performance Analysis; Boiler Turbine Plant Efficiency | International Micro Software Catalogue, Microbits Ltd. (Commodore) |
| Commercial load estimating Operating cost Analysis Lifecycle Cost Analysis | Carrier, Inc. (various) |



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## D. PROJECT PLANNING AND DEVELOPMENT

The planning and development of major energy and industrial projects is of increasing importance to developing country governments, major assistance organizations, financial institutions and investors. This importance stems from many sources. There can be little doubt, for example, that the current financial bind in many countries and of many major banks is the result of unwarranted (or, at least in hindsight, incorrect) assumptions used in making development decisions and the associated borrowing commitments.[20] More stringent criteria and methods are now applied in taking development decisions to avoid repetitive "balkanization" in development; to ensure that development fits a justifiable and viable growth pattern; to ensure that projects are as "self-sustaining" as possible and impervious to external events; and to ensure as much protection as possible to investors.

In the national energy planning section (II.A) a number of "portfolio and investment analysis programs were discussed. These programs have a number of applications. As used for national energy planning they integrate projects to evaluate the effects of development on energy supply and demand and to identify an optimal mix of projects given stated financial, economic and other criteria. They are also used to evaluate single projects under the same conditions. Such programs are useful in selecting specific development opportunities from a package of candidate projects and, as discussed, have been applied in several countries.

Beneath this integrated level of planning are a series of needs that relate to the evaluation and justification, design, and scheduling of specific projects. By-and-large these needs can be aided with computer modeling techniques; but, again, in developing countries such models are applied predominantly-if not exclusively- by consultants or design and construction firms. In effect, national planners cede authoritative analytic responsibility to external, often biased, parties.

As with utility planning the basis for this results from the fact that most development projects are highly complex and require extensive experience and skills. This state is, however, changing both with regard to projects of specific types (as in the oil and gas sector) and decisions of a generic nature. It is, for example, now realized that the only basic difference between analyzing the economic viability of an electric power plant versus an oil pipeline lies in the nature of the feed information, not the structure of the decision or the results. Many common decision methods are now applied to quite distint projects. And, it is these decision methods which are best applied by staff in developing country organizations.

So far as project development is concerned one might set out three distinct types of project oriented computer models: financial evaluation models; engineering design and evaluation models (these often being sector specific); and project planning models. Table 6 shows examples of commercially available software. These are representative of project oriented models which might be used in developing countries. To the extent that the techniques included in the financial evaluation and project planning columns are widely used

TABLE 6

Project Planning and Development Models

| Engineering Design and Evaluation | Financial Evaluation | Project Planning |
|---|---|---|
| 1. Oil Pipeline Design | 1. Buy-vs.-lease | 1. Decision Tree Analysis |
| 2. Gas Pipeline Design | 2. Rate of Return Analyzer | 2. Set up Time Sequencing |
| 3. Transient Analysis Source: Ecotech | 3. After Tax Cash Flow Analysis Source: IIE | 3. Critical Path Analysis |
| 4. Optimal Plant Location | 4. Pipeline Economics | 4. Project Evaluation and Review Technique. |
| 5. Plant Layout Evaluation Source: Institute of Engineers (IIE) | 5. Refinery Operations Econ. Source: Ecotech | 5. Resource Allocation |
| | | 6. Node Network Analysis Source: IIE |

and taught, it is to be expected that they are familiar in theory (if not in their actual computer representations) to engineers and planners in developing countries.

## E. ALTERNATIVE ENERGY RESOURCES

Evolving energy strategies in developing countries focus on a variety of problems and opportunities. One energy development strategy emphasizes the development of indigenous and renewable energy sources as alternatives to imported fuels and as more appropriate to the disbursed, non-intensive nature of agricultural and domestic energy demands.

The range of such alternatives is large and includes active and passive solar systems, micro and other low-head hydropower projects, agricultural and animal wastes, and wood. Of these wood use has received fair attention because such uses account for a significant fraction of current consumption and, consequently, has contributed to the processes of deforestation and desertification.

Evaluating the development of these resources involves such considerations as the distribution and intensity of the resource; selection of the most appropriate recovery and conversion technology; comparison with the specific need it will provide and/or technology it will offset; evaluation of the costs and benefits; and, ultimately, analysis of the affect of using these resources on the national energy and economic systems.

To date the orientation of most such work in developing countries has focused on applying these alternatives to specific identified

needs as in, for example, the installation of solar photovoltaics for a rural health facility in Guyana and the development of forest/fuelwood plantations in Kenya. National energy planning efforts oriented to identifying high priority alternatives and technology evaluations oriented towards selecting the most beneficial and practical technologies and applications have been conducted in only a few cases.

For many of these alternatives microcomputer based information and assessment programs already exist. Table 7 shows a variety of available models which address such subjects.

As in other cases the availability of these models is directly related to the historic demand for such planning tools in developed countries. It is, thus, natural that solar and related models dominate the list for there is a ready market for their application. It is also to be expected that Forestry/Fuelwood models are available, for forestry problems have been the focus of significant work over the past 5 years and the use of fuelwood is one of the major factors contributing to the decline of forests in LDC's.

Wind, agricultural biomass and other wastes, solar photovoltaics, cogeneration and district heating models which can be applied on microcomputers and span a variety of needs are rare. The availability of such models would make a major contribution to application planning in developing countries for these alternatives are among the most important opportunities contributing to the development of indigenous energy supplies and to alleviating continued dependence on imported energy supplies.

TABLE 7

Renewable Energy Systems Models

| Subject | Models | Source |
|---|---|---|
| Forestry/Fuelwood | LEAP | Energy Systems Research Group |
| | FUELWOOD | The Futures Group, Inc. |
| | EEFAM (E/DI Energy Fuelwood Analysis Model) | Energy/Development International |
| | Total Resource Base (TRB) | Dartmouth Resource Policy Center |
| Wind | SYSWIND | CIED, ANL |
| Solar | well over 60 solar models, examples of these are: | |
| | TROMBE: analyzes thermal storage devices | The Bickle Group |
| | SOLDHW: calculates energy savings from solar-hot water | The Bickle Group |
| | Solar Collector: F-Chart and Economic Analysis | McClintock Corp. |
| | PASODE 1: calculates auxiliary heating requirements | Londe-Parker-Michaels |
| | IMPSLR: calculates solar savings fraction and auxiliary heating requirements | Princeton Energy Group |
| | Solar Staircase: calculates transmission, absorption and reflection | Norman B. Saunders |



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## F. MICROCOMPUTER EXPERIENCE IN DEVELOPING COUNTRIES

By and large computers -of any type- are not widely used for energy planning by national staff in developing countries. It is only over the past two to three years that such tools have started to appear in planning organizations and in most cases these first steps were taken as a result of some consultant applying hardware and software for their own professional purposes.

