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ENERGY EFFICIENCY AND CONSERVATION IN WEST AFRICA

Proceedings of a Seminar

Lome, Togo
March 30 - April 8, 1983

Co-sponsored by

ECONOMIC COMMUNITY OF WEST AFRICAN STATES (ECOWAS)

and

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT (USAID)
Office of Energy, Washington, D.C.

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Hosted by
THE GOVERNMENT OF TOGO
Ministry of Public Works, Mines, and Energy

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BROOKHAVEN NATIONAL LABORATORY, Upton, NY

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State University of New York/Stony Brook, NY

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ABBREVIATIONS, UNITS AND CONVERSION FACTORS

boe	Barrel of oil equivalent
bdoe	Barrel per day of oil equivalent
tce	Metric ton of coal equivalent
toe	Metric ton of oil equivalent
tpy	Metric ton per year
Btu	British thermal unit
kcal	Kilocalorie (1,000 calories)
kW	Kilowatt (1,000 watts)
MW	Megawatt (1,000 kW)
GW	Gigawatt (1,000 MW)
TW	Terawatt (1,000 GW)
kWh	Kilowatt hour
GWh	Gigawatt hour
MMCFD	Million cubic feet per day
tcf	Trillion cubic feet

- 1 barrel oil equivalent (boe)
  = 5.8×10^9 joule (J)
  = 1610 kilowatt-hour (kWh)
  = 1.4×10^6 kilocalorie (kcal)
  = 2160 horsepower-hour (hp-h)
  = 5.5×10^6 British thermal unit (Btu)

- 1 ton petroleum or oil equivalent (tpe, toe)
  = 7.49 barrel oil equivalent
  = 40.47×10^3 cubic feet of natural gas

- 1 ton standard coal = 0.7 toe

- 1 ton firewood = 0.20 to 0.35 toe

- 1 ton charcoal = 0.63 to 0.69 toe

- 1 ton bagasse (30% moisture) = 35 toe

- 1 m^3 = 1×10^6 cm^3
  = 1000 liter
  = 35.31 ft^3
  = 264 U.S. gallons

SECTION 1

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION AND BACKGROUND

David J. Jhirad

The West African region, consisting of the 16 member countries* of the Economic Community of West African States (ECOWAS) faces severe energy and economic problems. In common with many other developing countries, the oil-importing ECOWAS nations have been seriously affected by the rise in oil prices of the 1970s, while simultaneously confronting the problem of dwindling supplies and increasing costs of traditional fuels such as fuelwood and charcoal.

Recognizing that cooperative energy strategies at the regional level can play an important role in complementing country-level initiatives, ECOWAS convened its first energy symposium in Freetown, Sierra Leone, in November 1981, with financial support from the U.S. Agency for International Development. This symposium was jointly managed by ECOWAS and the Board on Science and Technology for International Development (BOSTID) of the United States National Research Council (NRC).

The fourteen project recommendations made at the symposium were later endorsed by the ECOWAS Council of Ministers at Cotonou, Benin, in May 1982. Following this meeting, planning was undertaken for implementation of the first of its recommendations: convening a working seminar on energy efficiency and conservation in the power generation, transportation, industrial, and building subsectors. The seminar was held in Lome, Togo, March 30 - April 8, 1983, jointly organized by ECOWAS, Brookhaven National Laboratory, and the Institute for Energy Research, SUNY/Stony Brook, with financial support from the Office of Energy of the U.S. Agency for International Development. The seminar was hosted by the Togolese Ministry of Public Works, Mines, and Energy.

1.2 SYNOPSIS OF SESSIONS

1.2.1 Objectives and Scope

The major objectives of the seminar were to acquaint senior policymakers and technical personnel with:

- The basic technical and economic concepts associated with energy efficiency, conservation, and demand management
- The costs and benefits of energy efficiency measures from an enterprise and a national perspective

*They are: Benin, Cape Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo, and Upper Volta.

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- The role of energy efficiency in the energy strategy of the ECOWAS region

- Institutional and policy mechanisms to implement energy efficiency projects and programs

- Recommendations for specific steps to initiate and sustain action programs.

These objectives were approached through a discussion of case studies of energy efficiency programs in developed and developing countries, surveys and audits that have been carried out in some ECOWAS countries, and analytic methods that have proved useful in assessing the costs and benefits of energy efficiency in industry, power generation, commercial and institutional buildings, and transportation. Lectures and discussions were supplemented by a field trip to the phosphate plant in Togo, where energy audits were performed with the active involvement of seminar participants.

Throughout the seminar, it was emphasized that energy efficiency did not mean austerity nor curtailment of supply. Instead, it was stressed that energy efficiency should be viewed as a reduction in the amount of energy used to produce a unit of output in the economy, and therefore part of a strategy to replace expensive sources of energy by cheaper ones.

Even though much of the experience with energy efficiency has been gained in the industrialized countries, case studies carried out in the developing countries have revealed that substantial energy and cost savings can be achieved relatively quickly through technically proven energy efficiency measures.

As requested by ECOWAS, the seminar confined itself to the four sectors -- industry, electric power, commercial and institutional buildings, and transportation -- that account for the bulk of the utilization of commercial fuels. The seminar was not designed to address issues involving fuelwood or charcoal, which are the principal fuels for households in developing countries, and account for between 60 and 90 percent of total energy use in the West African region. The relationship between energy and agriculture is another important issue that was outside the scope of this seminar. However, in response to requests by many of the participants, the conference chairman convened a special session on the efficient use of wood.

Since the seminar was designed to serve a need for information and training in the region, the lecturers' presentations are reproduced in these proceedings. What follows is a brief summary of the major issues discussed in the sessions, together with the conclusions and recommendations of the seminar.

1.2.2 The Industrial Sector

There is a lack of reliable information on the consumption of petroleum and electricity by sector, but available data indicate that the transportation sector is the largest consumer of petroleum fuels in West Africa and the

industrial sector is the second or third largest. An exception is Nigeria, where the industrial sector is the largest user of petroleum.

The large energy-intensive industries, such as iron and steel, petroleum refining, cement, fertilizer, chemicals, and pulp and paper dominate petroleum consumption, and the costs of the energy utilized are generally between 10 and 50 percent of total production costs. Evidence was presented to show that energy use per unit of output in these industries could be reduced substantially through a variety of measures, ranging from no or low capital investment options such as better housekeeping, and improved management, monitoring and control systems, to medium and high capital investment options such as new equipment and process modifications. Potential energy savings of 10 to 30 percent are possible in most industries, with payback periods for investment ranging from less than one year for good housekeeping measures to less than five years for the capital-intensive equipment replacement options that one needed to achieve large savings.

The importance of energy audits in realizing these savings was stressed. Audit types include (1) the initial basic audit, which requires 2-3 days depending on data availability and which will reveal inadequate metering, records, or measurements, and (2) the comprehensive audit, which requires several months for energy and material balances to be carried out, including inputs and outputs by department or function, and which provides detailed evaluations of the costs and benefits of various efficiency improvement options. Examples of audits carried out in Togo, Senegal, Tunisia, and Morocco were presented and seminar delegates were instructed in the use of diagnostic instruments through their participation in a one-day short audit of the phosphate plant in Togo. Delegates were also shown a film on industrial plant efficiency improvements, demonstrating good housekeeping, minor, and major capital investment approaches.

Many delegates stressed that ECOWAS countries needed the methodology to carry out the energy surveys and audits by ECOWAS engineers without relying on outside consultants, and it was agreed that there was an important role for training programs to follow the seminar.

The economic attractiveness of cogeneration systems using petroleum fuels or bagasse highlighted the need for coordinated planning in the industrial and electric power sectors. A novel proposal to utilize the waste heat from large diesel generators for centralized refrigeration facilities was received with a great deal of interest. Waste-heat recovery systems, heat pumps, instrumentation and control systems, and process changes were also discussed. Such systems address the basic physical and engineering reasons for inefficiency, which include

- combustion of high-grade fuel to produce low temperature heat
- loss of high temperature heat
- use of inefficient processes.

Financial support will generally be required for those capital-intensive but rapid payback measures.

The problem of implementing energy-efficiency measures in the large number of small- and medium-sized industries was also discussed. Government measures proposed included pricing policy, regulations, technical assistance and training programs, fiscal incentives, and capital allocation schemes. The involvement of regional development banks was also cited as an important factor in implementing industrial energy efficiency programs.

1.2.3 The Electric Power Sector

Measures discussed to reduce the cost of electric power generation included the following:

- Maximizing output from existing power generation units through preventive maintenance
- Minimizing down-time of power generation units by increasing availability of spare parts, such as through a regional spare-parts bank
- Load management to cut the demand of large users during peak hours
- Cogeneration of electric power and process heat, or waste-heat utilization for refrigeration
- Reduction of technical losses and unmetered consumption in electric power distribution systems
- Grid connections among ECOWAS countries using the success of the Ghana, Togo, Benin, and Nigeria experience.

A brief history of the Tennessee Valley Authority was presented to illustrate the cost effective nature of preventive maintenance, which requires trained and dedicated maintenance personnel, commitment, patience, and perseverance. It was pointed out that the attitude of management is critical. It is management who must maintain the maintenance budget in the face of temptations to borrow from it each year, postponing maintenance "just this once" again and again.

In the discussion, some delegates expressed doubt about the relevance of TVA's experience to their countries, given the vast differences in scale and reliability between TVA's system and theirs. It was pointed out that TVA had started fifty years ago in a region that was then in many ways like a developing country of today. More concrete discussions centered on the need for better personnel management (making assignments match experience and schooling) and problems resulting from having budgetary overlaps with other branches of government. Serious unsolved problems in the region are the plethora of different power generation systems supplied by donors' loans from a number of different countries, the lack of funds for maintenance, and the unavailability of spare parts.

Delegates saw a role for government in organizing training of personnel, in making a commitment to maintenance, in anticipating personnel needs well in advance of completion of installations, and in setting up a spare parts bank.

Some delegates felt that load management was not getting enough attention in the region, and various schemes for large users to shift their demand to off-peak hours were discussed. One technically proven and cost effective scheme involves the use of off-peak power to cool water, which can then be used to cool circulating oil through large buildings during peak periods. This is expected to be less expensive then constructing new generation capacity to meet peak air-conditioning loads. It was stressed that load management schemes require tariff structures based on the economic cost of providing power and the use of modern metering and monitoring equipment.

The subject of loss reduction in electric power transmission and distribution systems was considered very important, and reference was made to the initiatives being taken by the World Bank in this field. All of the countries in the region have high loss rates -- some as high as 40 percent -- and cost-effective measures to reduce line-losses are urgently needed. Such measures include, but are not limited to, reactive power control with capacitors, load switching equipment, and higher capacity transformers. Studies performed by the World Bank indicate that the cost of saving electricity by improving the transmission and distribution system can be about a third of the cost of new supply.

1.2.4 Commercial and Institutional Buildings

The air-conditioning of hotels and commercial buildings in ECOWAS countries accounts for a significant fraction of electricity demand. Building energy audits performed in Dakar, Senegal indicate that savings of up to 20 percent and more can be achieved through improved energy management and monitoring, reduction of excessive lighting levels, and minor equipment modifications.

One of the lecturers stressed the importance of designing new buildings with energy-efficiency considerations in mind. The operation of the DOE-2 computer program to predict the energy performance of buildings was explained and extensively discussed. This method of predicting the energy performance of buildings in tropical countries has been successfully applied in Singapore to test their building standards, and to develop more realistic targets.

The importance of the system is its potential to model and design energy use in new buildings before the architect has completed the design, so that energy efficiency considerations can be included before the building reaches the engineering stage, by which time options are limited. Incorporating energy-efficient lighting and appliances in new hotels and commercial buildings was also considered important.

In response to questions about the implementation of the DOE-2 program in the ECOWAS region, it was suggested that ECOWAS establish a project in cooperation with a regional architects' professional association to apply the

program to construct local building design standards. One delegate pointed out that multinational corporations frequently have their buildings designed outside West Africa, leaving the electricity generation systems of West African countries the responsibility of meeting the resulting increase in load.

It was agreed that governments could play a useful role by revising the codes and regulations for new buildings, by supporting energy audit programs, and by providing information on designs and technology to local architects.

1.2.5 The Transportation Sector

As the largest user of petroleum fuels in West Africa, the transportation sector is an important but complex target for well-conceived energy-efficiency measures, especially since opportunities for fuel substitution in the near future are limited. However, in spite of the importance of this sector and the possibility of substantial savings in road transport, methods for conducting energy audits and achieving savings are far less developed than those used in the industrial or power sectors. In addition, energy-efficiency measures should be compatible with the overall goals of a regional, national, and local transportation policy.

The results of a transportation survey conducted in Dakar, Senegal, were presented, comparing data obtained from local officials with those obtained from other countries in order to establish an approximate potential for energy savings. The survey led to the discovery that Dakar bus drivers started their engines hours in advance, so that they would not be delayed by start-up difficulties when they began their routes. Through improved maintenance to eliminate starting difficulties, and by making drivers start their vehicles only when they began their schedule, fuel consumption was decreased by 10 to 20 percent. Experiences in Zimbabwe and Canada have shown that a 10 percent improvement in fuel utilization can be achieved through training of bus and truck drivers.

Other efficiency measures proposed included technical options, such as conversion to improved diesel engines, organizational options such as better route planning, and changes in societal functioning to require less transportation, the elimination of trips home for lunch being an example of this last option. Some representatives thought that conversion to a workday without a break would be difficult and the necessary meals expensive. Other delegates reported positive experiences (Guinea).

A case study of the efficiency of transportation modes in the Dominican Republic prompted further discussion of technical and policy options. The importance of the speed and flexibility of a truck-based system was emphasized, despite the greater efficiency of rail or water transport. Delegates emphasized the following issues as of particular relevance to ECOWAS countries: the problem of measuring fuel efficiency on a mix of paved and unpaved roads, the low efficiency associated with the irregular start-stop patterns of taxis and minibuses, the use of illegal income for vehicle purchases and the possible role of better telephone and postal systems in cutting fuel consumption. Issues debated without resolution included the role

of public and private transportation, bus versus rail transport, the need for profitability and efficiency, the difficulty of road maintenance, and the transferability of results from industrialized countries. Assuming that cost-effective hydropower were available, the value of trackless electric trolleys for urban transport was stressed by several speakers, both as an energy efficient system and as a means to shift away from petroleum based fuels.

The Director of the ECOWAS transportation department was particularly interested in achieving energy savings at the city, regional, and national level, and proposed that teams of specialists visit target problem areas with a view to identifying short-term measures as well as longer-term electrification possibilities.

1.2.6 The Household Sector

Though outside the scope of the conference, a special session was held on the fuelwood problem. The panelists discussed various possibilities for improving the efficiency of fuelwood and charcoal use. The panelist representing GTZ, the German Assistance Agency, summarized their experience with wood stoves in Upper Volta. With a well-defined efficiency test, they found that the traditional three stone fire had an efficiency of around 14%. They have had some success in introducing an immobile clay stove with an efficiency of up to 30%. But most attempts to implement stoves have failed, a problem attributed to cost, poor manufacture, and lack of training of cadre.

Another panelist spoke on the universality of deforestation throughout the third world, and of the fundamental social and economic character of the problem. He suggested several alternate technical options for combatting deforestation, including the introduction of kerosene as a cooking fuel in the immediate future, the development of charcoal from agricultural residues and energy plantations, and the development of energy plantations for cooking fuelwood, power generation, and cattle feed. It was pointed out that the economics of woodstoves must be evaluated from the perspective of the user, (for whom costs in cash must yield cash benefits) the society, and the government. One panelist concluded that a realistic program to disseminate cookstoves could not be implemented at any reasonable rate given the virtual absence of a marketing infrastructure. In the discussion that followed, only one representative claimed any success for a wood stove program, and most speakers were quite pessimistic.

Recent studies of stoves and fuelwood production in Africa sponsored by the Board on Science and Technology for International Development of the U.S. National Research Council indicate that there is no evidence that the introduction of stoves saves fuelwood. These studies also show that reforestation efforts have only yielded tree survival rates of 20 percent after 2-3 years. Delegates agreed that there is a great need to improve incentives for people to plant and nurture trees in their farming systems, a goal that will require research on better species to supply more diverse benefits to growers and the identification of an organization to monitor the research and distribute better seed among ECOWAS countries.

1.2.7 Implementing Energy Efficiency Measures

Policy and institutional mechanisms for implementing energy-efficiency measures were extensively discussed and debated during the seminar, with examples drawn from a number of industrialized and developing countries. Five major categories of measures were identified.

- Technical and financial assistance to carry out energy audits and training programs, as well as promotional and educational programs directed at energy decision-makers

- Changes in pricing policy, to reflect the economic costs of various energy supply and efficiency options, while preserving the social benefits of subsidized prices for low-income users

- Capital allocation for medium- and large-scale investment

- Establishment of mandatory energy-efficiency standards through legislation and regulatory procedures

- Fiscal incentives to install, manufacture, and import energy-efficient equipment. These incentives could include tax credits, reduction in import tariffs, and licensing arrangements.

The relative importance of these measures will necessarily vary considerably depending on the specifics of each contry's situation. Many delegates, while perceiving the economic benefits of a pricing policy based on marginal costs, were aware of the social and political difficulties associated with raising prices and were concerned about the impact of higher fuel and electricity prices on poorer people. Some delegates expressed a wish to receive detailed information on country-specific experiences with changes in pricing policy. The former head of the Canadian Energy Conservation Program discussed the importance of government assistance and initiatives in providing information, conducting energy audits, implementing demonstration projects, and convincing upper management of the financial and economic benefits of energy efficiency.

Many delegates stressed the concept of local expertise to undertake audits and pre-feasibility studies. One proposal was that ECOWAS could assist member states by developing a cadre of qualified local experts who could aid countries with their pre-feasibility studies. In this way, the costs of these studies could be reduced, and their relevance to local realities increased, although it would probably still be necessary for the major lending agencies to do their own final feasibility studies before approving loans. There was general agreement with this proposal.

1.3 CONCLUSIONS AND RECOMMENDATIONS

1.3.1 Introduction

A follow-up energy program by ECOWAS should be designed with a view to demonstrating concrete results in energy conservation and efficiency over the next one to three years. The seminar's recommendations have also been guided by the following additional considerations:

- The need to take steps to implement the recommendations made at the ECOWAS energy symposium in Freetown, Sierra Leone, in November 1981, and later endorsed by the ECOWAS Council of Ministers at Cotonou in May 1982.