That is not to say that microcomputers are unknown in LDC's. Indeed they are rapidly becoming well known. Many assistance projects requiring data development and full-time resident consultants have been supported by microcomputer systems. These include the census projects of the UN statistical office (with systems in over 15 countries); the population and resource projects carried out by the Futures Group (with microcomputers used in 38 countries); and numerous AID supported population, health, agricultural, education and energy projects. In a recent survey the Department of Agriculture identified 75 applications of microcomputers in 33 countries. The common denominator of all such efforts, however, is that they are used primarily by long and short-term consulting staff, not nationals. If training was provided, it was done as a gesture of largesse. An uncommon denominator was that the selection of the systems to be applied was left, in most cases, to the consultants. No visible efforts were made to standardize or unify the hardware or software selected. These problems are understandable for it is only recently that the tremendous value of microcomputers to developing countries has been recognized. But there is another significant trend. Through

the initiative of the computer manufacturers, microcomputers are becoming more and more common in developing countries for commercial applications - word processing, inventory management, accounting, etc.

Until recently the problems noted above have held true in the energy planning context. By and large computers were provided for consultants-not staff, training was minimal and there was no uniformity in hardware and software.

Wherever microcomputers have been applied cooperatively, in concert with national energy planning staff in the LDC's, however, the planning process has been considerably enhanced. The effectiveness of national staff participation has improved, and the efficiency of and support for decisions increased. While such participative applications have not been widespread they have spanned most of the range of energy planning applications from national energy assessments[21], to investment and financial plans[22], and conservation analyses.[23] And, in all of these applications marked benefits were observed.

# III TRAINING

## A. INTRODUCTION[24]

Chapter II discussed how computers can be used in energy planning and in development of energy policies and programs. Whether they will be used is a separate issue: depending as it does on the availability of trained staff.

Recent studies carried out by the UNDP and UNESCO on needs for energy planning and management staff in developing countries have identified four distinct groups where significant numbers of additional individuals must be trained:

> Policy-makers: responsible for decisions involving large capital investments and programs with long term consequences for the stability of their countries energy supply/demand situation.
>
> Middle to upper level staff: responsible for planning and investment decisions in energy projects.
>
> Technicians: working in government and industry whose duties are directed to performing routine technical, economic, financial and energy analyses.
>
> Individuals: completing post-graduate programs prior to starting careers in energy planning and management.[25]

The number of individuals requiring training in these categories, according to the UN studies, range from several hundred at the top level to many thousands at the technician level. Training programs in-country and abroad supported by USAID, the UN agencies, the World Bank and other national governments can and will continue to play an important role at the senior policy and mid-career levels. If applied at the technician level the cost of such training programs would be prohibitive and a lack of trainers would limit possible

accomplishments. As a consequence of this lack of staff and training programs LDC's are implementing planning and development programs with far too few trained staff.

## B. THE ROLE OF MICROCOMPUTERS

Properly programmed and coupled with trainers familiar with their use microcomputers can serve to increase the ability of LDC's to train larger numbers of technicians in a relatively short time and to increase the capability of these technicians to perform routine and semi-routine data collection, assembly and analyses tasks. Examples of tasks that could be undertaken by technicians so trained are those associated with monthly up-dates of plant efficiency performance, calculation of price elasticities, and preliminary industry and commercial building audits.

This approach to the use of computers as a means of training and as a means of "expanding" the analytical capability of trainees is, of course, not new. Computer-based training has been available for 5-10 years (the PLATO system of Control Data Corporation is perhaps the best known example[26]). To provide training in energy planning and management specifically requires programs written to perform the function of simplified instruction manuals (although most existing applications programs already allow the trainee considerably more flexibility and interaction than main frame programs). These programs allow the trainee to be taken step-by-step through each analytical operation after learning a glossary of terms; to test himself for his

understanding of the material; and to apply exercises and examples in real-life applications. The trainer is assumed to be familiar with the programs in question and, to a limited extent, the fundamental concepts involved in the analysis being performed. This knowledge is usually transmitted in special trainer-applications courses. Trainers are also provided with a set of supporting training modules.

In the training context it is worth emphasizing several points. First, there are many possible levels of computer training, each oriented towards different uses. For example, as regards national energy planning activities the following levels or types of training might be required:

- Familiarization: a short training course focusing on the components and layout of a system, how it works, what it is used for;

- Standard processes: short courses in using computers for generic office and data purposes, such as word processing, mailing lists, filing systems, data storage and analysis, and the like;

- Technical applications: emphasizes the use of specific technical packages for analytic purpose. The course would show how the process works, data and format requirements, and input and output evaluation;

- Technical adaptations: again emphasizes the use of specific technical software but in this case provides participant training in altering the software to conform to process or data constraints;

- Programming: training in writing software for specific applications emphasizing structural, language and capacity considerations.

Second, the duration of such training will vary with the level and type of training offered and the level and skills of the participants. Formal courses covering all applications and programming might last up to 20 weeks: with simple applications training using available software requiring four weeks and programming

requiring extended training. On the other hand, some of these training systems are readily applied as a form of self-improvement using on-line tutorial systems. In this case all that is needed is 1-2 days of preliminary instruction, access to facilities and appropriate manuals.

In these contexts the microcomputer has proven as revolutionary in developed countries as it might well be in LDC's. Up until the last year few government and industrial managers actually applied computers: at best they might have defined a system or format for a decision and passed this on to a technician for programming. But, since the microcomputer has become available, user friendly packages ieveloped, and commercial training courses offered, hands-on applications of computers have moved up in the management hierarchy. All this simply because they are so easy to use.

Which brings up the third point worth emphasizing. So far as energy planning is concerned, with the exception of the Energy Management Training Program, no formal computer application training have been given to planning staff in developing countries. Where consultants have carried in computers to do planning, however, the participation, interest, and effectiveness of participating national staff has increased. Since these applications have been sporadic we cannot ascribe these reactions specifically to the use of the computer (any more than we can to the magnetic personalities of the consultants) but they have been distinctly greater than the case under non-micro circumstances.

Perhaps most importantly, however, the ability to apply computers will provide access to a wide range of analytic techniques and

experience. Since 1974 the developed countries have built and use many analytic systems: rejecting or changing those which prove faulty or problematic, revising those which proved unwieldy, usin those which yielded good results under a wide variety of conditions In the process these countries have filtered out the important fro the unimportant, the useful from the useless, and developed analyti skills and knowledge that are of immense importance in all areas o energy planning from national energy analysis, to integrated system planning, to sector and subsector technical analysis. Many, if no all, of these systems are computer based. Ten years of highl sophisticated experience is available if it can be adapted.

At the moment in LDC's this experience is currently availabl only through consultants and the transfer of the experience has bee slow and difficult. But the use of microcomputers, for pedagogic a well as analytical purposes there exists the possibility o accelerating significantly the transfer process. In effect, LDC's ca adopt the models and experience which it took other nations 10 years and many millions of dollars to develop. Developing an understanding of linked processes, the nature of decisions and the structure of energy-economic systems are all possible. The training process will never be effortless or costless but the microcomputer, if viewed as both an expert system and a training tool, has the potential of making that process significantly more effective.

# IV. SOFTWARE AND HARDWARE ISSUES

## A. SOFTWARE

Preceding discussions have focused on the possible applications of microcomputers for energy planning, defining these by distinguishing energy planning needs and then matching these needs against known and possible microcomputer applications. Accomplishing an actual application requires, of course, hardware, trained operators, and usable software: the software being a mathematical rendition of the system, process, method, or decision being evaluated.