- The need to implement projects that will have a significant impact on the major energy problems of the ECOWAS Member States.

- The necessity for establishing mechanisms to ensure that initial results achieved in one or two Member States can be successfully replicated throughout the region. This could be achieved through training sessions held in technologically advanced countries and in those countries selected for pilot projects.

- A strategy to implement projects that build local capabilities and institutions over the medium and long-term future while simultaneously showing tangible and measurable results over the short-term.

- With the support of donor agencies, ECOWAS can also make a substantial contribution to this institution-building effort through the establishment of a centrally funded cadre of technical experts, drawn from the Member States and outside sources. This group would be dedicated to working in cooperation with experts and local institutions in the Member States to solve specific development problems.

- The seminar noted the absence of adequate information on the quantity and quality of energy production and use in ECOWAS Member states, or of case studies documenting effective energy conservation and renewable energy strategies in these States. Therefore, we recommended that ECOWAS develop an information program to meet these needs.

- Realizing the importance of fuelwood (firewood and charcoal) to the overall energy economy of ECOWAS, it is proposed that a subsequent seminar be held to promote and improve the use of this resource in the West African region.

1.3.2 Training Courses in the Region

Training courses to transfer experience, analytic capability and technology to the ECOWAS Member Countries have been identified by the conference participants as being of major importance. It was felt that a training component should be an essential element of all energy projects in the region, and that, in addition, regular refresher courses should be held in the region in English and French to cover special topics. Such topics could include:

- Computerized energy data base management, possibly using microcomputer technology.
- Regional electric power system planning, as well as planning in the industrial, transportation, and commercial buildings sectors.
- Project financial and economic analysis.
- Technology awareness courses to communicate new technology developments to regional audiences, with special reference to those technologies that are likely to be widely applicable throughout the region.
- The design, installation, and maintenance of conventional and renewable energy systems from the production of the energy through its delivery to the consumer and the final end use equipment.

1.3.3 Industrial Energy-Efficiency: Target Achievements by the End of 1984.

- Training in audit techniques could be carried out in 3 cycles in 3 countries (as shown in the Appendix) for 45-50 engineers from ECOWAS countries including the participation of a minimum of 2 engineers from every ECOWAS Member State.
- Brief plant visits to a number of factories -- with some basic ideas for efficiency improvement thus developed, and guidance given to their engineers, who should be among the course participants.
- Approximately one week "audits" of some of these factories and more comprehensive suggestions for improvements, especially on the energy management side.
- Initiation of major programs at factories representing industries of particular interest to the bulk of the ECOWAS Member States. These programs should include case studies and success stories for several of these factories and industries.

Because many of the participants in the seminar came from the electrical sector, a fairly well-developed program for that sector is presented in this section. Relatively less well-developed programs follow for the building sector and biomass utilization. This difference should not be taken as indicating that energy conservation in those areas is any less important but rather represents a recommendation to the ECOWAS Secretariat to develop more complete programs for them.

1.3.4.1 Objectives

The objectives of projects in this sector should be:

- To increase the availability of units in existing power plants
- To increase the reliability of transmission lines
- To increase the efficiency of generation transmission and distribution of electricity
- To strengthen the organizational capacity of the power sector to plan, build, operate, and maintain power stations and transmission/distribution networks.

1.3.4.2 Strategy

The strategy for achieving these objectives should be:

- To demonstrate improved effectiveness in a few selected systems/installations.
- To conduct on-the-job training to implement action plans. The people to be trained should be drawn from the organizations directly concerned as well as from other organizations with similar plans.
- To provide power sector personnel with analytical and computational tools for planning, decision-making, evaluation and implementation of action programs.

1.3.4.3 Action Programs

To identify up to three electric power systems in the first phase as targets for the following activities:

(a) To plan and execute a plant renovation and efficiency improvement program;

(b) To set up an operations and maintenance organization with concrete plans of action to ensure that plants will be operated and maintained as established under point (a);

(c) To set up a spare parts management scheme which will include the examination of a proposal to set up a Regional Spare Parts Bank;

(d) To train adequate numbers of engineers and technicians at all levels to undertake points (a), (b), and (c) above;

(e) To examine the linkage of existing or new industries with either existing or new power generating plants with the objective of coupling energy and power via cogeneration plants, waste heat utilization, and topping and/or bottoming cycles;

(f) To examine cost-effective and practical solutions for fuel oil substitution by coal, peat, and other locally available primary energy sources;

(g) To study the regional electrical networks and grids with the objective of achieving optimum capacity utilization, minimum transmission and distribution line losses, and capacity expansion using locally available primary energy sources.

1.3.4.4 Planning Tools for the Power Sector

Developing robust plans for the future of the electric power sector in ECOWAS countries involves the integration of diverse generation, storage, and transmission options in each country and across national boundaries. During the last three decades, computer models have been developed for these same purposes in Europe and the United States. Recent rapid advances in microcomputer technology have made possible the adaptation of these models to hardware which can be purchased for $10-15,000, bringing such planning tools within the reach of individual West African national electric utilities, and certainly within the reach of ECOWAS itself.

The seminar proposes a three-year effort to adapt a suitable set of generation planning models to an inexpensive computer system, the installation of this system in an ECOWAS country or in a central ECOWAS electric utility office, the development of a suitable initial data base, and the training of West African personnel in its use. Such an effort would include:

(a) a future load projection system to give numerical expression to various scenarios foreseen as plausible by ECOWAS planners;

(b) a generation planning program which will develop a least-cost utility system for a scenario developed by the planners, based on a multi-decade analysis, and employing individual representations of actual generating plants. This planning model will be adapted to the smaller systems and special circumstances of ECOWAS Member utilities (such as the importance of mini and micro hydroelectric generation and its seasonal and stochastic variation). Inter-country power exchanges and the option of unified regional planning would be specifically included;

(c) a cost analysis model which will allow the estimation of future utility finances over the period of the simulation, and the comparison of different futures;

(d) a rate analysis module which will develop, for existing utilities or for any simulated future year, utility revenues and expenses as a function of various rate structures.

The above represent indispensible inputs to effective national and regional power sector planning.

1.3.5 Proposal for Establishing a Building Energy-Use Research Group in ECOWAS

It is proposed that a small group of building design professionals from ECOWAS countries (architects and engineers) be assembled to undertake studies in the field of building energy and efficiency, and to develop design manuals and standards of practice for the sub-region. In the first phase, in addition to amassing weather data and information on indigenous building materials, the group would be trained to model buildings using the DOE-2 Building Energy-Use Analysis Program. With this background, the group would undertake to develop nomographs, graphs, and other means of presenting the dependence of building energy use on design parameters for each climate zone of the sub-region. The group would be assisted in these efforts by design professionals who have developed and used DOE-2. The activities of this latter group would include implementing the computer program, training people in its use and formalizing the process for the creation of the design manuals.

1.3.6 Transportation Energy Efficiency: Target Achievements by the End of 1984

- Training transportation engineers from the ECOWAS nations in the techniques of energy audits for the transportation sector. This training will be carried out within one or more of the ECOWAS countries to permit field work associated with the topics discussed in this seminar.

- The establishment of programs for training drivers in fuel-efficient vehicle operation techniques.

- Field studies for initial transportation energy audits in several ECOWAS nations. The study team will include a consultant, engineers, and economists from the country under study and at least one transportation planner from another ECOWAS country (preferably a participant of an earlier training seminar mentioned above).

- One or more documented case studies of recent policy actions taken by ECOWAS nations to control their energy utilization in the transportation sector, such as increased bus utilization,

rationing, and petroleum price increases. These case studies will be distributed to all energy planning groups and transportation ministries in the ECOWAS region and can support training seminar programs.

- Preparation of an ECOWAS transportation-energy planning manual which contains:

  1) basic transportation-energy data for the ECOWAS nations

  2) energy conservation policies in effect

  3) a reporting scheme by which ECOWAS can maintain a transportation-energy data base and

  4) results of transportation-energy audits in selected countries.

  This manual will serve as a basis for continuing discussions among ECOWAS representatives on future transportation and energy policy.

In addition to the activities mentioned above, a major study of the interrelated factors of capital investment for roadways, transportation equipment and energy efficiency should be carried out for the ECOWAS region. The transportation system is tightly coupled to development, and, typically, 25 percent of the capital budget is devoted to the transportation sector. If in the interest of energy savings, taxis are displaced by minibuses, then less roadway is required per passenger carried. This may permit some reduction in road construction. At per mile costs now ranging from US $40,000 for laeterite roads to almost US $1 million for asphalt roadway in the ECOWAS region, substantial capital investment reductions can result from reduced roadway requirements. Since capital account (reflecting roadway construction) and current account (reflecting petroleum imports) are both important interrelated factors in transportation-energy planning, a study which includes these many factors is needed as a comprehensive basis for transportation-energy policy.

1.3.7 Proposed ECOWAS Program in Agroforestry and Renewable Energy

Background

Numerous recent studies have underscored the impact of rising energy prices on producing and cooking food in the West African region. Agricultural productivity has fallen as fertilizer costs have risen beyond the means of many farmers, and fuelwood is becoming scarce as populations increase and demand rises for substitutes to kerosene. Reforestation is lagging behind deforestation and affecting the ability of the land to retain moisture and withstand drought, as well as the ability of the forest to regenerate naturally through the activities of wild animals and birds. The importance of reforestation is well recognized by the ECOWAS Member States,

but implementation remains difficult because suitable technical packages have not yet been sufficiently developed to combine technical feasibility with practical economic and social incentives.

At the technical level the traditional species promoted by forestry departments for commercial forestry and watershed or roadside planting must be supplemented with species which farmers can integrate into their farming systems for each crop, fodder, mulch fertilizer, windbreaks and living fences, and fuelwood production. Recent evaluation of reforestation efforts indicates that seed availability is a serious constraint. The range of species or varieties well-adapted to local conditions is inadequate, as is nursery technology to germinate seed and raise satisfactory seedlings in sufficient numbers, and systems for providing care for seedlings after planting. As a result, it is estimated that in existing reforestation activities, only perhaps 20 percent of seedlings survive beyond two to three years.

Recently a number of ECOWAS States have initiated agroforestry and renewable energy research and development activities in attempts to develop more effective technical packages for forestry and rural energy supply integrated with farming systems. However these efforts are limited in scope and there is as yet no effective mechanism for coordinating results and making available seed and other technical components within the West African ECOWAS region. Organizations concerned with this topic include USAID, the International Council for Research in Agroforestry, the Centre Technique Forestier Tropical, the US National Academy of Sciences, GTZ, IDRC, IBRD, and a number of private and voluntary organizations.

Proposed Role for ECOWAS

As part of its responsibility for supporting Member States' activities in energy supplies and conservation, in agriculture and in the "Reforestation Decade," ECOWAS can stimulate and support forestry and renewable energy activities which strengthen local capabilities, improve coordination of efforts among states and provide a means for rapid distribution of technical results and packages for implementation.

ECOWAS should convene a regional meeting of forestry and renewable energy officials from Member States, and representatives of the principal organizations supporting research and development of this technology in West Africa. The objectives of this meeting should include:

- reviewing the renewable energy potential in Member States
- identifying needs for improved genetic resources, seed collection, storage, and distribution possibilities
- identifying improved fuelwood and charcoal combustion technology systems

- identifying possibilities for substitution of renewable energy sources for petroleum-based fuels, e.g., biogas, producer gas, direct solar energy

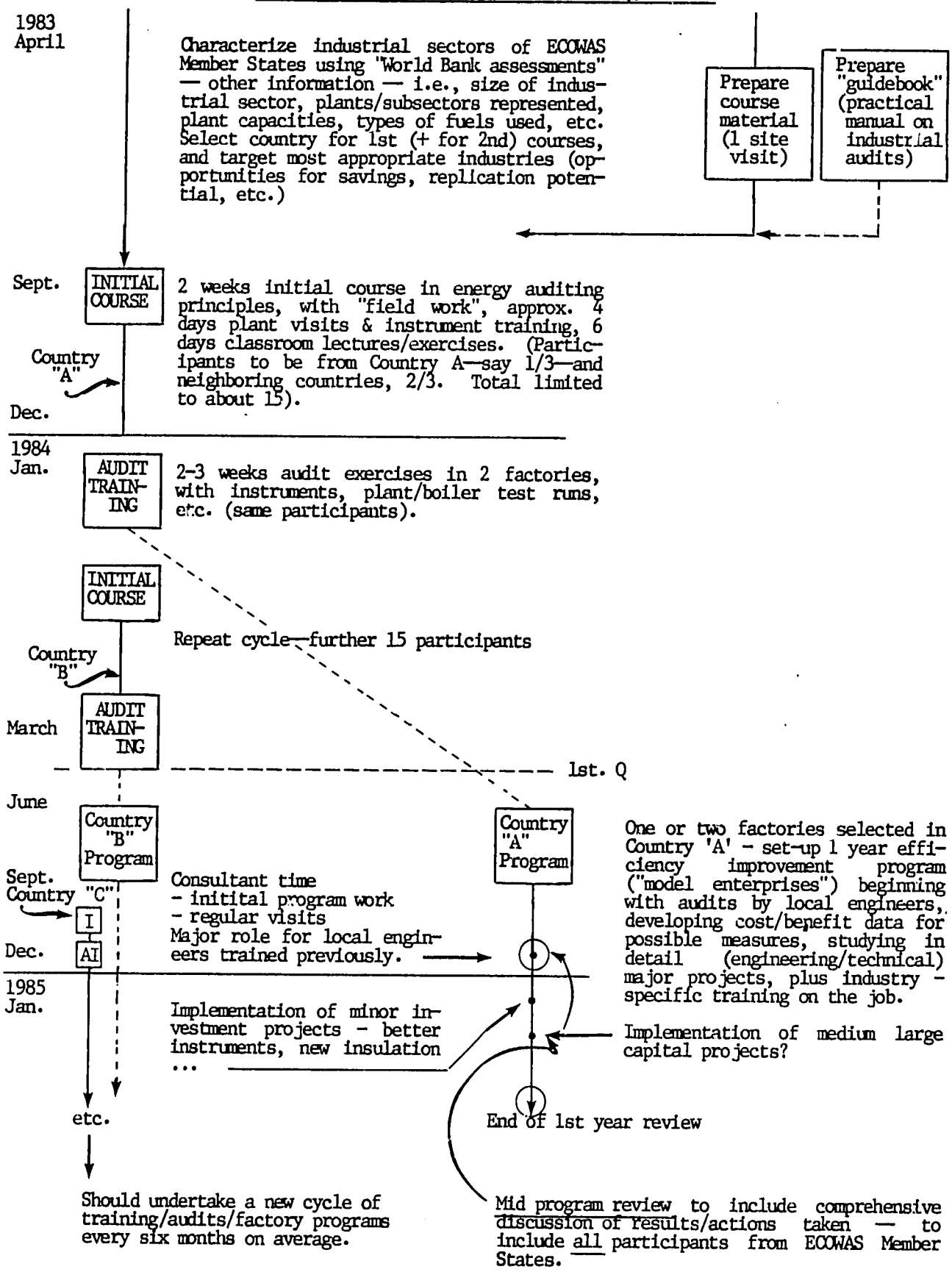
- identifying training needs

- discussing cooperation with the Microbiological Resources Centre (MIRCEN, Dakar), concerning soil microbial factors

- discussing social and economic aspects of integrated systems of food and feed production, soil improvement, natural products, fuelwood and charcoal production

- establishing guidelines for regional cooperation in information needs and technical package dissemination.

Suggested Schedule for Industrial Energy Audits



SECTION 2

THE RATIONALE FOR ENERGY EFFICIENCY AND CONSERVATION

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2.1 OVERVIEW OF THE ENERGY SITUATION IN ECOWAS COUNTRIES

Asif M. Shaikh

1 INTRODUCTION

In the limited space available, and for a topic of this complexity, we can only hope to touch upon the main features of commonality and diversity within ECOWAS countries. Therefore, this paper will merely present a series of statistics and perspectives, which, when taken together, may create a picture of value.

The implications of the topic being addressed should be made clear at the outset: the energy situation in any country is the product of that country's economic situation, and at the same time, is a component of that economic situation. I believe it is self-evident that the relationship between energy and economics is the principal reason for concerning ourselves with energy.

a) At the macroeconomic level, energy is an essential input into production and exchange. Energy scarcity can constrain or disrupt those processes and high energy costs can siphon resources from other high priority development objectives.

b) At the level of individual decision-making units, energy can be viewed primarily as a cost of doing economic activity. The importance attached to energy by private decision-makers will depend on, amongst other things, the ratio of energy costs to total costs, the existence of alternatives to high priced energy inputs, and the ability to pass costs along to consumers.

Economic Overview

The vast majority of the population in ECOWAS countries is engaged in agriculture, with nearly seventy-five percent of the population of the region living in rural areas. Despite the importance of this sector in providing the livelihood for the majority of the population, agricultural production has failed to keep pace with the growth of other sectors, or even with population growth.

It is surprising, and somewhat disconcerting to note that as of 1979 -- based on available data from fifteen countries -- the service sector contributed the largest share of GDP in ten countries, agriculture in only four, and they were equal in one. For all fifteen countries considered together, both the agriculture and service sectors contribute about 39% of GDP each, while industry and mining contributed roughly 22%.

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These statistics, it should be noted, tend to mask the central role of agriculture and forestry. Agriculture provides subsistence for 75% - 80% of the population, it provides the cash crops which constitute the majority of exports for most countries, and it generates a substantial portion of the transport and food processing which is counted as industry or services. Forests provide energy for rural and urban households, forage for livestock and timber for domestic and export uses (in several coastal countries).

Only four member states have per capita incomes in excess of $500 per year -- Nigeria, Ivory Coast, Liberia, and Ghana.* As of 1980, an average of 23% of the ECOWAS population lived in urban areas, approximately a twofold increase over 1960 levels. Over the latter half of the same period (1970 - 1980), average annual food production per capita fell in fourteen of sixteen member states. Finally, at least twelve of the sixteen member states of ECOWAS face chronic current accounts deficits in their balance of payments. These and other statistics are presented in Table 1.