To apply software (alternatively programs and/or models) most effectively, a few basic but rigorous conditions must be met. These include the following:

- the software language must be compatible with the hardware operating system; few programs can transfer from one hardware system to another easily;
- all information required (input) must be available and in the format necessary; and
- trained operators must be available.

One of the benefits of microcomputer models versus those used on larger systems is that the last two conditions are abated. In the argot, most microcomputer programs are both "user-friendly" and simple. While the data requirements are rigorous they are not nearly so complex or voluminous as is the case with larger systems. Additionally the technical skills required to operate standard software on microcomputers are modest and easily developed.

The technical fly in the ointment -at least so far as current energy planning models are concerned- is that of hardware/software



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compatibility. There is little uniformity in software languages or hardware systems in microcomputer based energy models being developed for and applied in the LDC's. And there is little uniformity in software languages and hardware systems for generic microcomputer based energy planning models available commercially. There are, however, hardware systems such as Apple II, IBM-PC and Texas Instruments whose programming languages are more common and are likely to remain so for general application programs. (There are also interface programs which translate programs from one to another common languages, but using these requires elevated technical skills.)

There are two additional software considerations that deserve consideration in this paper, these being the ability of users to identify appropriate software and suppliers and, following that, to acquire such software.

In assessing existing and potential energy planning applications for microcomputers in developing countries over 60 organizations were contacted, including the major software houses, technical software vendors, commercial consultants, private corporations, not-for-profit research organizations, and federal, state and local energy planning agencies. The results were mixed. We identified fewer than 50 specific microcomputer programs useful in the entire energy field with only a handful of appropriate planning models. The only conclusions possible are that many energy planning models have yet to be adapted to microcomputers or that some of the organizations contacted did not identify such models because they have proprietary uses for them.

Indeed, during the review it became very clear that some existing models which were not already commercially available, might not be

available at all: even where some or all of their development cost had been sponsored by a government agency and, thus, they might be considered public property.

## B. HARDWARE

The selection and operation of specific microcomputer hardware for energy planning involves consideration of a number of issues. These relate to the configuration of the system; to the operating environment; to the selection of components and/or vendors which match these needs; and to protection of the system while in operation. This section reviews these issues as they apply in developing countries.

### 1. System Configuration

Initial configuration of a microcomputer hardware system should be based on the needs of specific users which, in most cases, are not limited to simple data processing and modeling. In most developing countries where national energy assessment and planning activities are being conducted microcomputers are seen as providing a number of general benefits, including the following:

- data processing and storage;
- interactive modeling;
- report preparation (word processing and graphics);
- and, to a much lesser extent, record maintenance.

Such needs must be characterized further to be useful in defining hardware. For example, how much information is to be processed and stored? Is information to be fed in remotely, by hand, daily, or hourly? The answers to these and other structural questions define

the amount of memory needed, the type of storage and access to be provided; the need for interactive communications and processing; the need for auxiliary peripherals; and the like: in other words a highly specific characterization of the uses and capabilities of the system will define the capabilities of the hardware needed.

In our experience in LDC's we have found uniformity in identifying generic uses but almost no specific knowledge of detailed system requirements. It is natural to assume that these will vary from one country to another, and within countries among participating ministries and organizations.

The system described in the introduction (an IBM-PC, 256k internal memory, 5MB hard disk drive, monochromatic display, and dot matrix printer) could be considered a generic system providing all estimated hardware requirements for single users, but multiple uses. This system provides all estimated initial requirements for national energy planning systems. (Appendix A).

Many other microcomputer hardware configurations are possible. The system could be extended to service multiple interactive users via direct links to remote terminals. More memory can be added. Communications facilities can provide linkage to compatible systems in other organizations. The system can be developed in a manner that allows integration into a larger computer system as demand and needs increase.

## 2. The Operating Environment

Few generalizations are possible about operating conditions in developing countries other than to suggest that the physical environment is often severe and inhospitable. Temperature extremes,

rapid temperature changes, high humidity, and sand and dust all pose real operating and maintenance problems for computer hardware and software. Such conditions are pervasive in many LDC's but may be partially mitigated through appropriate location and security measures.

Equally important are infrastructure conditions such as electric and telephone service whose quality vary from country to country. Electric supply is, for obvious reasons, of special importance. But the actual operating characteristics of the electric system also plays an important role. Line surges, load shedding, interruptible service, and load loss all affect computer operations and may result in program and information losses if the electric supply fails during operations.

Such environmental conditions play an important role in the selection of computer and system support hardware. For example, as noted previously, the U.N. Statistical Office has adopted a program which provides complete system redundancy, additional spare parts, and provision of uninterruptible power supply packages (UPS) for those systems supplied to LDC's.

3. Hardware Selection and Support

After evaluating the system configuration and physical operating conditions users proceed to the selection of specific hardware components which may be provided by single-system vendors, or by matching compatible hardware from several vendors. Some of the criteria used in selecting systems are derived from the proceeding considerations, others are specific to the hardware and vendor involved. The latter criteria include the following:

- the quality of the component compared to others;

- the availability of service and parts at the location involved;
- self-servicing capabilities;
- the ability to integrate the hardware into larger systems; and,
- cost

Of these criteria the availability of service and parts assumes special importance, simply because it is to be expected that there will be hardware problems wherever microcomputer systems are used. To our knowledge only Wang, National Cash Register and Apple have established representatives selling microcomputers and providing contract service and parts in more than a handful of LDCs. Vendors of other equipment do have representatives in some countries but these dealers focus on sales and support for large systems and have not announced marketing plans for microcomputer sales and service.

In general, the systems of the specific vendors mentioned do not meet the criteria set out for national energy planning purposes without fairly extensive upgrading. Other systems, such as the IBM-PC, have developed diagnostic packages which allow users to do fairly extensive problem identification and service on their own. Regardless of these capabilities, service and parts are still basic requirements for the acquisition of microcomputer systems.

Integration capabilities are a strategic consideration. Historically, implementation of dispersed computer terminals was done from the top down: large computers were purchased for central uses and as demand increased remote terminals were farmed out, all feeding off the mainframe. The advent of competent microcomputers has altered this process and it is now possible to start out with dispersed,

single-user computer systems and as demand increases integrate these into larger systems.

This capability is particularly important because in many cases these computer applications will be the first attempt at computerization in LDC agencies. As energy planning is simply one of many possible applications success will lead to increased demand for larger systems.

# V ISSUES AND CONCLUSIONS

The preceding chapters have discussed potential and existing uses of microcomputers for energy planning, and hardware and software issues involved in applying these tools in developing countries. This chapter highlights the major issues which emerge from the analysis and conclusions which may be drawn.

## A. DIRECT BENEFITS

To a certain extent direct benefits of computerization are predictable, often calculable, and have been observed in most cases where microcomputers, training, and support have been provided previously. Among these are the following:

- increased speed and decreased labor in repetitive, routine tasks involving the processing of large volumes of information;
- quality improvements in routine and non-routine tasks involving processing and analyzing large volumes of information;
- integration and facilitation of all tasks involved in report preparation (data analysis, graphics and table development, word-processing), and improvements in the presentation of reports;
- increased data processing, storage and exchange capabilities (particularly important in countries where such tasks are done manually);
- improvements in staff training and upgrading; and,
- extended analytic capabilities.

The last point deserves some discussion. Previous sections presented numerous energy planning and analysis applications of microcomputers. Competent analysts could apply most -if not all- of

these models with only moderate training, even though very few analysts could actually develop the programs. The use of microcomputers decreases the time to do specific tasks from 10 to 10,000fold over manual/intellectual processing. If even part of the newly freed time is allocated to conducting other tasks which might not be undertaken under status-quo conditions the capabilities of the staff/organization are extended.

There are many examples of this. One, for example, occurred in Mobil/Sudan. In this case the chief engineer and 5 staff members spent one week each month (or roughly 160 staff/hours) preparing blending/loss calculations used in setting product prices. The engineer developed a simple program to run on the Apple II which did the same calculations in less than 5 minutes and required only 30 hours of staff time in data preparation.[27]

## B. INDIRECT BENEFITS

The indirect benefits of computerized energy planning at any technological scale are often difficult to characterize and vary from one setting to another. (They would, for example, not be so extensive in agencies that already use computers for other purposes as in agencies that do not currently use such tools.) Some tentative conclusions about these benefits are outlined below.

1. The application of microcomputers in developed countries has narrowed the gap between decision makers and analysts; quite often through direct interaction and participation. The quality of and support for decisions made on the basis of such interactive analysis

is great. In those few cases where a similar procedure was effected in LDCs, the same results obtained. More importantly the availability of these tools appears to have drawn senior officials directly into the planning process.

2. The use of centralized computing facilities serving several agencies causes inter-organizational friction resulting from disagreements about the costs of central services; physical access to the facility; distribution of computer time; distribution of remote access terminals; allocation of technical services; the potential revelation of proprietary information; and the like.

Microcomputers contribute to easing such friction by providing a relatively inexpensive, highly capable, tool for conducting work autonomously.

3. The use of microcomputers as analytic tools allows decisions to be based on more extensive and intensive criteria and to be made more expeditiously. It is to be expected that such decisions will be "better" (on average) than those of the past.

4. If, as many expect, computers have economic value their use is of critical importance to developing countries and would represent a quantum expansion in existing planning capabilities. If such tools are not used, planning capabilities will lag further behind developed countries.

In this regard an important consideration is improving the distribution of competent talent in national planning agencies in LDC's. In many cases there are only a few middle to senior level staff in each organization with good or better planning skills.

Providing microcomputers will allow these officials to do more, better, and at the same time assist in upgrading other staff.

5. There is one over-riding benefit from the use of microcomputers for energy planning that is entirely distinct from the benefits discussed above. That is, national energy planning organizations in LDCs can adapt existing planning models. By doing so they can almost immediately apply the lessons learned over the past 10 years in developed countries without repeating the most common mistakes, or incurring major development costs. Such acquisitions would expand their planning capabilities tremendously.

## C. MODELS IN PERSPECTIVE

A key issue to be understood in judging the role of microcomputers in energy planning in developing countries is the balance between the following:

Hardware

Software

Adaptation and Application

Training

Traditionally, countries or firms have entered the computer age by dividing what computer hardware they needed or could afford. The next stop in importance was the choice of software which might have to undergo some slight modification. Financial and/or technical assistance was often required for hardware and software costs. More often than not computer analysis of a major developmental problem was

carried out by consultants in their own country. Thus, the traditional view and practice ascribed relative importance as follows:

The Traditional View:

| | |
|---|---|
| ↑ | Hardware |
| INCREASING | Software |
| IMPORTANCE | Adaptation and Application |
| | Training |

We would maintain that relative importance should be ascribed in exactly the opposite order. It is becoming widely recognized that software costs are growing while hardware costs are decreasing. More important, however, is the fact that existing models or software packages for example in the energy planning field are relatively useless by themselves. They must be adapted to the local situation, data must be collected for them and often their structure must be modified to address new issues of importance. Furthermore, computer-based models provide only a partial set of tools to address important issues. Learning the limitations of models is often more important than learning to manipulate them.

Thus, the training component of a computerized planning approach is far more complex than simply learning to operate the computer and run prepackaged software. It should include developing skills to modify existing programs and create new programs to meet new requirements. But, even beyond that, it should also include training in policy analysis as that analysis can be enhanced by computerization. Thus, for many applications of microcomputers to energy planning in developing countries, the training component is paramount.

Thus, in our view the correct view of the relative importance of the components of a computer based planning program is as follows:

The "correct view":

| | |
|---|---|
| | Hardware |
| INCREASING | Software |
| IMPORTANCE | Adaptation and Applications |
| ↓ | Training |

Larger Implications

In this paper we have examined a very specific application of modern computer technology - microcomputers and energy planning. The analysis is convincing - at least to the authors - that

a) microcomputers have distinct advantages in developing country environment and

b) there are several potentially beneficial applications of microcomputers in the planning and implementation of national energy programs.

The advantages of computers in increasing the effectiveness of planning; in producing a more efficient system (e.g. through applications in the industrial sector); and in enhancing the transfer of technical expertise are clearly not limited to the energy field. This analysis confirms the hypothesis stated in the introduction to this paper: computer technology can be of significant benefit to developing countries. Given the rate at which computers are being adopted by the industrialized world, the developing countries risk a further comparative disadvantage if they do not adopt them for their own social and developmental purposes.

There may be more to be gained than simple parity in applications. As we saw in the energy area the appropriate use of microcomputers can enhance the transfer of technological information and expertise. Thus in some instances the computer "revolution" could be more advantageous to developing countries than to the industrialized ones. Modern computer technology can, in effect, be used to accelerate the process of technological development by short-cutting some of the more laborious historical transfer mechanisms. Although an example of this in industrial energy conservation has been discussed in this paper, a more telling paradigm is perhaps medical diagnostic programs on battery operated micros. Such "expert systems" have the ability to upgrade the medical care provided by very large numbers of rural health workers[28].

One can also imagine ways in which computers will work to the disadvantage of developing countries. Robots, for example, tend to replace repetitive low skilled labor of the kind now sought out by industry in developing countries. When the hourly cost of robotic labor becomes sufficiently low the competitive advantage of many developing country exports will disappear.

There is a resistance to the introduction of computers for just this reason. Such a perception was expressed recently by President Moi of Kenya. Although this contains a grain of truth we feel that this is a short term view detrimental to the country[29]. But, given this kind of perception, if developing countries are to profit from the long term benefits of computers, they should be introduced with caution and into areas in which there are clear and immediate benefits. For example, in many countries there is a small but well

entrenched group of senior clerks who are now responsible for data compilation, accounting and some analysis. This group could well feel threatened by the introduction of computers. However, if computers are introduced in an appropriate way, they can be used to upgrade the skills and prestige of that group, benefiting them substantially and ensuring their support of the change.