These and other characteristics of the economic situation of ECOWAS states are reflected in their current energy systems. In the remainder of this presentation, I will:

- touch briefly upon energy resources in the region
- discuss the highlights of energy consumption patterns
- conclude by attempting to draw out some of the priority issues which emerge from this brief perspective across sixteen economically, graphically, and culturally diverse countries.

*Based on 1979 national income account statistics.

Table 1
Economic Overview

Country	GDP Millions of Dollars	Average Annual Growth Rate (percent) GDP (1970 - 1979)	GDP Per Capita in $	Current Account Balance Before Interest Payments on External Public Debt (millions of dollars)	Gross International Reserves (millions of dollars)	Average Annual Rate of Inflation (percent) (1970 - 1979)
Benin	850	3.3	250	-87	20	9.2
Cape Verde	60		200			
Gambia	132	2.8	220			
Ghana	10,160	-0.1	899	282	404	32.4
Guinea	1,540	3.6	290	-54	35	4.4
Guinea Bissau	137		171	-68	22	
Ivory Coast	9,130	6.7	1,113	-560	168	13.5
Liberia	940	1.8	522	-91	55	9.4
Mali	1,220	5.0	179	-64	17	9.7
Mauritania	470	1.8	293	-70	118	10.1
Niger	1,710	3.7	329	-96	5,870	10.8
Nigeria	75,170	7.5	910	1,429	137	19.0
Senegal	2,480	2.5	450	-394	35	7.6
Sierra Leone	790	1.6	263	-109	47	11.3
Togo	1,000	3.6	417	-219	71	10.3
Upper Volta	860	-0.1	154	-68	67	9.8

Source: Accelerated Development in Sub-Saharan Africa - An Agenda for Action, The World Bank, Washington, D.C., 1981.

2 RESOURCES

The principal indigenous energy resources now being exploited in the ECOWAS countries are biomass, hydroelectric capacity, and hydrocarbons. There is limited use of coal and lignite, mostly in Nigeria and Niger.

While all countries are now experimenting with new and renewable sources of energy -- primarily solar and wind energy -- the actual impact on energy consumed is negligible in most countries, and is likely to remain so for a number of years. The lead times before dispersed rural technologies can achieve sizable market penetration are estimated at between ten and twenty years.

The most widely available and used energy resource, by far, is wood. Every country is endowed with considerable wood resources, although the sustainability of wood supplies relative to recurrent demand varies sharply between countries in the tropical and the arid zones. Wood resources are the subject of more detailed presentations at this workshop. Therefore, this paper will not explore the pressing issues of sustainable wood supply, wood energy consumption, and conversion efficiency of woodfuels.

While virtually all countries in the region have some hydropower potential, only a small fraction of that potential is being used at this time. Nevertheless, seven countries already derive a majority of their electric power from hydro facilities. There remains major untapped potential for small scale, decentralized hydroelectric power generation.

Finally, although petroleum resources are sufficient to cover twelve times the region's consumption of petroleum fuels, petroleum production is concentrated in a small number of countries. In 1983, fifteen of the sixteen ECOWAS countries (all except Nigeria) are net oil importers. Of these, only the Ivory Coast has a clear prospect of approaching petroleum self-sufficiency within the next five years.

3 PATTERNS OF ENERGY CONSUMPTION

It is impossible to present the patterns of energy consumption across sixteen countries without falling prey to generalizations which may sometimes appear cliched.

The data on which this section is based in drawn largely from Energy Sector Profiles for thirty-seven sub-Saharan African Countries prepared by Energy/Development Interational under the US AID Energy Initiatives for Africa Project. Those profiles, in turn, draw from a number of published and unpublished documents for each country. Particularly in West Africa, there are few published and reliable energy sector reports. Therefore, the data may be viewed as providing the correct orders of magnitude to permit a better understanding of the situation. They do not, however, constitute a sufficient basis for detailed energy analysis or planning.

3.1 ENERGY CONSUMPTION BY FUEL TYPE

Fuelwood and charcoal account for an average of over two-thirds of the total energy consumed in the ECOWAS countries, when measured as a percentage of total energy resources consumed. When we measure final energy consumption -- that is, after taking account of losses in conversion and of differences in end-use efficiency, this percentage becomes much lower, perhaps by a factor of two (i.e., approximately 35% of final energy consumption).

Returning to our original measurement basis, in only one of the sixteen ECOWAS countries (Ivory Coast) is woodfuels consumption (charcoal and fuelwood) less than about 60% of total energy consumption. It is greater than three fourths of the total in six countries.

While no reliable information is available -- except in a few urban areas where detailed surveys have been performed -- on the relative shares of charcoal and firewood, there is clear evidence that the share of charcoal in total woodfuels consumption is rising steadily. A principal cause of this shift is the rapid rate of urbanization (averaging 6% per annum), because a much higher percentage of urban families use charcoal than do rural households. The trend of urbanization in the region is shown in Table 2.

The economics of transportation are such that it is financially cheaper for producers to ship charcoal over relatively long distances to urban demand centers because it is much lower in bulk and weight per Btu of energy than is firewood. However, under traditionally used methods of charcoal production and end use, this implies a much faster rate of forest depletion. A very high percentage of the useful energy in firewood is lost in converting it to charcoal (often up to 85%). This substantial discrepancy between the financial incentive to producers and consumers (lower transport costs) vs the economic costs to society (faster deforestation) arises because the forests being depleted are generally exploited as a free good. The cost of using up more wood does not enter into individual financial calculations. Improving the efficiency of charcoal production and end use, and rationalizing the transport and production options for woodfuels supply to urban centers are

Table 2
Urbanization
Urban Population as Percentage of Total Population

	1960	1980
Benin	10	14
Cape Verde	--	--
Gambia	12	--
Ghana	23	36
Guinea	10	18
Guinea Bissau	14	--
Ivory Coast	19	38
Liberia	21	33
Mali	11	20
Mauritania	3	23
Niger	6	13
Nigeria	13	20
Senegal	23	25
Sierra Leone	13	25
Togo	10	20
Upper Volta	5	9

Source: Accelerated Development in Sub-Saharan Africa -- An Agenda for Action, The World Bank, Washington, D.C., 1981.

major opportunities for public policy intervention. Moreover, such policies may be especially suitable for interstate cooperation, as can be provided through the ECOWAS framework.

Petroleum consumption, other than for electricity generation, accounts for roughly one quarter of total energy consumption in member states. The percentage share of petroleum products varies considerably between countries, ranging from a low of about six percent in upper Volta to a high of forty percent in Senegal and the Ivory Coast.

As regards electricity consumption, six countries (Benin, Togo, Ghana, Guinea, Ivory Coast, and Nigeria) rely on hydroelectric capacity for over three quarters of their electricity needs. Five countries rely on diesel or fuel oil to meet virtually 100% of their power generation needs. Detailed energy consumption patterns are displayed in Tables 3, 4, and 5.

An interesting and unusual feature of the region is that several countries have, for a number of years, successfully cooperated to import electric power from neighboring states, the most obvious examples being Benin and Togo, which purchase electricity generated at the Akossombo Dam in Ghana.

Table 3
Total Energy Consumption by Form of Energy Consumed
(percentage of total energy consumed)

	Petroleum Products	Hydro-electricity	Electricity	Charcoal & Fuelwood
Benin	21	2		77
Cape Verde	30.6		5.7	63.7
Gambia	25			75
Ghana	20		10	70
Guinea	34	1		65
Guinea Bissau	27		4	69
Ivory Coast	39.4	10.6		50
Liberia	16		22	62
Mali	8		16	76
Mauritania	34		6	60
Niger	13		7	80
Nigeria	23		17	60
Senegal	40			60
Sierra Leone				80
Togo	25		4	71
Upper Volta	6			94

Note: Reliability of this data is questionable for several countries.
Source: EIA Energy Profiles.

Table 4
Petroleum Fuel Consumption by Sector (percentage)

	Other	Electricity	Residential/Commercial	Agriculture	Industry (including mining)	Transport
Benin	17	3	17	1	15	47
Cape Verde	--	NA	16	NA	3	81
Gambia	5	20	NA	6	1	68
Ghana	--	NA	NA	NA	20+	60+
Guinea	16	1	NA	NA	40+	31
Guinea Bissau	10	45	13		--	32
Ivory Coast	NA	NA	NA	NA	NA	NA
Liberia	1	7	1	2	5	32
Mali		20	8	20	20	52
Mauritania		19	2		31	48
Niger		37	3		10	50
Nigeria			3.2		89.3	7.5
Senegal	--	26	4	24	24	46
Sierra Leone	NA	NA	NA	NA	NA	NA
Togo	3		9	2	42	47
Upper Volta	NA	NA	NA	NA	NA	NA

Note: This data is thought to be extremely unreliable for most countries. It is presented here only to show what information is currently available.
Source: EIA Energy Profile.

Table 5
Sources of Electric Energy

	Fuel Oil	Diesel	Hydroelectric Plants
Benin		7.8	92.2
Cape Verde			
Gambia	100		
Ghana			main source is hydroelectric
Guinea		12	88
Guinea Bissau		100	
Ivory Coast	26		74
Liberia	57	16	27
Mali		80	
Mauritania		100	
Niger			50
Nigeria	19		81
Senegal		mostly diesel	
Sierra Leone		97.5	2.5
Togo	5		95
Upper Volta			

Note: This data is thought to be reasonably accurate for most countries.
Source: EIA Energy Profiles.

3.2 ENERGY CONSUMPTION BY SECTOR

The largest simple energy consuming sector in ECOWAS countries is the household sector -- urban and rural. Statistics on this sector are extremely spotty, but it is well understood that the vast majority of households consume firewood and charcoal. Much of the firewood consumed by households is in rural areas and is self-collected. The principal end uses are cooking and lighting.

Upper income households in urban areas also account for a sizable portion of electricity consumption. This percentage is known to vary widely between countries, but no reliable statistical information is available for the region as a whole.

Many of the statistics available on energy consumption in ECOWAS countries merely tend to confirm our preexisting understanding or expectations. However, little things run counter to every generalization: just as it is somewhat surprising that agriculture no longer makes the largest sectoral contribution to GDP, and that woodfuels do not contribute the majority of delivered energy, so we must be at least mildly surprised at the almost complete dominance of the transport sector as a percentage of petroleum fuels consumption, in view of the relative lack of attention this sector has received.

For the thirteen ECOWAS countries for which we have data, the transportation sector's share of petroleum fuels ranges from a low of about 30% in Guinea to a high of about 80% in Cape Verde. The average share of the transport sector is about 50% of petroleum consumption. No other sector even approaches this percentage. In the ten countries for which more detailed data are available, the share of industry averages less than 7%, while power generation uses, on average, 14% of petroleum fuels.

It is often asserted, and rightly so, that transport poses the most intractable energy efficiency improvement problem, for a number of reasons which are well known. However, it should be recognized that in the ECOWAS region taken as a whole, a 10% overall efficiency improvement in transport would yield the same savings as a 33% efficiency improvement in oil-fired electricity generation or a 67% efficiency improvement in average industrial energy efficiency.

4 ENERGY PRICING AND INSTITUTIONS

4.1 PRICING

Energy pricing is a highly sensitive political and economic issue. Yet appropriate energy price structures are fundamental to any long term energy conservation strategy. Prices provide signals to energy producers and consumers, which in turn, influence the financial viability of their decisions. For example, subsidies to charcoal prices will inhibit the development and spread of improved charcoal-burning coalstoves. Similarly, in a number of countries, natural gas development will be impeded unless the price of fuel oil (usually the next cheapest alternative) is kept high enough to allow gas to gain a foothold in the market.

The situation on energy pricing in the ECOWAS states remains a complex mix of sound economic policy and sound political policy.

- In a number of countries, electricity prices do not cover the operating costs, much less the marginal costs, of electricity generation.
- Subsidies to major users of electricity and petroleum fuels are frequent. This is especially true in countries which have major mining operations.
- Nevertheless, a majority of member states, have recently brought about substantial increases in energy prices, bringing them more closely in alignment with international prices. The responses to the most recent declines in world oil prices have yet to be seen, but they will be of considerable import to future energy policy formulation.

4.2 INSTITUTIONS

In a number of member states, responsibility for energy policy formulation remains dispersed amongst a number of agencies in the areas of forestry and rural energy, petroleum refining and distribution, electricity generation, research and development, and so on, with no coordinating mechanisms effectively in place.

Recently, some ECOWAS countries have either created or have under serious examination, a centralized energy planning and policy formulation agency. The most commonly adopted formula is one of an energy planning unit housed within a coordinating ministry -- such as the Ministry of Planning -- with direct links to an interministerial advisory panel.

5 PRIORITIES

The facts, numbers, and averages put forth in this brief presentation can only tell a limited story based on a static overview of the current energy situation. In order to address the priorities in energy policy, we need to return to the underlying premise of energy analysis: the linkage between energy and economic development, with specific reference to the standards of living of average citizens in the region. There are two distinct perspectives which are generally adopted in this regard:

- First, to stem the depletion of natural or financial resources which could otherwise serve developmental purposes. From this perspective, it is of the highest priority to stem the alarming rate of deforestation which threatens all semi-arid member states, as well as the drier and/or more heavily populated areas of the coastal countries. Deforestation depletes not just forest wood resurces per se, but also robs the soil of its nitrogen fixation, nutrient cycling and soil stabilization services. In addition, it eliminates a source of animal fodder, commercial lumber, fruit, medicines, and a multitude of other economically valuable forest products.

  Also from this perspective, logical reasoning impels us to look first at the transport sector as the largest energy contributor to the depletion of foreign exchange resources. The capital shortage created by this outflow constrains development efforts across all sectors.

- Second, to assure adequate energy inputs to high priority economic activities. This perspective tends to view energy policy as a means to achieve economic ends, rather than as a way of solving energy problems for their own sake. From this perspective, the highest priority in member states is likely to go to assuring energy supplies to agriculture, to export industries, to the transport of critical supplies (food, fertilizer, spare parts, etc.), and for the satisfaction of basic human needs -- especially health and nutrition.

Taken in isolation, these two perspectives can lead to very different energy policy strategies. They need not, of course, be mutually exclusive. In many ways, they are closely related to each other, perhaps the most fitting example being integrated land use management encompassing agriculture, herding, and reforestation.

6 CONCLUSIONS

A few concluding observations are offered to provide some insights which may be of value in formulating energy strategies in the region.

However, all such conclusions should be prefaced by the observation that this presentation leaves out much more then it presents. It has consciously not discussed in any detail such fundamental issues as energy pricing and energy planning and coordinating institutions, simply in order to preserve the clarity of the few thoughts which have been offered. Appropriate energy pricing, in particular, is essential to the success of energy conservation investments. It is therefore the precondition for policy measures which may be the subject of this ECOWAS Energy Conservation Workshop.

1. It is common practice to distinguish between long term and short term energy solutions. While such a distinction may be appropriate, it can often be misleading. One notices, for example, in projects identified in earlier ECOWAS conferences and workshops, that all "long term" solutions offered are in fact energy resource development options. but it must also be remembered that there are, and there must be long term policy, technology and conservation options as well. Technology, for example, may be tested and developed in the short to medium run, but widespread implementation of truly viable improved or alternative technologies is manifestly a long term process. In the same vein, energy conservation cannot be simply viewed as a short term or interim solution. A successful energy conservation program can result in a permanent (long term) downward shift in energy intensity, thereby releasing long term economic resources for further development efforts.

2. It is easier and far more cost-effective to influence the course of future energy consumption than it is to alter the existing pattern of energy use (although both activities are of extremely high value). Yet far less attention has been paid to a close examination of the energy implications of major new investments in agriculture, industry, and transport -- the mainstream economic activities -- than the potential energy/economic benefits would justify. It is virtually costless to introduce sound energy planning at the stage of project development.

In Senegal, Mali, Mauritania, Gambia, and Guinea, for example, the OMVS[1] and the OMVG[2] projects -- large, multilateral integrated schemes to develop the areas around the Senegal and Gambia Rivers, respectively -- will both be amongst the largest individual energy consumers in participating countries. Yet only limited effort has gone into assuring that they will be efficient from an energy perspective.

In Benin, a decision to construct a new cement plant at Onibbolo will add 10 MW of peak load to an electric system with a present capacity of 25 MW. Once the plant is complete, energy conservation measures will be trivial

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[1]Organisation pour la Mise en Valau du Fleuve Senegal.
[2]Organisation pour la Mise en Valau du Fleuve Gambie.

in comparison with the initial decision to proceed with it in the first place.

Similar examples exist throughout the region vis-a-vis building design, vehicle, and appliance imports and so on.

3. There is a sharp distinction to be drawn between countries (or areas within countries) which face serious deforestation problems and those which do not. In virtually all of the former set, forest resources are being depleted at a geometric rate as excess demand for forest products and land is met by cutting live trees, resulting in further imbalances between supply and demand and dwindling levels of sustainable forest yield.

In such countries (or areas) it is recognized that it simply takes more resources and more time to influence the production and consumption patterns of millions of dispersed users of forest resources -- who are often not even part of a monetized economy -- than it does to affect modern sector energy decisions.

Throughout the region -- as elsewhere in Africa as well -- attempts to disseminate technologies for isolated rural applications have achieved very mixed results. Even the relatively successful programs -- such as the Ban Auk Souf cookstove program in Senegal -- have yet to prove their ability to reach a majority of the target population in the next decade.

4. Finally, the human and financial capacity for governments in the region to directly implement and spread energy systems solutions is extremely limited -- more so than almost anywhere else in the world. This impies that increasing emphasis will have to be placed on energy options which are cost effective to users and, where possible, will allow them to increase their disposable incomes without undue risk. That is, the energy solutions we propose should be attractive enough, from a private standpoint, that it will be in somebody's interest -- other than just in the government's -- to adopt them and to use, maintain, and spread them.

2.2 THE IMPORTANCE OF ENERGY EFFICIENCY IN THE DEVELOPING COUNTRIES

David J. Jhirad

1 INTRODUCTION

Many developing nations have been seriously affected by the rise in energy prices of the 1970s, and planners from these nations are seeking methods and technologies to reduce energy costs associated with economic output, while simultaneously maintaining economic growth and improving their balance of payments.

Several developing nations have therefore embarked on energy strategies that involve increasing their indigenous supply of conventional fuels, expanding the use of large-scale hydroelectric and nuclear systems, improving the efficiency of oil utilization in industry and transportation, and developing renewable energy technologies. More attention is now being paid to a balanced approach that combines investments in energy supply with investments in energy saving.

However, experience gained by the World Bank over the last few years has shown that few developing countries have given a high enough priority to energy-efficiency and demand management strategies, in spite of the fact that investments in energy-efficiency are very attractive compared with investments in new supply, often yielding significant energy savings in a relatively short time.[1]

The unpopularity of the phrase "energy conservation" is probably due to the fact that energy conservation has traditionally been equated with austerity or curtailment, rather than with a modern economic and engineering concept which stresses improved efficiency of energy conversion devices and processes. In this paper, the terms "energy-efficiency" and "energy conservation" are used interchangeably in order to emphasize the view that improved energy utilization can be desirable from an economic as well as an engineering perspective.

The paper presents some results from ongoing work at the Brookhaven National Laboratory on the economics and potential for energy-efficiency and substitution in the developing countries.[2,3] By and large, the emphasis in this paper is on energy conservation in the industrial sector. A detailed financial analysis of one particular technology, industrial heat pumps, is presented for one developing country, Brazil, to illustrate the effect of government financial incentives on the attractiveness of investments in energy efficiency.

Studies in the industrialized countries have revealed conclusively that, from an economic and technological viewpoint, there are substantial opportunities for using energy more efficiently in all sectors of the national economy. One representative study has indicated that an average of 25% of energy use in the U.S. manufacturing sector could be saved through measures whose

capital and life-style costs are les than those needed to generate equivalent amounts of new energy supply.[4] Particular industries will differ considerably in their potential for energy-efficiency measures, and also in the mix of energy savings that can be achieved in coal, gas, and electricity.

A straightforward yet powerful technological idea appears therefore to be an essential ingredient in all short- and long-term energy options: that the aggressive development and implementation of energy efficiency technologies is an essential element of any financially and economically responsible energy plan. Research and experience in industrialized countries has suggested that energy efficiency technologies could play a vital role in improving industrial productivity and sustaining economic growth in the 1980s and 1990s, and would be less costly and more environmentally benign than a national energy strategy oriented exclusively to supply. In addition, the relatively short installation times of energy efficiency measures allow rapid and cost-effective responses to unanticipated changes in energy needs.

Many important lessons have been learned, both in the developed and in the developing countries, about the effect of pricing and non-pricing policy tools on energy demand, and there appears to be a significant potential for the transfer of these learning experiences to countries in the early phases of their energy-efficiency strategies.

Even though many energy-efficient technologies are cost competitive with new sources of energy supply, there are still significant barriers that impede the flow of capital in developing countries into these technologies. These barriers include:

- The limited availability of capital for investment in energy-efficient technologies and systems.
- A government pricing policy where the average price of energy charged to private manufacturers is considerably below the escalating replacement cost of new supply.
- The fact that many manufacturers require a higher rate of return on energy-efficiency investments relative to competing investments which are critical to maintaining or expanding their market share of particular products.
- The existence of laws and regulations restricting or preventing the generation of by product electricity by manufacturers.

Government policy incentives to remove barriers and to encourage energy conservation investments should be based on appropriate criteria for public and private decision making, as well on careful micro and macro cost-benefit calculations.

Examples of such incentives could include:

- Low-interest loans for purchase of energy-efficient equipment, and reduced import duties on such equipment.

- Changes in pricing policy, such as decreasing or removing fuel subsidies for industrial users.

- Changes in tax policy, such as added taxes on fuels for low-efficiency users or tax credits for installing more efficient equipment.

- Mandatory energy productivity targets and performance standards for boilers and other equipment.

- Permission to generate on-site electricity, receive standby power, and sell excess power to the grid at reasonable prices.

Government policies should be designed to improve industrial energy efficiency and to encourage private decision makers to invest in nationally beneficial energy conservation projects. These policies must be carefully integrated with a comprehensive national program to increase industrial productivity and to meet important national objectives such as equity, improved balance of payments, increased employment and economic growth.

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2 ENERGY EFFICIENCY IN DEVELOPING COUNTRIES: TECHNICAL AND ECONOMIC POTENTIAL

2.1 ENERGY CONSUMPTION PATTERNS

The use of commercial energy in the most energy-intensive industries in developing countries has been extensively reviewed elsewhere,[1,2] so that what follows is only a brief summary of commercial energy consumption patterns in developing countries.

The relative magnitude of energy consumption in the different sectors of the economy depends greatly on economic structures, technological development, and various fuel mixes. In addition, the relative amount of energy consumption in each end-use sector is strongly dependent on whether one is considering only commercial energy or all forms of energy, including "traditional" fuels such as firewood and cattle dung. If traditional fuels are excluded, the industrial, power, and transport sectors account for the largest segment of energy consumption. The industrial sector may consume from 25% to over 70% of the commercial energy in developing countries. In India, for example, industry accounts for over 75% of commercial fuel consumption.

Typically, the largest 5 or 6 industries in developing countries represent over 70% of total industrial energy use. The major energy consumers are cement, iron and steel, aluminum, chemicals including fertilizers, pulp and paper, and mining.

There are different ways of measuring the energy intensity of a national economy, or of buildings, industries, transportation, and power systems. A widely used but crude yardstick is the amount of energy consumed (in tons of oil equivalent) per unit of gross domestic product (GDP).

A better indicator of the way in which energy is used is the ratio of energy use (measured in megajoules or kilocalories) to activity level in a particular sector (tons of output in industry or agriculture, passenger-mile or ton, kilometer in transport, square feet or square meter in residential and commercial buildings). Table 2.1 displays the specific energy consumption per metric ton of product for a number of developed and developing countries, and Table 2.2 focuses specifically on the energy intensity of steel and cement production in various countries.

According to this measure of energy intensity, there is great scope for improved energy-efficiency in the energy-intensive industries of the developing countries, brought about through low-cost, good housekeeping measures, and by means of capital-intensive investments in new and existing plants, such as the introduction of continuous casting in the steel industry and the dry process of cement manufacture. Conservative estimates of the savings that could be achieved by modifying existing plants are presented in Table 2.3.

Table 2.1
Specific Energy Consumption Per Metric Ton of Product
(10^4 kcal)

	Pulp & Paper	Cement		Aluminum	Fertilizer
		Dry	Wet		
United States	970	136	170	947	1132
Sweden	756	140		1648	--
United Kingdom	--	89	160	2107	1223
Germany	--	74-90	120-140	1492	--
Egypt	--	162		2120	1625
India	--	170		--	1700
Bangladesh	1566	170		--	--
Kenya	1285	134		--	--

Source: J. Jankowski, Jr. Resources for the Future, Discussion Paper D-73A.

Table 2.2
Energy Intensity Comparisons in Selected Countries -- 1979-81
(kilograms of coal equivalent per ton of output)

	Crude Steel	Cement Clinker
Japan	650	125
U.S.	890	215
Brazil	920	150
India	1400	215
China	1260	206

Table 2.3
Developing Countries: Possible Savings in the Major Energy-Intensive Industries, 1980s

	LDC Percentage of World Production, 1978	Energy Consumption per Metric Ton of Output[a]	Potential Savings With Existing Plant (1978) Production Levels)	
			Percent	000 bdoe[b]
Aluminum (from Alumina)	8.2	28-36	5-10	5-12
Copper (Smelted & & Refined)	22.3	3-8	5-10	1-4
Steel (Crude	8.1	4-6	5-10	35-90
Cement (Clinker)	27.4	0.5-1.0 (fuel)	15-25	60-170
		0.2-0.3 (electricity)	5-10	7-15
Ammonia	15.1	6-8	5-15	10-40
Petroleum Refining				
Distillation	11.6	0.4	10-20	35-70
Cracking	6.9	0.7	10-20	7-15
Pulp and Paper	11.8	4-8	20-25	35-95

[a]Expressed in barrels of oil equivalent, assuming that 1 kWh of electricity input requires 2,670 kcal (10,600 Btu) of heat. This conversion factor varies widely depending on the type of primary energy, transmission losses, etc.
[b]Thousand barrels a day of oil equivalent.
Source: "Energy in the Developing Countries," World Bank, 1980.

2.2 RELEVANCE OF EXPERIENCE IN INDUSTRIALIZED COUNTRIES

The US Industrial Energy Efficiency Program found that during 1976, 1977, and 1978, the ten most energy-intensive industries improved their energy efficiency by 8 percent, 11 percent, and 14 percent respectively in comparison with 1972 levels (measured as energy consumption per unit of output). These energy efficiency savings were achieved largely through short-term measures whose capital investment requirement was modest, with pay-back periods of few weeks of months. Those improvements have also been made in other industrialized countries. For example, energy consumption per ton of steel produced in Germany and Japan has declined by about 7% and 14% respectively between 1945 and 1979, and energy consumption per ton of cement has declined by about 5% and 10% in Germany and Japan over the same period.

Actions that have proved successful in promoting energy-efficiency in the industrialized countries include:

- Providing financial assistance for investments in energy-efficient technology in small-, medium-, and large-scale industry possibly in the form of loans from development banks at concessional interest rates. Government incentives to manufac-

ture or import energy conservation equipment should also be adopted. These could include tax credits, import policies, and licensing arrangements.

- Promoting changes in regulatory policy to induce the manufacture and installation of energy-efficient equipment, such as household applieances, automobiles, and cogeneration systems.

- Establishing a legislative framework to encourage energy-efficient activities by industrial and commercial enterprises.

- Introducing technical assistance and training programs in energy audits for industry, buildings, the electric power sector, and transportation. Detailed energy audits should be performed in all key energy-intensive industries, where energy costs range between 20 and 50 percent of total production costs.

- Promoting rational pricing policies for industrial users.

2.3 FINANCIAL AND ECONOMIC ANALYSIS OF ENERGY-EFFICIENCY INVESTMENTS

This section reviews briefly the analysis and planning tools used in the financial and economic analysis of energy conservation investments in developing countries. (See reference 1.3 for a detailed discussion.)*

Governments in developing countries have to take into account the impact of policy incentives on investment by specific firms, the effect of investment on industrial energy use, and the impact of changed industrial energy use on economic growth, balance of payments, employment and inflation.

One method of analyzing the economics of energy conservation investment from a national perspective is to use "shadow prices."** Shadow prices try to capture the marginal opportunity costs of factors of production in the context of national objectives. For instance, in most developing countries, the availability of foreign capital goods is a constraint on economic growth and anything that reduces the availability of foreign exchange would therefore reduce economic growth. Since growth is an important objective, the shadow price of oil should be greater than the world market price of oil, and economic analyses conducted by the government would have to use shadow prices to compare alternative investment options. In contrast, industrial decision makers use financial - internal rate of return - criteria to estimate the attractiveness of an investment.

A number of technical, economic and financial factors combine to determine the financial feasibility and economic attractiveness of investment in energy efficient technologies. As one may expect, there is often a substantial difference between what is attractive to private businesses and what is good from the nations perspective.

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*Available as a supplementary paper at the West African Seminar.
**UNIDO, Guide to Practical Project Appraisal, U.S., New York, 1978.

Businesses make investment decisions by comparing the cost of an investment project, the expected returns (yearly cash flow), and the price of capital. The price of capital can be taken as either the rate of interest at which the firm obtains loans or the rate of return that investors expect on the equity for the project. The degree of risk associated with the project would affect the price of capital; high risk ventures have a high price of capital.

Widely used methods in the engineering literature for evaluating the engineering-economics of energy conservation investments (e.g., Gyftopolous, Widmer,[2.1]) are the internal rate of return (IRR) and the gross payback period (GPB). Another widely used method in the economics literature is the net present value (NPV) of a stream of costs and benefits of an investment project. In fact IRR, GPB and NPV are all related to each other. Most private sector investors use Gross Payback period and the Internal Rate of Return as the criteria while national economic planners, who have a longer term perspective, tend to use the net present value approach.

When the investment is analyzed from the point-of-view of the government, social benefits and costs should be taken into account. In this case the benefits are measured in terms of fuel saved at shadow prices, where a premium is added to the price of the fuel. The costs to the government from instituting policy incentives are estimated by computing the difference in cost of the energy conservation investment with and without the appropriate incentives.

Other factors that a government planner would take into account would be indirect benefits and costs. These would include the impact of energy conservation investments on aggregate consumption, employment, balance of payments, economic growth and the impact on the poorest section of the population. Methods for doing this are discussed in detail elsewhere.[2-4]

The priority attached by the government to any incentive scheme should depend on the results of a social cost-benefit analysis. The government should take into account the criteria used by private firms for specific investment decisions and design incentive schemes that would lead to private sector investment in industrial energy conservation while providing net positive social benefit.

When assessing the costs and benefits of energy conservation from a national perspective, it is essential to have some data on the costs of saving and supplying equivalent amounts and forms of energy. The data presented here are for the industrial sector only, and are derived from studies carried out in the U.S. and Canada. Similar data should be obtained for the developing countries, and should be assembled for the other energy-consuming sectors of the economy -- transportation, electric utilities, and residential and commercial buildings.

In general, capital costs for energy savings (up to a certain point) are substantially lower than those for equivalent new energy supplies. Several studies have shown[1,5,6] that cost effective efficiency improvements represent an energy saving of about 25 percent for all manufacturing in the U.S.

and Canada. In one study, a total of 39 energy-saving conservation projects in five industries were selected and evaluated as the basis for determining the economics of industrial energy conservation. The projects were classified according to four categories of conservation measures. The categories and industries are as follows:

Categories

A Insulation and general housekeeping
B Waste heat recovery
C Instrumentation and controls
D Process change

Industries

1. Food and Beverage, predominantly Meat and Poultry Products
2. Pulp and Paper Mills
3. Iron and Steel Mills
4. Industrial Minerals, predominantly Cement Manufacturers
5. Chemicals, predominantly Industrial Chemicals

Full implementation of these projects was found to yield a saving of 16 percent of the energy demand in the five industries.

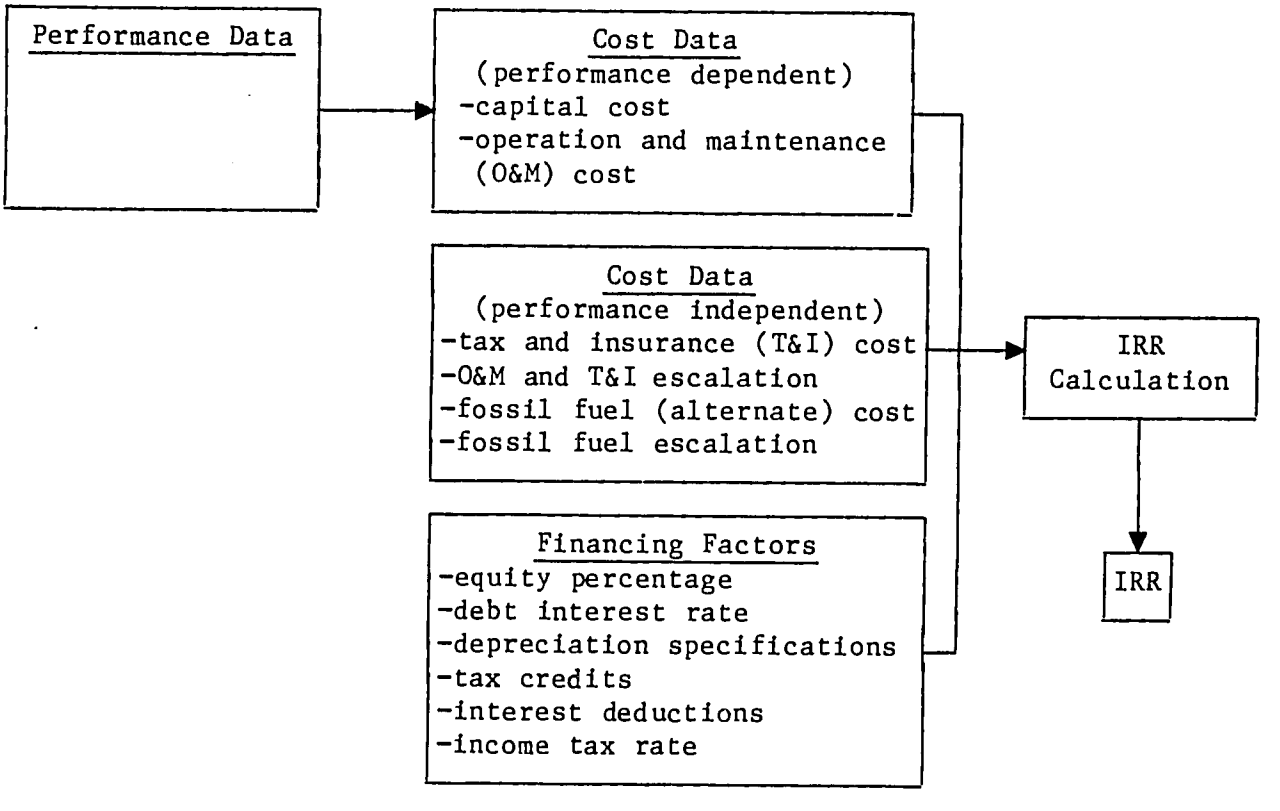

Figure 2.1. Determination of Internal Rate of Return for an Energy Efficiency investment.