Introducing microcomputers first in fields such as energy can also be advantageous. In the energy field there is a receptive and technically qualified cadre to adopt the technology and make it their own. The application of microcomputers to aspects of energy planning and management discussed in this paper can have far-reaching implications for the development process. This in turn has implications for USAID's policy towards microcomputer applications which will be discussed in the next chapter.

# VI IMPLICATIONS FOR AID POLICY

## A. INTRODUCTION

The discussion of national energy planning, electric utility applications and energy conservation reveals important common trends. For a variety of reasons, including the cost and capability of microcomputers, computers are moving from the home offices of consulting firms and the jealously guarded central sites in developing countries to the desks of managers and technical groups. This fissioning of computer capacity is of potentially great significance in increasing technical competence and the quality of decisions in the energy sector. This change, which affects the structure of analysis and decision making in a fundamental way , also affects the very meaning of technology transfer and training. It therefore has profound implications for AID programs and policies. In evaluating these implications and possible uses which affect AID policy it is necessary to consider what AID's general responsibilities are and their support for microcomputer development in other programmatic areas.

AID is generally charged with administering U.S. programs providing technical assistance in support of the economic and social development of developing countries. Among its principle policy directions the following are particularly relevant for (energy planning and) microcomputers:

- encouraging developing countries to adopt sensible national policies;

- enhancing the role of the private sector (both in LDC's and the U.S.) as the most certain generator of progress;
- enhancing institutional capabilities in developing countries; and
- increasing the application of science and technology to the needs of developing countries[30].

There is every reason to believe that the use of microcomputers provides as fine a fit with the foregoing AID policy directions as any information technology one can find. The list below illustrates this.

1. Development of Sensible National Policies: Microcomputers considerably extend data management and processing capabilities, allow integrated multi-variate decision analysis, extend existing analytic capabilities, provide the capability to develop new decision structures and provide monitoring capabilities. The analysis summarized in this paper suggests that AID should give consideration to a new area of national policy formulation: computers.

2. Enhance the Role of the Private Sector: The applications are clear, as they apply to business decisions, are capable of process control and monitoring, save labor time in skill positions, perform office and accounting functions more efficiently and effectively, and provide improved communications support. Furthermore, the private sector has a clear new role to play in developing national capabilities in computer technology.

3. Enhance Institutional Capabilities: Computers have a direct contribution to more effective use of skilled managers, staff training and upgrading, improved access to information relating to functional roles.

   In energy ministries, as in many others, there is a recurrent problem of retaining highly skilled staff. A ministry which is introducing microcomputers and providing training in their use has a greater power to draw and keep capable young staff than one that has no such program. Correspondingly there is a need for new institutional capabilities in using and managing decisions related to computers at the national level.

4. Increasing Application of Science and Technology: Microcomputers are the state-of-the-art management information technology; interactive communications provides access to other S&T information and developments.

Recognizing this match between policy direction and technological opportunity it is not surprising that AID has spontaneously - from the bottom up, as it were - moved quite vigorously to apply microcomputers. An illustrative list of microcomputer applications in other AID programmatic sectors is given in Table 8. There have been one or more projects in each sector which have included formal applications of microcomputers. Beyond these, AID has supported research on microcomputer applications and software/hardware development in support of some sector programs. For example, software development for analysis of socioeconomic and agronomic data; networking of videodiscs and microcomputers for teaching science; and development of a microprocessor for interpretation of satellite image data.

A review of actual experience in these applications, however, would probably result in findings similar to those discussed in Chapters I-V. That is, there are many practical applications, no planned pattern of support, many hardware and software problems, a paucity of trained users, and a clear need for a well defined development program.

## B. CONCLUSIONS AND RECOMMENDATIONS

We believe that AID recognizes the need for a more consistent or organized agency approach to microcomputer applications in developing countries. We also recognize that AID is in the process of reviewing applications and possible policies towards microcomputers. In any case, any conclusions and recommendations must, at this stage be

TABLE 8

Examples of Microcomputer Applications in Other AID Programmatic Areas

| AID Programmatic Area | Data Management | Data Processing and Analysis | Training | Communications | Research and Analysis | Office applications |
|---|---|---|---|---|---|---|
| Agriculture | x | x | | | x | x |
| Education | | | x | x | | |
| Population | x | x | | | x | |
| Rural Development | x | x | | | x | x |
| Health and Nutrition | x | x | | x | x | |

tentative. The difficulty of arriving at specific policies relative to microcomputer activities derives from several factors including:

- The rapid pace of development of the field and the difficulty, because of proprietary commercial interests, of obtaining accurate information from software and hardware vendors;
- The uncertainty regarding the official institutional and policy environment in developing countries vis-a-vis computers in general;
- Insufficient information regarding actual microcomputer experience in a representative cross-section of countries and programmatic sectors;
- Little information from national staff in developing countries outlining their experience with, views of, and prospects for, microcomputer use;
- Highly generic and anecdotal information on environmental and infrastructure problems affecting computer applications in developing countries; and
- The relatively undeveloped state of microcomputer policies in other international assistance organizations.

This having been said, a number of conclusions emerge from this study:

1. An AID Policy on Computers in Development

At the country level our contention is that governments should start to examine broadly the ways in which computer technology can be of most benefit. Similarly, within AID computer technology should be regarded from a broad perspective of technology transfer and development as well as from the perspective of sectoral applications.

It might be unwise, however, to establish specific policies until there is better information on actual microcomputer experience, opportunities and problems in developing countries. The specific recommendations outlined below are intended to increase potential microcomputer applications information and will contribute to the development of specific policies.

2. The Institutional Climate

The formulation of a concerted AID policy regarding computers in developing countries requires a much more thorough understanding of the institutional climate for acceptance of this technology. It also requires a deeper understanding of the potential long term role of "informatics" in development. AID should continue to carry out policy-oriented research on the opportunities and institutional conditions for the most effective uses for computers in the development process. This research should build on the analysis of sectoral applications such as this study.

3. Training and Education

In the last chapter we suggested that there may be larger developmental stakes in the application of microcomputers - or computers generally. Thus, specific application such as energy should be viewed in AID's program in two ways: first, as a means of upgrading or accelerating planning and development and, second, as a way of building a base for the growth of applications of computers more generally. For reasons discussed above there are distinct advantages to introducing computers in specific priority applications. This means, however, that a broader set of training programs, for example in programming and in servicing hardware, should be considered as an accompaniment to an applications-oriented technical assistance program.

4. Policies for Energy Software Development

No policy has yet been developed by AID on software development within AID energy projects. The result is an unfortunate ambiguity regarding documentation and availability of software. As discussed

above, one can easily exaggerate the importance of a computer software package and underestimate the importance of the assistance required to adapt and use a package intelligently. Nonetheless AID technical assistance projects in energy planning remain the most effective vehicles for the development of planning software.

AID should establish clear policies regarding the effective availability of software used in its energy projects. Two arrangements should be possible. In the first, in which software is developed solely with AID project funds, public availability of the software should be assured. In this case AID should approve the language and the hardware on which the program is to be run; require and provide adequate funding for documentation of the model; and provide listings and copies of the models (on tape or disk). A second alternative arrangement should allow a software developer to retain a proprietary interest in a software package. The system should provide an incentive to software developers to invest their own effort in developing software for application in AID projects. Such incentives can be provided through licencing or other agreements by AID to respect proprietary rights under certain conditions of company contribution to software development. The important point is to distinguish between these two arrangements, a distinction which is currently muddied.