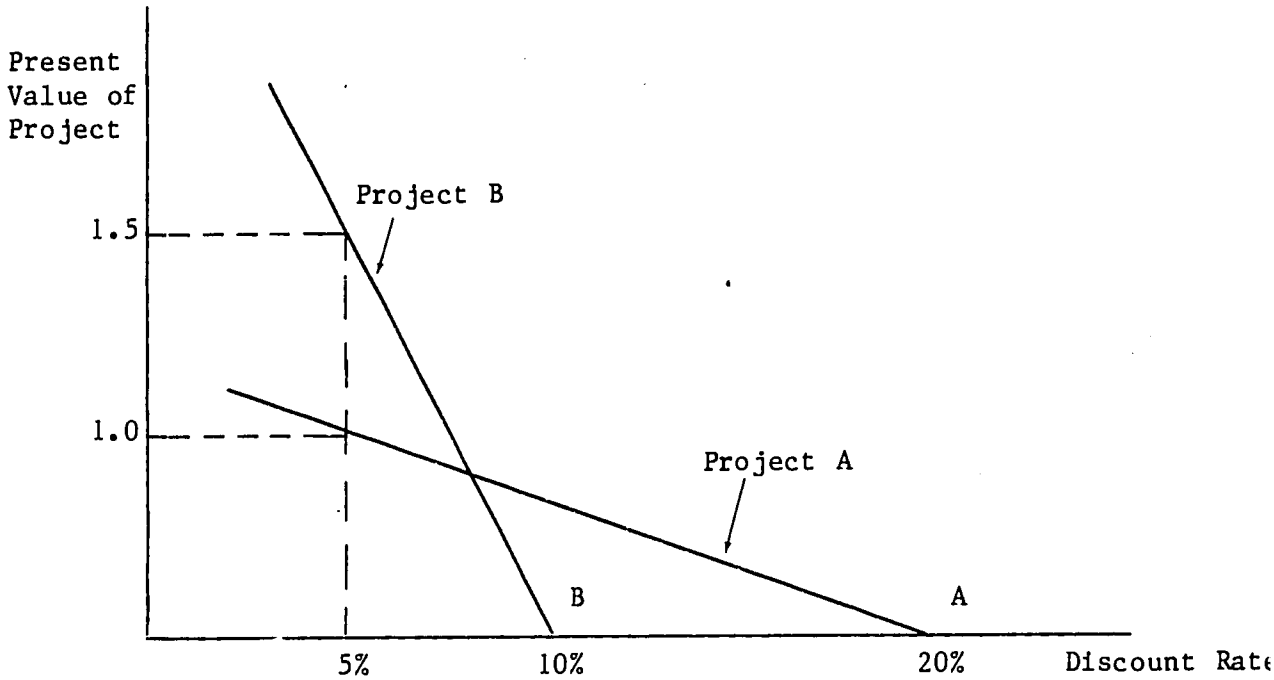

Figure 2.2. Conflict between Present Value and Internal Rate of Return in ranking projects.

Costs of individual projects ranged from two cents to $3.57 per million Btu saved. The average price of energy saved for all 39 projects, weighted by the annual energy savings for each project, was $1.58 per million Btu, equivalent to $9.16 per barrel of oil equivalent. It should also be noted that the Canadian Industry Energy Conservation Task Force considered that up to 23 percent reductions in energy intensity were possible over a 5-year time period. This is consistent with studies performed in the United States.[5]

The marginal and average cost curves for the 39 selected industrial energy conservation projects are shown in Figure 2.3.

In examining Figure 2.3, the following points should be borne in mind.

- the costs of energy supply projects are representative of the expected Canadian experience over the time frame 1980-2010. It is clear that, for many developing countries, some oil and gas fields can provide incremental energy at supply prices competitive with energy-saving measures. However, some options such as oil shale or coal liquefaction would generate energy at a higher cost than the projects described here.

- The Canadian study compared "Btu's supplied" and did not take into account the end-use efficiencies with which the different energy forms were utilized. The study also did not attempt to differentiate between the energy types -- electricity, natural gas, heavy fuel oil, etc. saved by each conservation project.

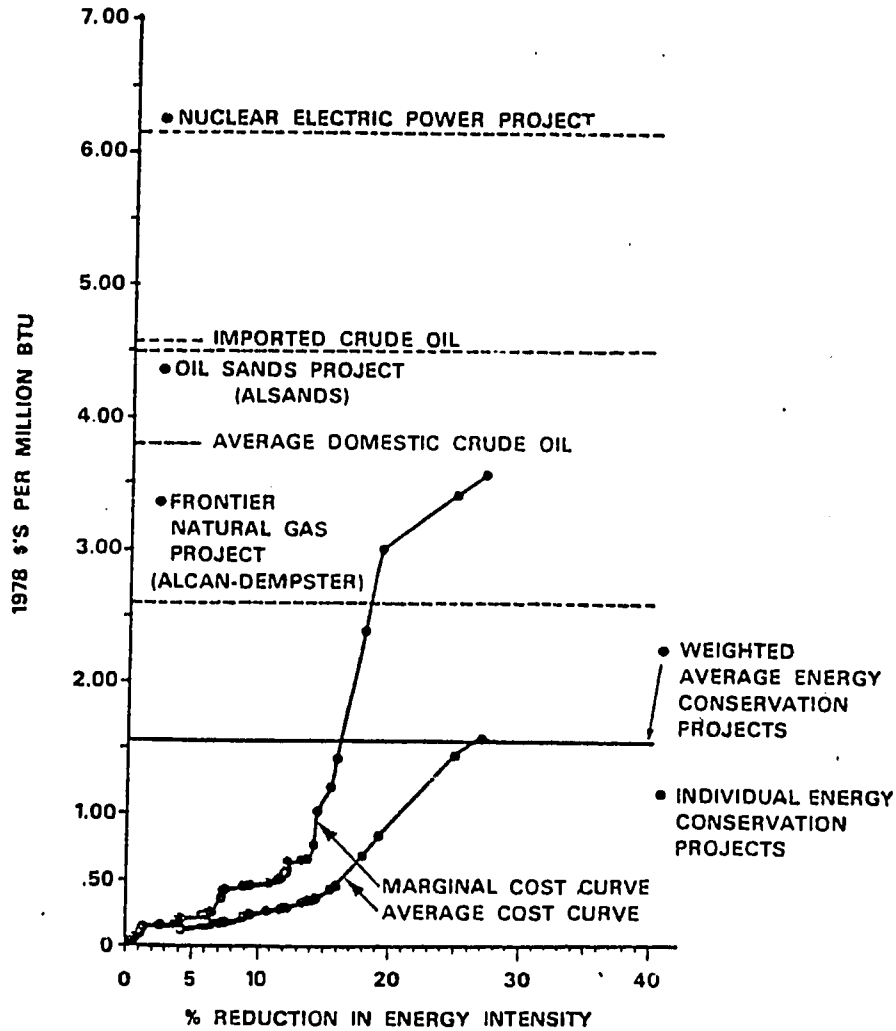

Figure 2.3

- The quantification of comparative benefits of energy conservation and energy supply projects is obviously very complex and was not attempted in the Canadian study.

Industrial energy conservation projects show a wide range of costs and energy savings, depending on the type of project, the relevant industry, and local energy prices, but one can reasonably expect an average, cost-effective energy savings potential of 25 percent or more in the industrial sector of developing countries. Detailed engineering and economic studies will, of course, be necessary to quantify the costs and benefits of industrial energy conservation projects compared with developing new sources of supply. Such comparisons will have to include questions such as the timing of new investments, relative implementation rates, employment, training, and foreign exchange aspects, and environmental and health effects.

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3 TECHNOLOGIES FOR WASTE ENERGY UTILIZATION IN THE INDUSTRIAL SECTOR

There currently exists a fairly broad spectrum of cost-effective and proven energy-saving technologies that have found application in all energy-using sectors of the economy. In this section, we list only those technologies that are relevant to the industrial sector. Excellent recent reviews of such technologies may be found in references 1 and 2.

The function of energy-saving technologies is to address the major sources of energy inefficiency in manufacturing which are

- Combustion of high-grade fuel to produce low temperature process heat.
- Loss of high-grade waste heat to the environment.
- Use of particular manufacturing processes.

The first two sources of energy inefficiency are common to many industries and processes, and can be reduced with technologies that are widely applicable. These inefficiencies are found in dryers, ovens, furnaces, and fuel-fired kilns, and can be reduced through recovery and recycling of waste heat. Good housekeeping measures such as insulation of pipes address mainly the second source of energy inefficiency.

The conventional method of raising process steam in fuel-fired boilers is very inefficient because the product is low temperature steam (300 to 350°F, 50 to 150 psi) while the combustion of the fuel generates high-temperature heat. To realize significant savings, one must make better use of the high temperature heat created by fuel combustion, and cogeneration, or the sequential generation of steam and electricity can accomplish this.

Processes for the manufacture of metals, ceramics, glass, and cement require high temperature heat, typically in excess of 2000°F. Losses are due to poor insulation, high-quality energy escaping in the form of exhaust gases, or materials leaving the furnace. Technologies to reduce these losses include better insulation, recycling of exhaust gases to reheat air, heat recovery from material leaving the furnace to preheat material entering, employing exhaust heat for steam raising or process heat or cogenerating electricity from exhaust heat.

In order of increasing capital investment, technical measures may be classified as follows.

- **Good Housekeeping Measures:** The improvement of the operating efficiency of existing processes or equipment. These measures require little or no capital investment.

- **Equipment Replacement:** Relatively simple modifications to plant or equipment requiring minor capital investment, such as improving insulation of pipes and tanks and installing additional instrumentation for better process control.

- **Major Retrofits and New Technology:** Substantial replacement or modification of plant requiring major capital investment. These measures include energy-efficient technologies and systems such as waste-heat recuperators, heat pumps, and cogeneration, as well as major process modifications.

Technologies and measures for improving industrial and commercial energy efficiency fall into the following categories:

- Waste heat recovery
- Improved thermal processing
- Cogeneration
- AC induction electric motors/controllers
- Fuel substitution
- Improved energy management in industrial and commercial buildings
- Energy saving advanced manufacturing processes and materials substitution.

Major features of systems in the first four categories are summarized in Tables 3.1, 3.2, 3.3, and 3.4.

Table 3.1
Waste Heat Recovery

Technology	Applications	Status
Advanced-design low-temp. heat exchangers	Heat recovery from previously non-exploitable sources	Commercial, payback of less than two years
Waste heat recovery heat pumps	Service hot water or hot process fluids from low temperature reject-heat sources such as refrigeration, air conditioning, equipment cooling, process liquids, treated sewage	Commercial, payback is 6 months to two years
Mid-temperature metallic heat recuperators and heat pipes	Recover boiler flue-gas energy up to 1000°F for heating boiler feed water, combustion air, or other loads	Commercial, payback is typically less than three years
Ceramic matrix or ceramic tube heat recuperators	High temperature heat recovery from melting furnaces, calciners, smelters, reduction and heat treat furnaces	Nearly commercial. Demonstration projects at variour locations in the U.S.

Table 3.2
Improved Thermal Processing

Technology	Applications	Status
Computer-based combustion control systems for boiler or furnace control & process controllers	Suitable for use with large industrial boilers, furnaces or cogenerators to maximize efficiency and minimize pollution	Commercial, economics variable with installation. Inexpensive process controllers reduce waste energy in practically every industrial process
High performance furnace/boiler insulation	Reduce heat loss, equipment downtime	Commercial. Short paybacks
Improved atmosphere generators, induction heating eqpt. burners, furnaces	Reduce energy consumption in conventional high temperature processing equipment	Commercial. Fuel savings vary with type of equipment

Table 3.3
AC Induction Electric Motors/Controllers

Technology	Applications	Status
Conventional motor design with larger cores & windings, & improved electrical insulation	Reduces internal resistance of of motor. Replacement for any heavy-duty application	Commercial, gives longer service life and lower optional costs than other conventional motors
Power factor controller, for motor load matching, speed control	Suitable for intermittent or low capacity factor electric motor applications	Commercial, savings of 25%-50% on motor energy costs
Advanced 3-phase motor coil configuration	For intermittent or low-capacity factor motor applications	Commercially available as new motor or rewind service for existing AC motor. 66%-75% savings, 4 month to 3 year payback
Solid state triac replacement of mechanical start-winding switch	For improvement of single-phase induction motors	Commercial. Enhanced reliability, reduced electrical noise

Table 3.4
Cogeneration

Technology	Applications	Status
Steam turbine, gas turbine, or diesel engine topping cycles. Waste heat recovery from electric generator prime mover.*	Suitable for industrial or large commercial applications with combined heat and electrical load. Choice of system depends on ratio of electricity to heat load	Commerically available, economics variable; depends on fuel cost, financing, grid or stand-alone. Many successful installations exist
Organic or steam Rankine bottoming turbine generators*	Waste heat streams are used to drive electric generators	Commercialization is just beginning

*Combined cycle systems, namely those which use a combination of topping and bottoming cycle strategies, have also been demonstrated commercially successful.

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4 OBSERVATIONS FROM A CASE STUDY OF BRAZIL

4.1 THE ENERGY SITUATION IN BRAZIL

Like other oil-importing developing nations, Brazil has been seriously affected by the rise in oil prices of the 1970s. It now depends on industrialized countries for capital and technology to support its program of economic development and on OPEC for petroleum to fuel its modern industrial sector.

Faced with these problems, Brazil has embarked on an ambitious plan to diversify its energy sector, reduce its dependence on imported petroleum fuels, and increase exports. Brazil's energy strategy contains the following elements:

- increased production of ethanol from biomass sources, mainly sugarcane and some cassava;
- increased domestic production of oil, gas, and coal;
- continued expansion of large-scale hydroelectric systems and nuclear systems;
- increased efficiency of energy consumption, particularly oil use in industry and transportation;
- increased use of renewable energy sources such as solar thermal and electric systems, wind power, biogas, and small-scale hydroelectric power.

These measures are being adopted by many other developing nations. The World Bank has estimated that the capital investment required for these programs in oil-importing developing countries over the next ten years, will total over 600 billion dollars. The average annual rate of $60 billion is higher by a factor of five than the corresponding rate of investment during the period 1966 to 1975.

As the largest oil importer in the developing world, and as the world's tenth nation in economic output, Brazil is likely to have unique needs for petroleum-substitution technology in its industrial and transportation sector. It is now apparent that Brazil's successful economic growth program of the postwar period contained a major flaw. The basic energy to run Brazil's vigorous and expanding industrial sector was oil, much of which was imported. Cheap imported petroleum and abundant domestic hydropower were taken for granted by Brazilian energy planners. In 1979, Brazil imported nearly 85% of its petroleum,* and these imports accounted for 42% of the total energy consumption of the country. In 1980, Brazil's bill for imported petroleum was $10 billion, about half the total value of its imports or exports. Figure 4.1 shows the evolution of Brazil's oil import bill.

Brazilian energy planners are currently seeking ways to use energy more efficiently, particularly in the industrial sector, while maintaining economic growth rates that have traditionally been much higher then those of the advanced industrialized nations. An important way out of this dilemma is offered by the potential use of methods and technologies that improve energy

Table 4.1
Petroleum Consumption in Brazil, 1979

Petroleum consumption	=	41% of total energy
Total petroleum consumption	=	1,079,000 barrels/day
Imported petroleum	=	914,000 barrels/day
Fuel oil	=	33% of total petroleum
Diesel oil	=	28% of total petroleum
Gasoline	=	20% of total petroleum
Other	=	19% of total petroleum

efficiency and utilize indigenous renewable resources. The federal government in Brazil has strongly encouraged such measures. For example, the Brazilian Energy Model, which is the central planning document issued by the Ministry of Mines and Energy in Brasilia, calls for a saving of 85,000 bbl/day of fuel oil in the industrial sector by 1985.

Brazil's industrial expansion has occurred mainly in the most energy-intensive sectors. In 1979, the cement and steel industries consumed 15 and 17% respectively of the total fuel oil used in Brazil, far surpassing their nearest competitors: petroleum refining (11%), petrochemicals (9%), and ceramics (9%). Tables 4.1 and 4.2 show the consumption of petroleum products in 1979 and the percentage of fuel oil used by different sectors of Brazilian industry.

Brazil is expected to rank among the top ten steel producers in the world in the 1980s. By the end of the 1970s it has already become the

Table 4.2
Fuel Oil Utilized by Brazilian Industry

Sector	Percentage of total fuel oil used
Steel	17
Cement	15
Petroleum refining	11
Ceramics	9
Petrochemicals	9
Food and beverages	8
Pulp and paper	6
Electric power	6
Textiles	4

*The latest (1981) figures show that the share of domestic oil production in Brazil's total oil consumption has risen to 23%, from 14% two years ago. The total amount of oil produced is now 230,110 bbl/day, compared with 203,100 in 1980 and 168,692 in 1979.

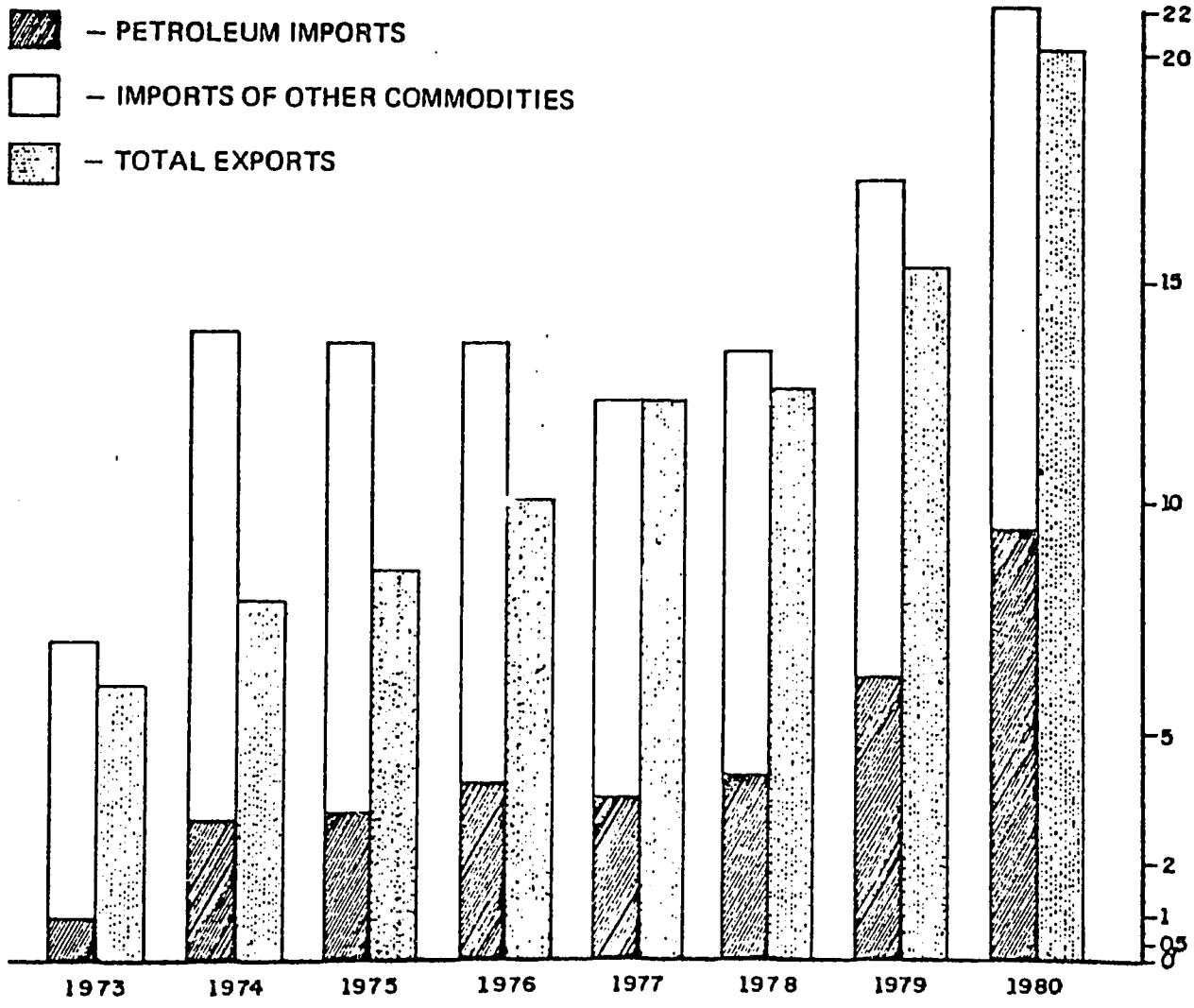

Figure 4.1 Brazil imports and exports, current prices (10^6 U.S. $).

world's tenth largest producer of petrochemicals, with major expansion plans on the drawing boards. By 1980, Brazil's oil-refining capacity was sufficient to produce its total domestic requirements for petroleum derivatives. Brazil is also rapidly expanding its production of nonferrous metals, including the smelting and refining of aluminum.