5. Software Support

It will be increasingly common for software to be developed and implemented as a part of AID energy (and other) projects. There is the danger, particularly in relatively short projects, that deficiencies or "bugs" in the software will only appear after the

project is over. AID should examine mechanisms for providing software support after the end of a project. This can be handled through provisions in the original contract or a special quick response contracting mechanism for this purpose.

6. Advanced Software Development

Thus far in the energy area the software that has been developed in AID projects has been relatively elementary and supported almost incidentally as part of assessment activities. There is an advantage to this in that the software thus developed is attuned to real needs. Commercial software in the U.S. is either inappropriate for developing country use or has not been adapted to such use. AID should investigate the possibility of commissioning the development of advanced software for energy applications in developing countries. Support for this kind of development could be provided in a number of ways but the process should remain close to practical applications.

7. A Clearinghouse Function

AID should develop an office responsible for monitoring and supporting programs where computers play an important role. This office should not have direct control over such projects but should function in an information, review and advisory capacity. It should act as a clearinghouse. At a minimum it should collect information on past and on-going AID projects with computer support; have current state-of-the-art information on commercially and publicly available hardware and software; have state-of-the-art information on advanced technologies with specific application to AID programs; maintain and update information relevant to providing computers for projects by country; and maintain an evaluation system.

There are questions as the extent to which these functions can be decentralized to the sectoral programmatic offices (for example, the Office of Energy). Our conclusion is that the sectoral offices are the logical locations to act as monitors of sectoral models and much of the technical evaluation can be done by those offices. Nonetheless, there is an important intersectoral job to be done in fostering compatibility between sectoral models, hardware configurations, etc. Furthermore there should be a locus in AID to investigate the broader issues of computers in development raised in this paper. A centralized office would be best equipped to carry out these functions.

## C. A FINAL NOTE

Our investigation of the applications of microcomputers to energy planning and management in developing countries has led us to conclude that this technology can be very important in the energy area. Our analysis also led us well beyond the confines of energy. Energy applications served as a window for our analyses on to a far wider world of applications for a technology which might have remarkable impact on the development process. Our sense is that computers - defined very broadly - can have a profound influence on that process; exactly how profound and in what ways remain to be seen. But in no small measure, because of the nature of the technology, the programs of AID and other assistance organizations can have a major impact at the very least on the rate at which that influence is exercised. For AID that represents a signal opportunity and a serious responsibility.

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# APPENDIX A

## Microcomputer Characteristics and Glossary



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## The Basic System

There is no hard and fast demarcation useful to distinguish between microcomputers, minicomputers and main frames except in the qualitative sense that micro's are smaller than mini's which are smaller than main frames. "Smaller" being applied to physical size, cost, memory, processing capability, and speed. Some "typical" characteristics of microcomputers as they apply to developing countries are discussed below.

### 1. Memory Capacity

Working memory (see glossary at the end of this appendix for an explanation of technical terms) capacity ranges from 16 Kbytes to 256 Kbytes depending on the configuration of the system with most current off-the-shelf systems having 32k-64k capacities. External operating memory capacities range from 0.03-160 Mbytes depending on the media used.

Specific data processing requirements for national energy planning will vary widely among LDCs. For example, at a highly disaggregate level we might assume that rough data to be aggregated to national totals will be equivalent to the volume shown in DOE's State Energy Data Report[31]. In this case memory requirements are approximately 3.5 Mbytes. Processed to the national level and including pricing and production information we might assume that memory requirements are roughly equivalent to those shown in EIA's Annual Report to Congress[32]. In this case memory requirements are less than 1 Mbyte. Finally, let us assume that the average memory for a specific analytical model approximate those required for making

projections using the Sudan Reference Energy System[33]. These amount to less than 64 Kbytes.

The memory of the generic microcomputer configuration shown exceed these requirements in all cases.

2. Processing Speed and Capability

This depends on the configuration of the system and the particular microprocessor (chip) used. For example, the IBM-PC uses a 16 bit, 8088 microprocessor and can carry out 0.1 million operations per second on average, directly addressing up to 1 Mbytes of memory. A microcomputer employing an 8 bit microprocessor might address up to 64 Kbytes of memory and process 20,000 operations per second on average.

There is little factual comparison between the time a computer takes to manipulate information and the time a person would take to do the same as the processes are generally completely different. The essence of this consideration is two-fold: microcomputers can process information from one hundred thousand to one million times faster and, because of the time savings, analysts can undertake useful tasks which are impossible to do by hand.

Processing time is a consideration only when moving from manual to machine operations, when evaluating whether to purchase small or large systems, and when deciding whether a specific procedure is cost effective.

As with processing speed analytic capabilities are enhanced by computer operations: analysts can undertake tasks which are impossible to do by hand. Perhaps more importantly existing models

and programs can be adapted for use in LDCs at little cost. Those can be applied immediately to problems which are not currently addressed.

Physical Size

This ranges from lap, to desk top, to multi-desk top depending on peripherals.

Costs

These vary widely with a range of $200 - $4,000 for the computer and disc drive alone. Peripherals such as screens, printers and remoted terminals are provided at additional cost. Such peripherals are necessary accessories of a fully configured microcomputer system and some typical systems include up to 3 workstations (CRTS). An "average" configuration serving 1-3 users is shown below:

| System | Configuration | Hardware |
|---|---|---|
| Number of users | 3 | CRTs |
| CPU memory | 256 Kbytes | CPU |
| Peripheral memory(total) | 64 bytes | floppy-disc drives |
| Mass storage | hard disc | hard disc drive |
| size | 5.25 inch | monochrome screen |
| capacity | 10 Mbytes | dot matrix printer |
| access time | 100 ms | modems |
| Operating systems | UNIX Extended | |
| Language support | Basic III, Cobol, Fortran, RPG, PL/1, C-Language | |
| CRTs | 3 | |



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## GLOSSARY

In part derived from the
International Microcomputer Directory
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ixth Street, Berkeley, CA.

| | |
|---|---|
| Address | A number indicating the position of a word in the memory. 16-bit addresses range from 0 to 64K. |
| Applications Software | A prewritten program or group of programs designed to serve specific technical purposes, such as financial analysis, systems planning and the like. |
| Bit | A contraction of binary digit. A bit is a 0 or a 1. Bits are universally used in electronic systems to encode information, instructions, and data. Bits are usually grouped in larger units such as nibbles(4), bytes(8), or words (16, 24,32, 86 or more). |
| Byte | A group of 8 bits. A byte is universally used to represent a character. Microcomputer instructions generally require one, two or three bytes. One byte has two nibbles. |
| Compiler | A translation program which converts high-level instructions into a set of binary instructions (object code) for direct processor execution. A compiler translates the complete program once, yielding object code which may then be executed repeatedly. |
| CPU | Central Processing Unit. The computer module in charge of fetching, decoding and executing instructions. It contains a control unit, an ALU, and other related facilities such as registers, clocks, or drivers. |
| CRT | Cathode Ray Tube. The television tube used to display pictures or characters, and thus, by extension, a computer terminal which uses a CRT. |

| | |
|---|---|
| Firmware | A program stored in a ROM, i.e. software on a hardware support. Historically, firmware was used only for microprograms, but with the advent of microprocessors, many kinds of programs reside in ROM, and firmware designates any ROM-implemented program |
| Floppy Disk | A mass-storage device using a flexible (floppy) mylar disk (diskette) to record information. The diskette is permanently sealed in a square plastic jacket lined with a soft material which cleans the diskette as it rotates. A cut-out slot provides access to the moving head which must actually come in contact with the diskette surface in order to read or write. Other holes in the jacket provide access to sector index holes in the diskette itself. |
| Hard Disk | A disk composed of a magnetic coating applied to a rigid substrate, such as aluminum or ceramic. The term is generally used to contrast with "soft" (floppy) disks, which are flexible but are slower and have less storage capacity. |
| Kbyte or KB | Kilo-Byte, 1024 bytes. |
| Mbyte or megabyte | 1024x1024 bytes = 1.05 million bytes = 1024KB. |
| Memory | A storage area for binary data and programs. Also: any device which will store information. In a computer, memory is divided into fast electronic memory integral to the computer, and external, slower memory such as disk drives and tape drives, using magnetic recording methods. |
| Microprocessor | An LSI implementation of a complete processor (ALU+Control Unit) on a single chip. It is the CPU of the microcomputer. |
| Modem | Modulator-Demodulator. A device used to interface a digital device to a telephone line, it encodes and decodes serial bits into frequencies. |
| ms | MilliSecond. 1 millisecond=$10^{-3}$ seconds. |

| | |
|---|---|
| Peripheral | Any device connected to a computer which is to some degree controlled by the computer. |
| Program | A sequence of user-specified instructions which result in the execution of an algorithm. Programs are generally written at one of three levels:<br>(1) binary or hexadecimal code (directly executable by the MPU),<br>(2) assembly language (symbolic representation of the binary code, requiring an assembler), or<br>(3) high-level language (requiring a compiler or interpreter, e.g. BASIC). |
| RAM | Random Access Memory. Memory internal to a computer from which information can be drawn or where information can be stored. |
| ROM | Read Only Memory |
| Systems Software | A collection of related computer programs that work in tandem with one another or in sequence one after another for the purpose of doing a specific job is called a system. |
| Unix | A mini- and microcomputer operating system developed by Bell Labs which features multi-programming, a hierarchical file structure, and numerous useful utilit'-- |

# APPENDIX B

## Electric Utility Model Descriptions and Special Purpose Programs

1. Probabilistic Production Cost

PPC combines the load supply probability distributions with forced outage probability distributions at generating plants to form an "equivalent load" which represents that load seen by each generating unit after accounting for forced outages.

2. Generator Capacity Margins

This program determines from a day-by-day analysis all possible capacity margins which could be expected to exist between load and available capacity. The program is based on reliability criterion such as Loss of Load Probability (LOLP) and simulation of daily peak loads and daily available capacity.

3. GOES: Generator Outage And Equipment Status

The purpose of the "GOES" program is to provide a data base for power plants covering statistics associated with generator outages and equipment availability. The information from GOES can be used to monitor and set goals for MBO's on such things as availability, forced outage rates, etc.

4. Short Circuits

The problem of planning the protection scheme for distribution circuits requires the calculation of short circuit currents at various locations on the circuit. This program calculates the three-phase, two-phase and phase to ground fault currents for distribution circuits.

5. Load Flow And Transient Stability

This is a combined load flow and transient stability program for steady state and transit analysis of small power networks. It is used

for predicting power systems response to system disturbances such as three-phase short circuits, sudden application or removal of loads and induction motor loading effects. The program is ideal for studies of industrial systems, and plant auxiliaries where system loads often form a large part of synchronous and induction motors drive.

6. Distribution Load Flow

The Distribution Load Flow Program is used for analysis of distribution circuits on a balanced three-phase basis. The program gives the distribution planning engineer a tool with which to evaluate the power system from the substation down.

7. Adjusted Fuel Cost Program

The Adjusted Fuel Cost Program is a CPS Program. The user enters the month's heat input, fuel cost, and operating factor for each plant. This information is stored in the files by month. The file system also contains data which describe each plant and its operating variables such as:

- Maintenance factor
- Fuel handling cost
- Unit operating factors
- Fuel burned at each plant
- Heat required for start up
- Fuel used for start up

8. Load Flow

The Load Flow Program calculates terminal conditions-voltages and power flows for a specified power system taking into consideration the regulating capability of generator, condensers, TCUL and

phase-shifting transformers as well as the specified net interchange between individual operating systems.

9. Capital Expenditure Predictions (CEP)

CEP provides financial information about construction projects for electric utilities. The information comes from two sources and is maintained in two separate files. T & D data and all remaining project data, such as generation, general plant, heating plant, etc. are used for processing. CEP covers a five year time span beginning with the current budget year.

10. Financial Model

The Financial Model is a planning tool used in preparing long term forecasts. Data is placed in the system to provide an accurate financial picture of the previous corporate year and to describe any critical factors in the future economics of the company, such as major construction, price of fuel, and number of customers.

## D. SPECIAL PURPOSE PROGRAMS

1. Budget Proposals and Projects System
2. Overhead Lines Detail Estimating
3. Manpower and Resources Scheduling
4. Line Design Technician Manpower Report
5. Crew Data Supplement Report
6. Electrical Design Bills-of-Material
7. Budget Estimating
8. Underground Lines Detail Estimating
9. Annual Load Duration Curve