Table 4.3 provides forecasts of primary energy consumption by type in Brazil. An important feature of these data is that, while total primary consumption is projected to increase by 42% over the period 1980 to 1985, petroleum consumption is expected to drop by 15% in absolute terms. This is a substantial reversal of the trend during the 1970s, when petroleum consumption more than doubled to maintain a fairly constant 40% of the primary energy market. Energy sources expected to displace petroleum include

Table 4.3
Primary Energy Consumption and Goals, Brazil (From [1,2])

Primary energy source	1979 boe/d*	1979 Percent	1985 boe/d*	1985 Percent
1. Non renewable	1,100,000	45.4	1,217,000	34.7
Fossil				
Imported petroleum	836,000	34.5	420,000	12.0
Domestic petroleum**	149,000	6.2	420,000	12.0
Natural gas	10,000	0.4	25,000	0.7
Coal	105,000	4.3	304,000	8.7
Oil shale	--	--	25,000	0.7
Nuclear	--	--	23,000	0.6
2. Renewable	1,320,000	54.6	2,293,000	65.3
Biomass				
Alcohol	39,000	1.6	145,000	4.1
Bagasse	113,000	4.7	198,000	5.7
Firewood	421,000	17.4	394,000	11.2
Charcoal	61,000	2.6	187,000	5.3
Hydro Electric	686,000	28.3	1,354,000	38.6
New sources (solar, wind, etc.)	--	--	15,000	0.4
3. Primary energy consumption	2,420,000	100.0	3,510,000	100.0
4. Energy conservation	--		200,000	
5. Total (3 + 4)	2,420,000		3,710,000	

*boe/d - Barrel of oil equivalent per day.
**The figures for petroleum and alcohol do not include the amounts to be used as industrial feedstocks.

alcohol, bagasse, and charcoal. By 1985, alcohol is expected to supply about 4.1% of Brazil's primary energy, and bagasse and charcoal are each expected to provide about 5%; coal production is projected to nearly triple; and direct solar, biogas, wind, refuse, methanol from wood, and minihydro are projected to grow substantially.

By far the most significant primary energy source in Brazil's future is hydroelectricity. Expansion of electric generating capacity figures heavily in Brazil's plans for future reduction in dependence on imported oil. Use of hydropower is expected to double over the next five years, providing almost 40% of Brazil's energy by 1985. Hydropower will continue to be the dominant source of Brazil's electric energy, growing from about 85% of installed capacity in 1979 to about 90% in 1985.

Between 1969 and 1979, the portion of national primary energy consumption supplied by imports rose from about 26% to almost 40%. By 1985, however, Brazilian energy planners expect petroleum imports to drop to 50% of present levels. Imports are projected to provide only about 12% of primary national consumption in that year.

While gasoline and fuel oil needs are expected to decline significantly by 1985, diesel oil consumption is projected to grow by about 20%. Finally, it is significant that the planned contribution from conservation in 1985 exceeds that of the alcohol program, and is about 20% of projected total petroleum consumption in that year.

Electricity consumption by sector is shown in Table 4.4. (SP = Sao Paulo, PR = Parana, SC = Santa Catarina, RGS = Rio Grande do Sul.) Electricity generated from on-site power sources, mostly within large industries, amounts to < 5% of total generation in Brazil.

The transportation sector is the largest user of petroleum, consuming virtually all the gasoline and 80% of the diesel fuel. The next largest user is the industrial sector, which consumes over 90% of the fuel oil. Table 4.5 presents the percentage breakdown by end-use sector.

4.2 ECONOMICALLY ATTRACTIVE TECHNOLOGIES IN BRAZIL: SOME SELECTED EXAMPLES

4.2.1 Heat Pumps: Commercial and Industrial Applications

Air chilling--water heating heat pumps and industrialized waste heat heat pumps appear to be appropriate technologies for use in Brazil. Both utilize available, domestically produced hydroelectric energy to directly displace imported oil. In the case of air chilling--water heating heat pumps, simultaneous production of air conditioning and hot water is ideally suited to the local climatic conditions. In the case of industrial waste heat heat pumps, the technology is well matched to Brazil's very important textile, pulp and paper, and food processing industries. The economic performance of both types of heat pumps appears to be superior to that of resistance heating, fossil fuels, and solar, based on current electricity prices in the U.S., and this is likely to hold true also for Brazil.

The physical and engineering principles underlying vapor compression heat pump technology have been understood for decades (Heap,[10] p. 3) and are the subject of a large body of technical literature. For this reason, as well as reasons given below, further discussion of heat pumps will be limited to two basic applications:

- Residential or commercial sized heat pumps that simultaneously provide water heating and space cooling;
- Industrial sized heat pumps that utilize low temperature waste heat as the heat source.

Air-to-air heat pumps used for space heating will not be discussed because, in Brazil, space heating is not a significant application, and the applications of primary interest are industrial and commercial. Solar-assisted heat pumps are also not considered for residential and commercial applications, but this appears to be a fruitful area for further investigation.

Table 4.4
Electricity Consumption by Sector, 1979 (GWh)[3,8]

	Industrial	Residential	Commercial	Rural	Other*	Total
SP	25,928	8,341	4,381	581	4,114	43,34
	60%	19%	10%	1%	10%	100
PR	2,475	945	700	139	578	4,83
	58%	20%	14%	3%	12%	100
SC	1,904	496	343	178	216	3,13
	61%	16%	11%	5%	7%	100
RGS	2,471	1,238	792	234	537	5,27
	47%	24%	15%	4%	10%	100
Southern states	32,778	11,020	6,216	1,132	5,445	56,59
	58%	19%	11%	2%	10%	100
Brazil	63,776	21,131	12,603	1,520	10,824	109,85
	58%	19%	12%	1%	10%	100

*Includes public lighting, government, water, and sewage.

Table 4.5
Petroleum Products Consumption by Sector, 1979[9]

State	Product	Industry	Transport.	Commercial	Household	Rural	Others
SP	LPG	9.8%	--	4.1%	85.9%	<0.1%	0.2%
	Gasoline	2.0%	93.8%	2.8%	--	0.2%	1.2%
	Diesel oil	19.5%	68.0%	8.3%	--	2.3%	1.9%
	Fuel oil	91.0%	0.5%	6.8%	--	1.4%	0.3%
PR	LPG	2.6%	--	5.6%	91.5%	--	0.3%
	Gasoline	0.9%	94.5%	2.5%	--	0.3%	1.8%
	Diesel oil	8.3%	76.3%	5.9%	--	2.5%	7.0%
	Fuel oil	91.6%	1.4%	3.4%	--	2.9%	0.7%
SC	LPG	13.7%	--	5.5%	80.4%	--	0.4%
	Gasoline	1.3%	96.2%	1.4%	--	0.2%	0.9%
	Diesel oil	11.5%	81.3%	3.2%	--	0.8%	3.2%
	Fuel oil	91.5%	0.5%	3.1%	--	1.2%	3.7%
RGS	LPG	3.7%	--	6.5%	86.6%	--	3.2%
	Gasoline	0.7%	95.6%	2.1%	--	0.3%	1.3%
	Diesel oil	5.4%	76.7%	3.7%	--	6.9%	7.3%
	Fuel oil	85.7%	0.1%	6.4%	--	1.0%	6.8%
Brazil	LPG	6.8%	<0.1%	3.7%	88.8%	--	0.6%
	Gasoline	1.5%	94.2%	2.5%	--	0.3%	1.5%
	Diesel oil	14.4%	71.3%	7.1%	--	2.9%	4.3%
	Fuel oil	92.3%	0.5%	4.8%	--	1.5%	0.9%

The following sections present some interesting examples of applications for air chilling--water heating pumps and for industrial sized heat pumps using waste heat recovery as the thermal source. The list of uses is by no means comprehensive; it simply serves to illustrate the variety of elegant ways in which heat pumps can be applied to the efficient utilization of Brazil's hydroelectric resources.

4.2.2 Air Chilling--Water Heating Heat Pumps for Commercial and Residential Applications

Figure 4.2 schematically illustrates the basic operating principles of an air chilling--water heating heat pump. The electrically driven compressor forces refrigerant through a condensing heat exchanger that transfers the latent heat to the hot water supply. This condensor may be remotely located as shown, or immersed in the storage tank. The hot water is stored for use on demand. The refrigerant is then expanded through a capillary tube, where it is cooled by its change of state from liquid to gas. The cold refrigerant is used to cool the ventilation system via a fan forcing ventilating air over the heat exchange evaporator. The heat provided to the water system can be used either directly or in a preheat mode, depending on the hot water use and required temperature. The chilled air can be used for cooling and dehumidification, either as a stand-alone system or in conjunction with a conventional air conditioning system.

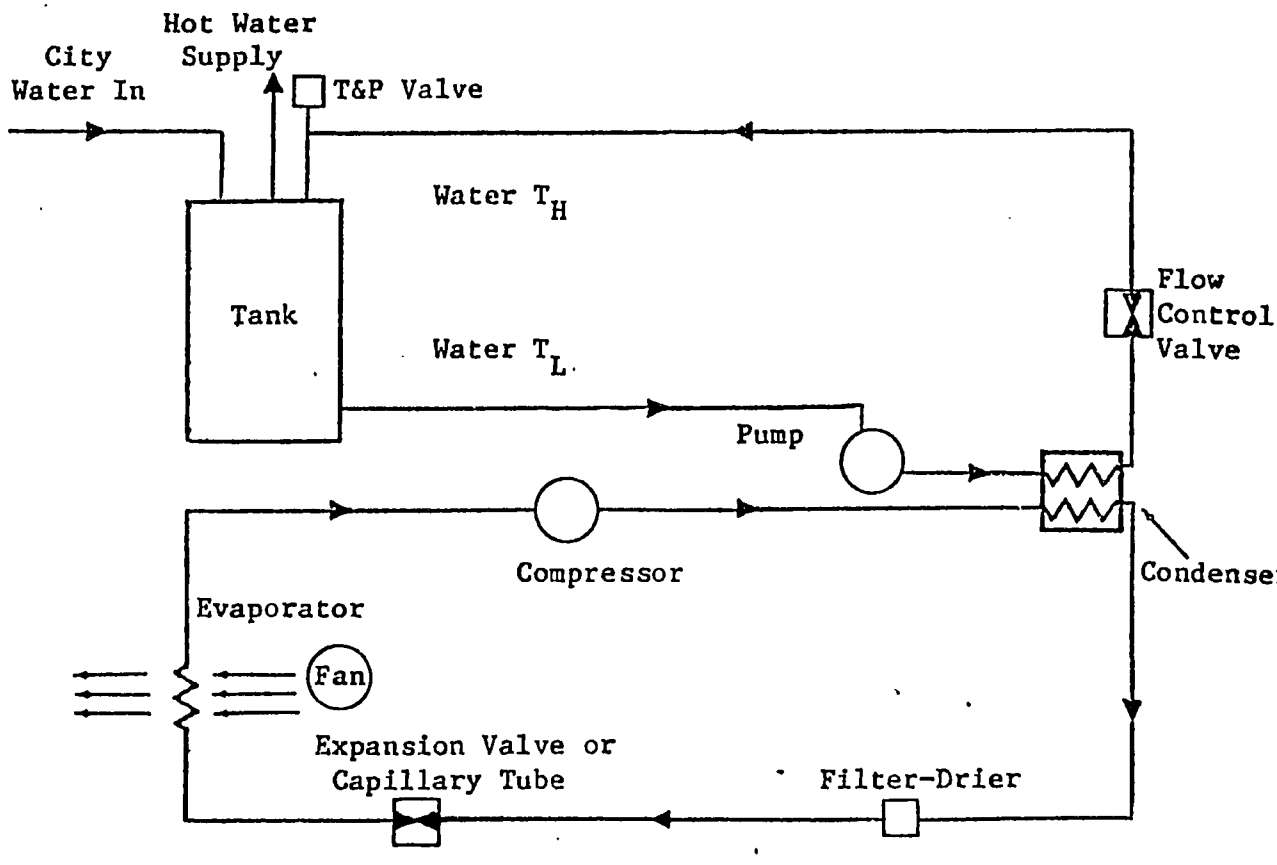

Figure 4.2 An air chilling--water heating heat pump: basic principles (from E-Tech, Inc., Atlanta, GA).

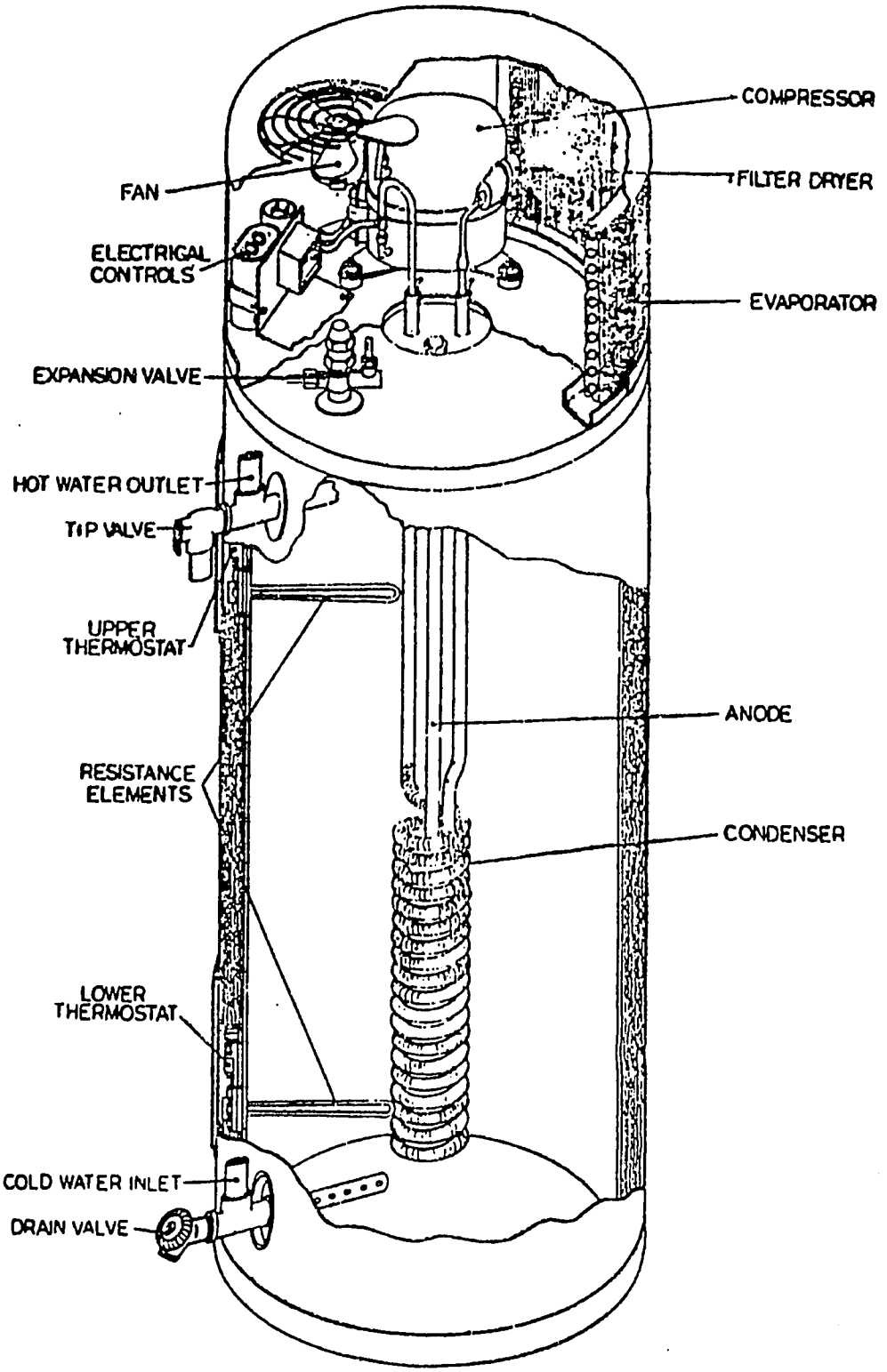

Figure 4.3. The Temcor unit (from TVA[11]).

The performance of air chilling--water heating heat pumps is optimal in warm climates, where applications combining air conditioning and water heating are in demand. The climate of Southern Brazil appears suitable for such pumps since the average daily winter temperature in the southern coastal region is no lower than 13° to 16°C, and since building cooling loads become larger further north. Air cooling--water heating heat pumps can be expected to have good economics in commercial buildings such as hospitals, hotels, offices, schools, restaurants, and apartment houses, and to find a market in private homes for use in smaller air conditioning and domestic hot water systems.