10. Pipe Stress Analysis

11. Polynomial Curve Fitting

12. Boiler Efficiency

13. Structural Steel Design

14. Beam Deflection

15. Heat Rate Reduction

16. Generation Planning

17. Column Load Distribution

18. Fuel Buying Statistics

19. $SO_2$ Dispersion

20. Power Plant Testing

21. Cable Routing

22. $SO_2$ Emission

23. Pressure Drop Calculation

24. Orifice Design

25. Architectural Fence Bill of Material

26. Maximum Flow in a Piping System

27. Coal Analysis History

28. Forced Outages Probabilities

29. Lighting Design

30. Minimum Pipe Wall Thickness

31. Seismic Analysis of Piping

32. Condenser Water Discharge (Thermal Phase)

33. Weather Information Survey Program

34. Concrete Quality Control

35. Steel Column Design

36. Section Modulus Program

37. Historical Data Base

38. Concrete Quality Assurance Program

39. Concrete Sampling and Forecasting

40. Reliability of Sampling/Steel Testing

41. Parson's Structure Programs

42. Fuel Costing Program

43. Overtime Reporting

44. Automated Concrete Proportioning

45. Frame Analysis

46. Steady-State Boiler Models

47. Structural Properties

48. Cable Routing II - Output Reporting

49. Department Order Status System

50. Plant Information Network

51. Air Quality Monitoring

52. Load Data Accumulation and Reporting

53. Transient Stability

54. Transient Stability Network Equivalents

55. Fuel Estimating Program

56. Numerical Analysis Package

57. Auxiliary Programs for Induction Motors

58. Speed Tongue Curves

59. Equivalent Circuit Program

60. Distribution Factors

61. CPS Short Circuit

62. Linear Network Reduction (Equivalence)

63. Complex Short Circuit

64. Automated Shopping

65. Unbalanced Feeder Drop Program

66. Storm Analysis

67. Underground Cable Parameters

68. Electromagnetic Transients

69. Unit Commitment System

70. Common Format System

71. Motor Start

72. Power System Simulator

73. Trunk Line Analysis

74. Machine Data Base

75. Firm Rating

76. Interactive Load Flow System

77. Load Information System

78. Substation Metering

79. Corporate Strategy Model

80. Rate Structure Design

81. Hydro-Thermal Dispatch

82. Energy Demand Forecast

83. Peak Demand Forecast

84. Ash Disposal Cost Estimating Model

85. Performance Model for Evaporative Cooling Towers

86. Cooling Tower Plume Dispersion Model

87. Ground Water Flow Model

88. Area Control Simulator

89. Transmission Line Broken Wire

90. Capacity Allocation Model

91. Dynamic Equivalents

92. Single Unglued Transmission Pole Design

93. Distribution System Reliability and Risk Analysis Model

94. Diagnostic Stability Program

95. Distribution Planning

96. Load Shape Model

97. Cost and Benefits of Over Versus Under Capacity in Electrical Power System Planning

98. Residential Building HVAC Energy Use

99. Coal Mine Cost Model

100. Solar Heating and Cooling Systems Design

101. Load Shape Simulation Program

102. Fracture Analysis

103. Program Maintenance System

104. Construction of Fault Trees

105. Data Base Management/Executive System

<u>Data Bases</u>

106. Equipment Qualification Data Base

107. Regional Systems Data Base

108. Fuel Performance Data Base

109. Relational Information Management System

# APPENDIX C

## Model and Data Base Needs For Industrial Energy Conservation Planning and Analysis

(1) BASIC DATA COLLECTION AND HANDLING

| | |
|---|---|
| Regression analysis | For curve filling, trend analysis, etc. Standard packages should be available for specific hardware. |
| Statistical analysis | Significance testing, etc. - standard packages should be available. |
| Plant survey questionnaires | Program to be written based on questionnaires developed for plant surveys/audits in Tunisia and other countries: to enable various analyses to be conducted using the computer, such as conversion of all energy forms to standard units (kilocalories, TEP, etc.) and calculation of specific energy consumptions (kilocalories per tonne output, etc.). Should include graphical presentation of results. |
| RES model | To include data for LDCs, if available, and to allow user to include new country data and to manipulate sectors, fuels, etc. as required. |
| Matrix manipulations (Visicalc) | Standard packages available. |
| Matrix projections | To allow rapid calculation of projected national energy balances; input to be the current balance (matrix) and subsector growth rates, with options for limits on fuel types, fuel substitution guidelines, etc. |
| Specific energy consumptions | Subroutine to calculate specific consumptions in a range of units (using kilocalories, joules, Btu, etc.) from input data in physical units (litres fuel oil, kilowatt-hours electricity, tonnes output, etc.) |

| | |
|---|---|
| Conversion of units | Subroutines for conversion of units commonly used in energy analyses (e.g. from Btu to joules, tons oil equivalent to tons coal equivalent). |
| Energy consumption and capacity utilization | Estimation of the effect of capacity utilization on specific energy demand. |

(2) ENGINEERING AND ECONOMIC ANALYSES

| | |
|---|---|
| Furnace efficiency calculations | Calculation of stack losses for standard furnaces, from stack temperature and gas analyses (e.g. from Siegert formulae). Allowance to be made for unburnt carbon in ash for coal-firing units, radiation losses, etc. Program to be capable of handling wide range of fuels. Output to be efficiency, excess air rate, stack gas volumes etc. |
| Boiler efficiency calculations | Similar to above; including also the effect of blowdown and condensate return. |
| Heat losses from structures | Calculation of heat loss from structures by convection and radiation (e.g. from boilers, furnaces, cement and brick kilns, etc.) |
| Degree day calculations | Correction of space conditioning energy data for degree day effects. Can include option for use of actual degree day data or use of standard climatic data. |
| Power factor correction | Cost-benefit analysis of power factor correction equipment. |
| Plant material balances | Correction of plant material balance data to give statistically "correct"balance, based on input of expected accuracy of measurements of material flows. To include option for input of data in terms of |

| | |
|---|---|
| | volumes of liquid or vapour (and specific gravities at various temperatures, pressures, etc.) |
| Fuel combustion calculations | To calculate stoichiometric air requirements, stack gas volumes and compositions from basic analyses of fuels (coals, oils, gases). |
| Project evaluations | Calculations of project economics in various terms, e.g. simple payback, DCF, net present value. Options to include cash flow calculation and report. |
| Orifice plate constants | Calculation of meter factors (for standard orifice plates) for gases and liquids. |
| Steam turbine calculations | Calculation of work input and efficiencies of steam turbines. |
| Pump and compressor calculations | Calculation of work required for pumping. |
| Pitot tube calculations | Calculation of work required for pumping and compressing in process plants. |
| Heat exchanger calculations | Calculation of heat transfer coefficients. |
| Steam leaks | Estimation of steam (and compressed air) leakage from holes, cracks, etc. for audit work at the plant level. |
| HVAC models | Estimation of heating and cooling loads for buildings (ASHRAE - type models). |

(3) DATA BASES

| | |
|---|---|
| Specific energy consumptions | Data on specific energy consumptions by different industrial subsectors for various countries (developed/LDCs, etc.)- such as cement, bricks, steel, food processing etc. |

| | |
|---|---|
| Industrial conservation measures | Listings of typical conservation measures for specified industries, with technical descriptions and costs. |
| Energy - GDP data | Historical data on primary energy use to GDP ratios for many countries (e.g. World Bank data). |
| Oil and petrochemical processes | Data base of yields, utilities consumptions, operating labor, capital and operating costs. |
| RES model | To include data for LDCs, if available, as well as option to include new country data. |
| Equipment manufacturer lists | For major process plant equipment, including heat recovery devices, etc. |
| Fuel heating values | Library of higher and lower heating values for common fuels, including wood, biomass, biogas, etc. |
| Insulation properties | File of data on insulation (ceramic fiber, etc.) |

(4) REPORTING

| | |
|---|---|
| Graphics | Standard package for reporting energy analyses, trends, etc. |
| Plant Monthly Report | To be developed for a "standard" plant; output to include tabular presentations and graphics, showing current month, year-to-date, prior months, trends, averages, etc. To be designed for use by plant energy managers. Can include standardized data for typical performance in the particular industry of concern. |
| Audit report | Possibility to develop standard package for reporting audit work at the plant level (a combination of the |

| | |
|---|---|
| | engineering programs listed under item (2). |

(5) ELECTRIC UTILITIES

| | |
|---|---|
| Dispatch model<br>Planning (capacity expansion) | Standard packages are believed to be available. |