Testing and evaluation of air chilling--water heating heat pumps have demonstrated their good performance under the climatic and power cost conditions in the U.S., particularly in the sunbelt region. In a TVA field test program,[11] two systems, the Temcor immersed condensor type and the remote condensor Efficiency II, demonstrated annual power savings of 46 and 57% respectively compared with resistance water heating, with the air conditioning benefits not taken into account. The Temcor unit, manufactured by Energy Utilization Systems in Pittsburgh, now costs $1000 to 1200 installed (Figure 4.3). The Efficiency II, is manufactured by E-Tech in Atlanta (Figure 4.4). The units tested were primarily for residential applications and sized accordingly, but there is no reason why similar or better results could not be obtained with higher capacity designs. Other U.S. manufacturers include Fedders Corp. of Edison, NJ, whose retrofit unit is similar to the E-Tech design, and Mor-Flo Industries of Cleveland, OH.

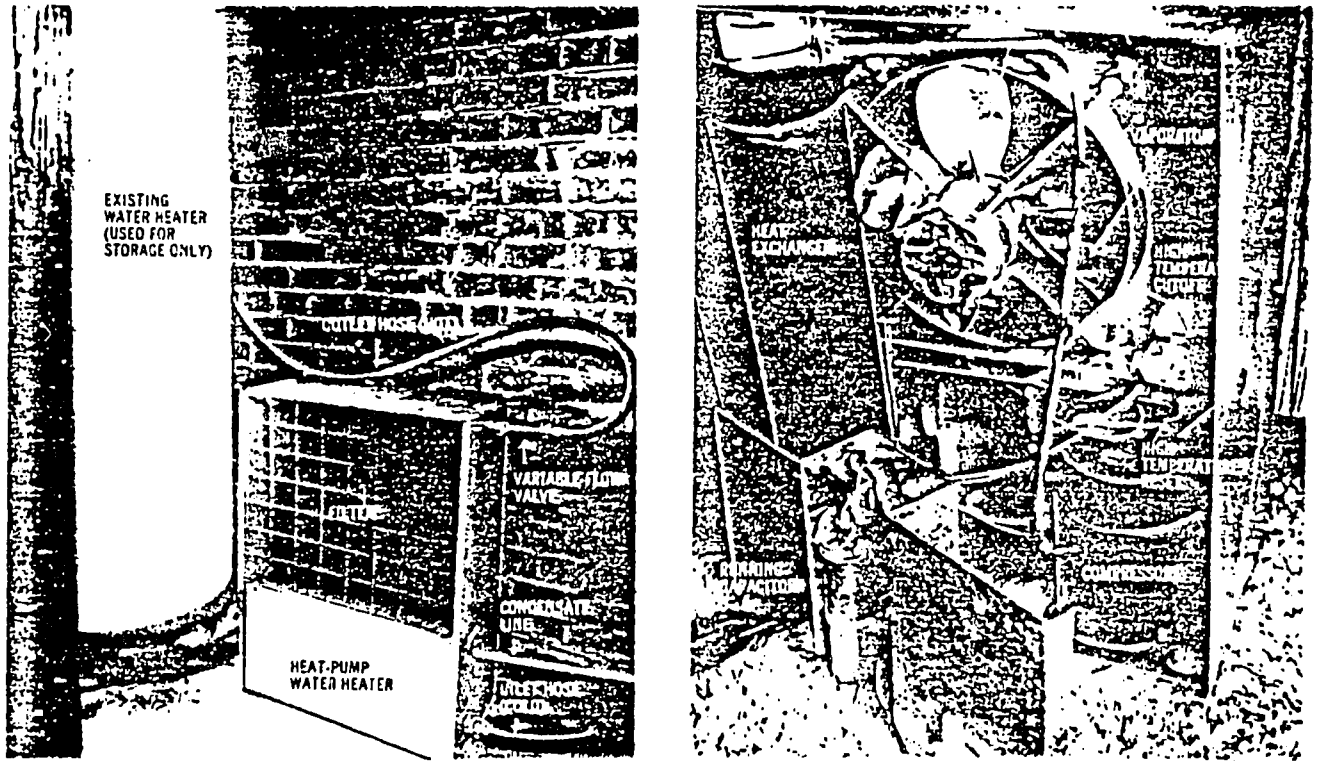

Figure 4.4 The Efficiency II heat pump (from Popular Science, April 1980).

The air conditioning benefits of air chilling--water heating heat pumps are easy to estimate. Basically, the heat provided to the water supply is the sum of the heat supplied by the electrically powered compression of the refrigerant plus the heat extracted from the ambient air: the latter is the air conditioning benefit of the unit. For example, if an air chilling--water heating heat pump has a heating coefficient of performance (COP) of 3.0, this means that two units of heat are extracted from the surrounding air for every one unit of electrical energy supplied; thus, three units of water heating and two units of air conditioning are delivered for every unit of electric power supplied. During the heating season, of course, a penalty for the heat withdrawn from room air is paid, by increased use of the building's heat system, but this consideration should not be significant in Brazil's year-round moderate climate.

In summary, a consideration must be given to Brazil's ample supply of electric power, a brief heating season, the proven performance and reliability of air chilling--water heating heat pumps, an established need for simultaneous airconditioning and water heating, and a government policy aimed at reducing fuel oil consumption while expanding the economy and improving the population's standard of living. The combination of these factors suggests that the air chilling--water heating heat pump is a system with much potential in Brazil's energy future.

4.2.3 Industrial Applications of Heat Pumps Which Use Low Temperature Waste Heat as the Heat Source

Although the use of heat pumps with solar collectors as the heat source has been shown to be a viable technique for enhancing the performance of solar systems,[12] this section will be limited to heat pumps which use low temperature industrial reject heat as the source to supply process heat at a higher temperature.

Exploitable waste heat streams exist in nearly every major form of industry, and heat pumps that use industrial waste heat as the source can be used in a variety of ways. One specific example, the McQuay-Perfex "Templifier" (developed originally by Westinghouse) installed at the Wolverine Division of UOP's Decatur, AL, plant, uses the heat contained in 38°C equipment cooling water to provide 71° to 88°C water to the distribution manifold at a COP of 3.45. This installation was inspected by U.S. and Brazilian energy teams in 1981, and additional details of its technical and economic performance are discussed below.

The installation inspected was a 600-hp, 5.4-MBtu/hr (1.58-MW_{th}) Westinghouse Templifier heat pump used to produce 160° to 190°F (71° to 88°C) water from low temperature waste heat. Table 4.6 gives performance specifications of the Templifier and compares its economic characteristics with those of gas-fired boilers, and Figure 4.5 schematically shows the operating strategy used.

Heat pumps have excellent market potential in Brazil for several reasons:

- Direct displacement of oil and gas with hydroelectricity.
- Excellent return on investment.

Table 4.6
Operating and Economic Characteristics of the
Templifier Industrial Heat Pump (from Wolverine Division of UOP, Decatur, AL)

Operating characteristics, Templifier specifications:

Maximum conditions: 5.43 million Btu/hr (1.58 MW) heating 1170 lpm of hot water to 71° - 88°C when supplied with 5680 lpm of source water at 43°C and 460 kW of electric power. Coefficient of performance = 3.45.
Minimum operating conditions: 24°C input water at 5680 lpm; 60° - 77°C output water at 1420 lpm. Coefficient of performance = 3.09.

Economic characteristics compared with those of boilers:

Templifier	Gas-fired boiler
Electricity cost: 2¢/kWh	Gas/propane cost: \$3.25/Mcf (\$0.11/m^3)
Installation cost: \$225,000	Installation cost: 0
Coefficient of performance: 3.45	Efficiency: 65%
System capacity: 5.43 million Btu/hr	System capacity: 5.43 million Btu/hr
Maintenance: \$6000	Maintenance: \$3000

Payback: 1.34 yr

ROI: 79.71%

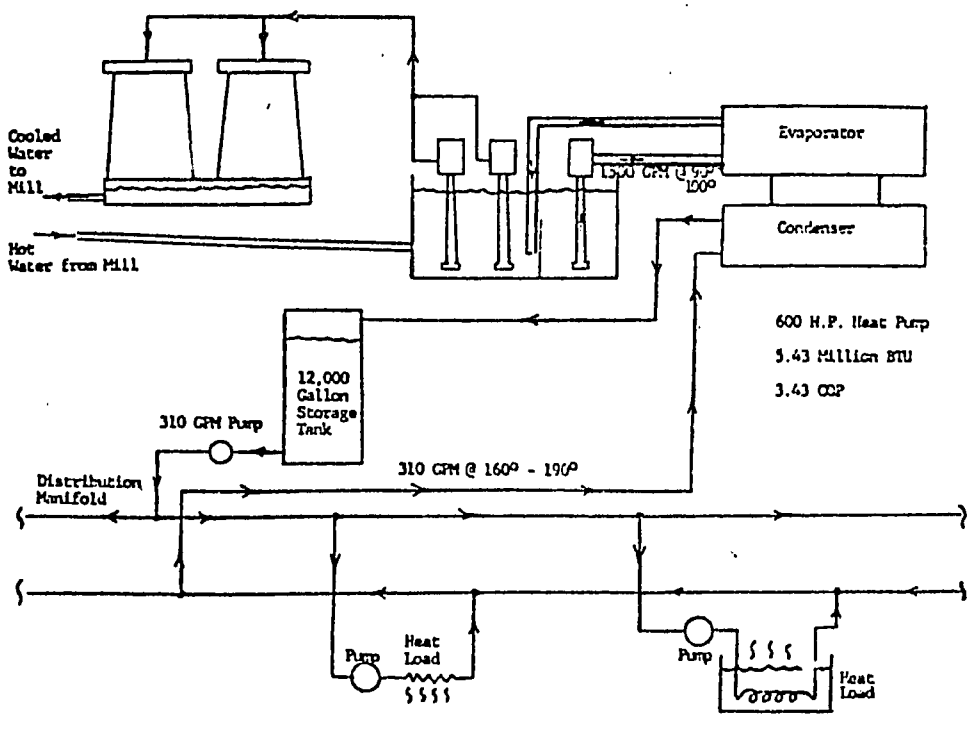

Figure 4.5. Operating strategy of Westinghouse Templifier heat pump (from Wolverine Division of UOP, Decatur, AL).

- Textile and food processing industries in Brazil consume over 10% of the fuel oil, and have temperature requirements well matched to the use of industrial heat pumps.
- Existing and potential Brazilian manufacturing capability for this technology. Brazil currently has a well developed air conditioning and refrigeration industry.
- Better utilization of the existing excess electricity generating capacity to meet a highly peaked evening lighting load.

Generally speaking, industrial heat pumps are applicable to industries that require a series of cooling and low temperature heating processes in close proximity. For example, an energy audit and analysis of a Detroit meat packing plant showed that the proposed installation of two 386-kW heat pumps, designed to use 32°C refrigeration reject heat, could provide 75% of the plant's heating requirement for 1.9×10^6 liter/day of 60°C process water. For an estimated capital expenditure of $150,000 to 200,000, a payback of slightly more than one year was calculated.[13]

4.2.4 Heat Pump Application Potential

The calculation of potential markets for new technologies is at best extremely imprecise. This is due in part to the large number of statistical and behavioral assumptions required; therefore, quantitative market potential estimates for air chilling--water heating heat pumps and industrial waste heat heat pumps are limited to maximum market saturation calculations. Factors taken into account include industrial or residential energy consumption profiles, historical petroleum use, technical characteristics of the equipment, and Brazil's well-known emphasis on reducing petroleum consumption. Factors such as capital availability, consumer acceptance, and projected growth rates are not included.

Air Chilling--Water Heating Heat Pumps. Total LPG consumption for the four southern states of Brazil amounted to about 1400×10^3 toe for 1979 and nearly all the LPG was used in the residential sector, mostly to heat water.

In order to calculate how much installed heat pump capacity this would have represented, a capacity factor range of 0.33 to 0.50 is assumed. Thus, assuming that

- all residential/commercial water heating is provided by LPG,
- 80% of all LPG is consumed to heat water in residential/commercial situations, and
- LPG is burned at 70% typical efficiency,

the maximum potential market for air chilling--water heating heat pumps in the four southern states in 1979 was 2310 to 3150 MW thermal output capacity, or 7.88×10^{12} to 11.78×10^{12} Btu/hr.

Industrial Heat Pumps. The approach taken to estimating the potential market for industrial waste heat heat pumps starts with the total Brazilian fuel oil consumption, which in 1979 was 17.6×10^6 toe, of which 85% was industrial, with 5% used to generate electricity (Table 4.7). Since industrial waste heat heat pumps are basically designed to deliver energy at 100°C and less, the market analysis was limited to applications within this

Table 4.7
Percent of Total Fuel Oil Consumption in Brazil, by Industry (from [21] p.81)

Industry[a]	Main application	% Total fuel oil consumptio
Cement[b]	High temp. heat	15
Ceramics	High temp. heat	9
Electric power	Thermoelectric gen.	6
Petrol. ref.	Steam	11
	Electric power	
Steel[c]	Steam	17
	Heat	
	Electric power	
Pulp & paper[d]	Steam	6
	Electric power	
Food processing	Steam	8
	Low to mid temp. heat	
Textiles	Steam	4
Petrochemicals	Steam	9
Total		85

[a]To encourage energy saving, the Brazilian Government provides 90% of the investment in energy-efficiency measures as a loan at 5% interest payable in 5 years with 1 year grace period.
[b]By December 1981, 39% of oil used in the cement industry had been replaced by substitute fuels.
[c]By December 1981, a 24% savings in energy use was achieved.
[d]14% energy savings had been achieved by December 1981.

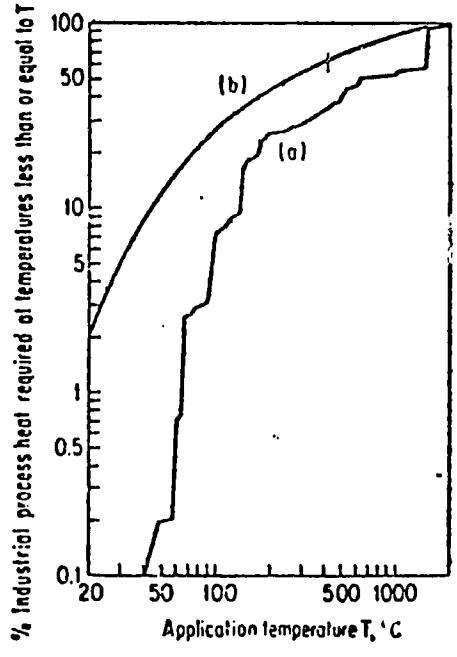

Figure 4.6 Cumulative process heat requirements as a function of process temperature: (a) all heat supplied at required process temperature, (b) heat supplied as preheat from 16°C up to T°C (from ERDA[14,15]).

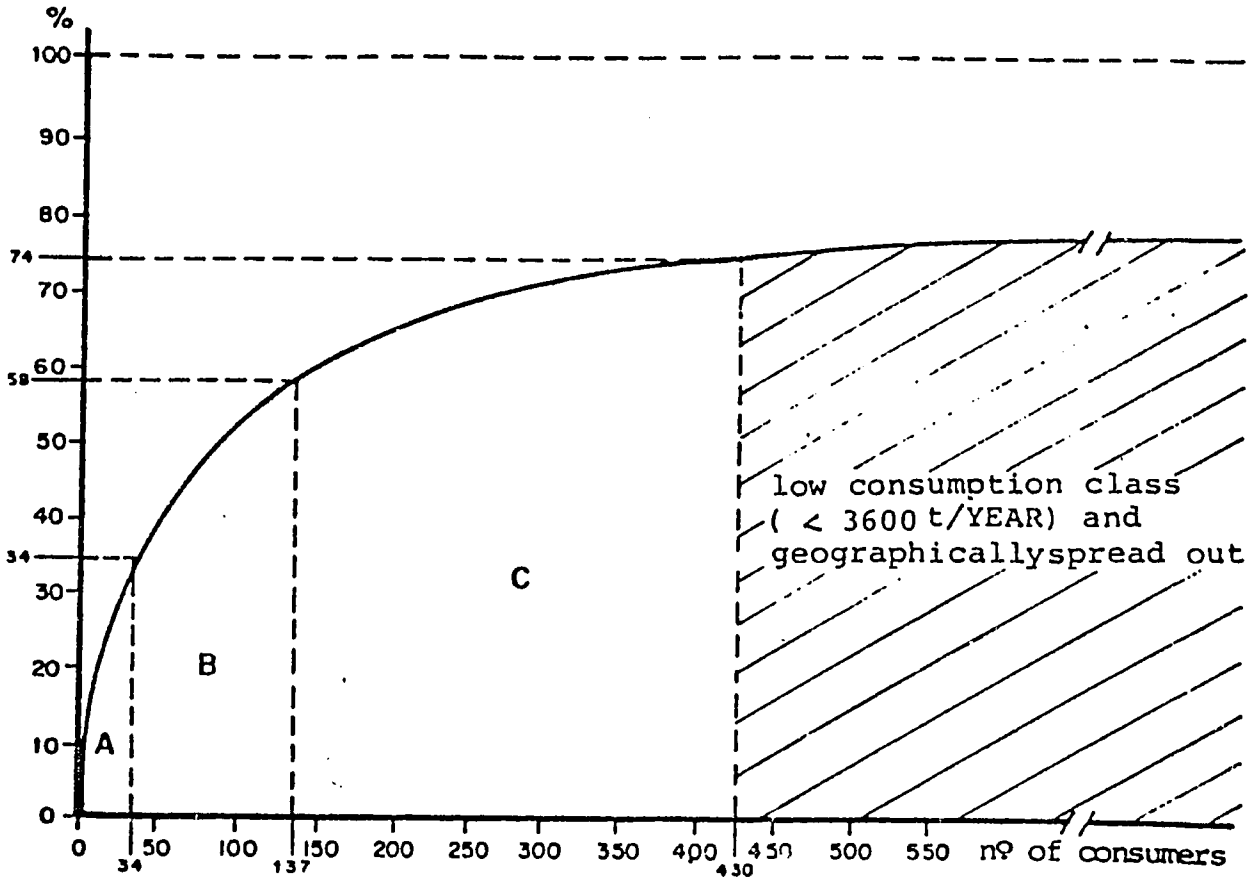

Figure 4.7 Concentration of fuel oil consumption by company (from MME,[2] p. 83). Consumption classes: A, >68,000 t/yr; B, 18,000 to 68,000 t/yr; C, 3,600 to 18,000 t/yr.

temperature regime. Figure 4.6, which characterizes the industrial heat temperature requirement profile for the U.S. industrial mix, shows that 20% of all process heat, including preheat energy for higher temperature processes, falls within this limit.

Another constraint on the maximum size of the potential market is the distribution of total Brazilian fuel oil consumption as a function of the size of the consuming unit because industrial waste heat heat pumps are less likely to be installed in small industrial facilities than in large ones. Figure 4.7 shows that 58% of fuel oil is used at facilities with consumption rates of 18,000 toe/yr or more and the balance at those with lower rates. If it is assumed that only those with rates >18,000 toe/yr could install industrial waste heat heat pumps, the calculation for the maximum potential fuel oil displacement that could have been achieved by industrial waste heat heat pumps for all of Brazil in 1979 is as follows:

17.6×10^6 toe/yr total fuel oil consumption
x 0.80 industrial thermal use
x 0.20 heat and preheat fraction <100°C, U.S.
x 0.58 suitable-size fraction of companies
= 1.63×10^6 toe/yr.

To calculate the approximate installed maximum thermal output capacity this represents, an annual utilization of 4000 hr is assumed. Thus, for 1979, industrial waste heat heat pumps could have accounted for

$$1.63\times10^{6}\ \frac{\text{toe}}{\text{yr}} \times 0.7\ (\text{eff.}) \times 0.0205\ \frac{\text{boe/d}}{\text{toe/yr}} \times 5.9\times10^{6}\ \frac{\text{Btu}}{\text{boe}} \times \frac{1\ \text{day}}{24\ \text{hr}} \times 2.9\times10^{-4}\ \frac{\text{kW}}{\text{Btu/hr}}$$

$$\times \frac{8760}{4000}\ (\text{utilization} = 3.65\ \text{GW} = 3650\ \text{1-MW units.}$$

4.2.5 Summary

Two specific types of heat pumps appear to offer outstanding prospects for use under Brazilian conditions. Factors favoring heat pump utilization include a national policy of reducing fuel oil consumption, ample hydroelectric generating capacity, a moderate climate, an industrial energy use profile in which about half of all thermal energy is low to mid temperature, a residential/commercial energy use pattern dominated by electricity, the desire to make efficient use of generating and transmission capacity, and the capability to produce vapor compression equipment.

Residential/commercial heat pumps which provide simultaneous air conditioning and water heating could capture a large share of both energy markets and at the same time provide very efficient utilization of electricity generating capacity. Furthermore, the excellent economics of these devices compared with other renewable energy technologies should provide rapid consumer acceptance in such applications as domestic hot water/air conditioning, and in hospitals, restaurants, and a variety of small commercial establishments.

Industrial heat pumps that utilize reject heat streams to provide low temperature process heat and preheat appear to be well suited to Brazil's energy needs. Such pumps provide excellent return on investment and their use is technically feasible in industries such as food processing, textiles, alcohol production, pulp and paper, refining, and petrochemicals. Furthermore, on the basis of Brazil's energy profile, such devices, powered by renewable indigenous hydroelectricity, could displace a maximum of about 9% of total fuel oil consumption, with perhaps 4.5% as a realistic goal.

4.2.6 Heat Recuperators

Basically, a heat recuperator is an air-to-air heat exchanger fitted to the exhaust of a combustion process. Generally, combustion air is preheated by passing through the recuperator, to save fuel (see Figure 4.8).

At Wolverine in Decatur, AL, recuperators have been fitted to annealing furnaces. By preheating combustion air to about 900°F (482°C), a 22% savings in natural gas consumption is realized. Installed cost is $12,000 for each furnace. With gas priced at $3.25/mcf ($0.11/m^3), this results in a simple payback of a little more than one year.

This recuperator was inspected by U.S. and Brazilian energy groups in 1981, and it was determined that recuperators have excellent market potential in Brazil for a variety of reasons: the technology is simple and well under-

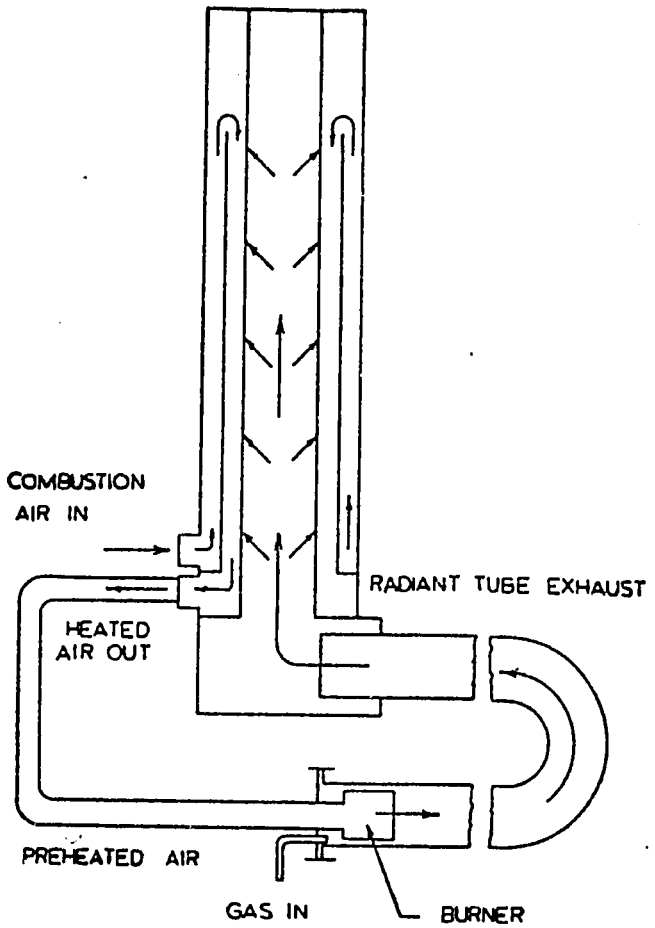

Figure 4.8 Heat recuperator (from Wolverine Division of UOP, Decatur, AL).

stood, it directly displaces significant quantities of oil, and it can be readily manufactured and installed by Brazilian concerns.

4.3 FINANCIAL ANALYSIS OF HEAT PUMP TECHNOLOGY

A detailed financial analysis of industrial heat pump technology has been performed for Brazil. For this technology, the financial criteria computed are the internal rate of return (IRR), the levelized cost of energy, and the payback period. The IRR is particularly important, since it is the criterion used by many international financial institutions for project evaluation. Figures 4.9 and 4.10 show the internal rate of return for industrial heat pumps and solar industrial process heat as a function of capital cost for two oil prices ($34 and 45 per bbl) and various debt interest rates. With inflation in Brazil running close to 100%, the Brazilian government has encouraged investment in alcohol and coal production by indexing loan payments at only a 55% rate of increase. This government subsidy is equivalent to a negative interest rate on loans, and it vastly improves the internal rate of return on a solar investment. Figure 4.11 demonstrates the effect that investment tax credits have on the internal rate of return, and therefore the economic viability, of renewable energy projects. Changes in financial policy variables such as tax credits and debt interest rates can thus play a powerful and decisive role in creating a favorable investment climate for indigenous renewable energy systems, and the national economy can be expected to benefit from the savings in imported oil.

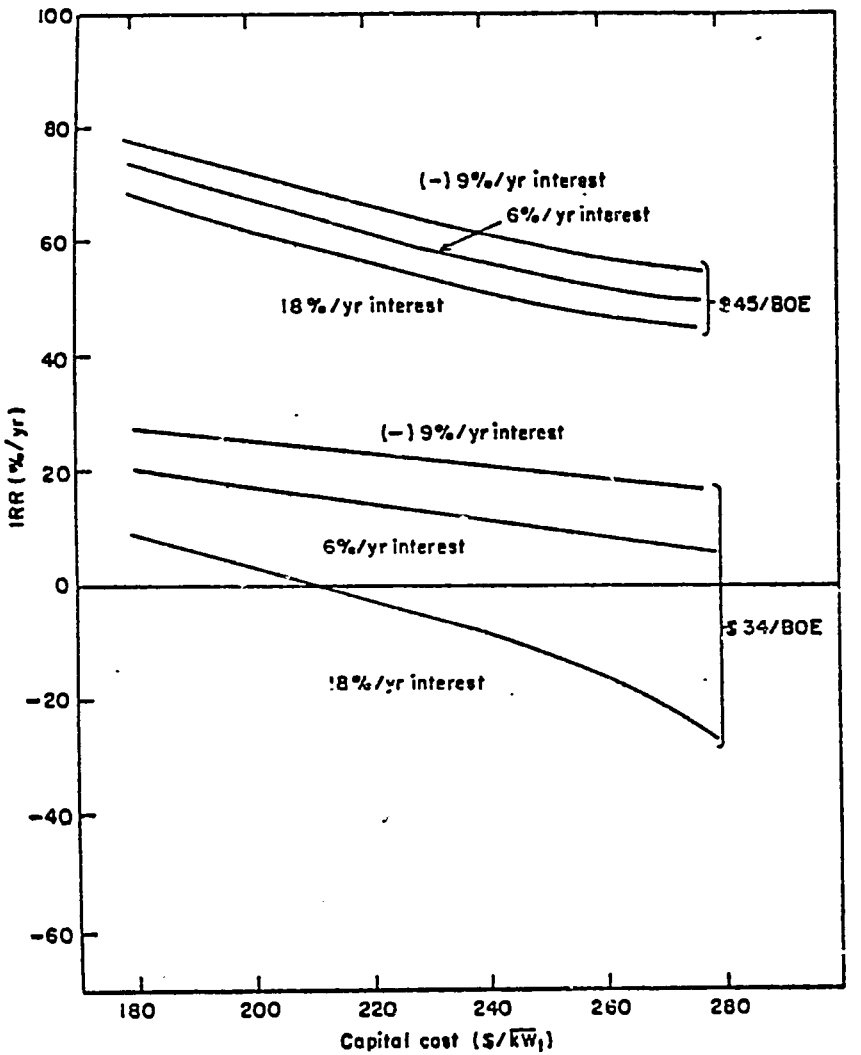

Figure 4.9 Industrial heat pump IRR vs capital cost.

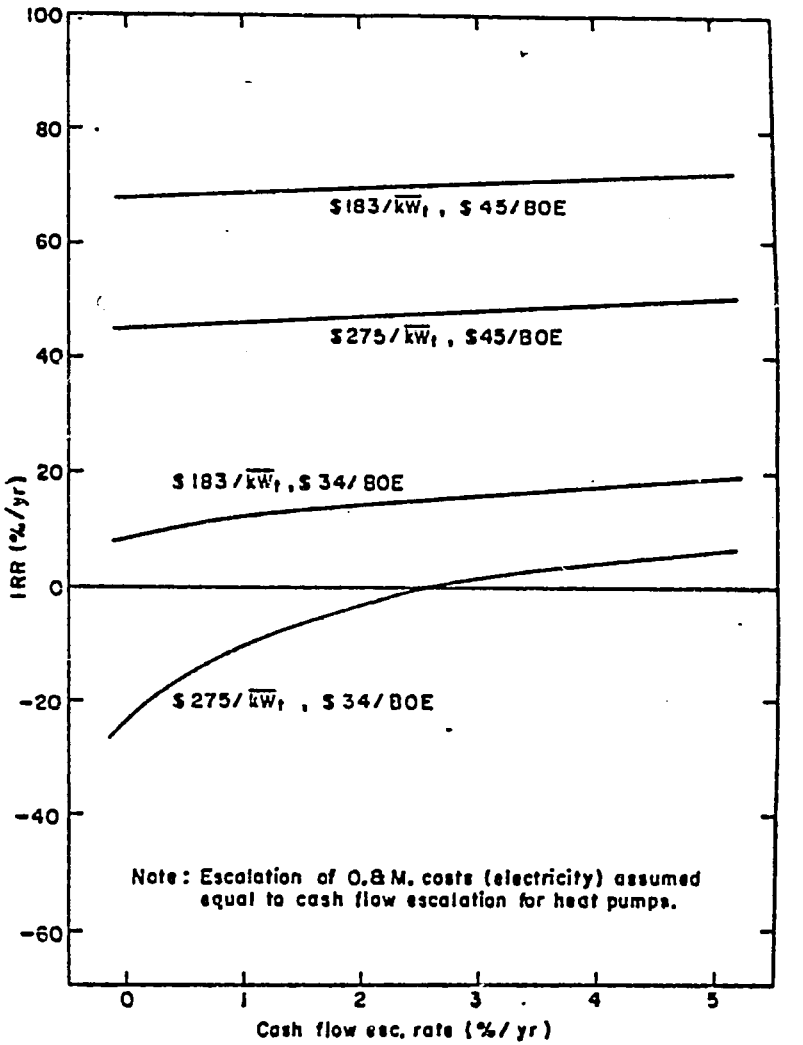

Figure 4.10 Industrial heat pump IRR vs cash flow escalation rate.

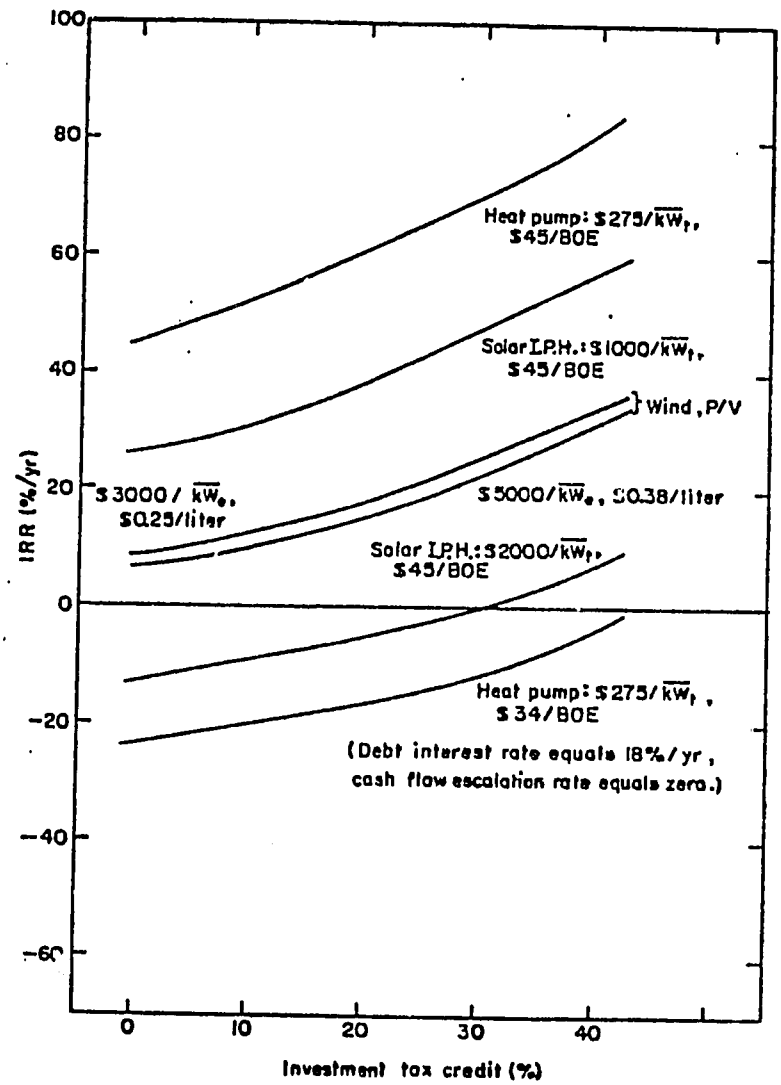

Figure 4.11 IRR vs investment tax credit.

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SECTION 3

THE INDUSTRIAL SECTOR

3.1 INDUSTRIAL ENERGY MANAGEMENT

Barry G. Tunnah

SESSION ONE: INTRODUCTION

1. INTRODUCTION

In many developing countries, industry represents the most important consumer of imported petroleum products and of electricity. Industry may also consume significant quantities of non-commercial fuels, such as wood and charcoal. The potential benefits of improving the efficiency of use of energy by industry can therefore be very important in developing countries. The rational use of energy will often provide an opportunity to reduce energy imports, to save scarce foreign currency, and thus to accelerate the development process overall.

There is a common misconception that, because developing countries consume relatively little energy compared with the industrialized countries, this energy must continue to be used for essential development purposes, satisfying basic human needs, raising the standard of living of rural populations and initiating industrialization programs. In fact, the mere existence of a low level of consumption provides no guarantee of a high efficiency of energy use. Significant energy wastage can, and frequently does, occur in developing countries. All uses of energy, whether viewed as "essential" for basic human needs or not, warrant close examination.

It is, therefore, important that developing countries be encouraged to examine industrial energy consumption at the plant level, to identify actions needed, and to establish priorities for the training of manpower and the investment of capital. The emphasis should be on immediate action to improve energy efficiency in the factories, including basic training for local engineers in the principles and practice of energy conservation.

Properly carried out, energy management programs will result in reductions in the level of energy consumption in particular processes or factories, but note that lowering overall national energy use is not necessarily the objective. Rather, energy management seeks to make each unit of energy input produce more in terms of the output of useful work, thereby freeing incremental energy supplies for purposes related to economic expansion and development.

2. POTENTIAL BENEFITS OF CONSERVATION

To get some idea of the levels of improvement in energy efficiency which are possible, the progress in the U.S.A. serves as an example. Energy efficiency improvement targets were developed for energy intensive industries for the period from base year 1972 to January 1980, and these ranged from 9 to 24%. The targets were estimated for each industry to include both techni-

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cally and economically feasible conservation measures. The equivalent target for the ten industries as a whole, calculated as a weighted average of the individual targets, was about 14%. By the end of 1979, the improvement actually achieved by the largest consumers in the energy-intensive industries was 15.4%, with some industries already reporting much greater improvement than their 1980 target:

Industry	1980 target %	Progress reported by end 1979 %	Difference %
Chemicals	14	22	+8
Primary metals	9	8	-1
Petroleum refining	12	15	+3
Stone, clay, glass	16	13	-3
Paper	20	17	-3
Food processing	12	15	+3
Fabricated metals	24	22	-2
Transportation equipment	16	23	+7
Machinery	15	25	+10
Textiles	22	18	-4

Over the same period, growth in output rose about 17%, but energy efficiency improvements were sufficient to "offset" this increase to such an extent that the absolute level of energy consumption by the companies reporting in the ten major industries was actually lower in 1979 and 1972. In absolute terms, the savings represent a savings of over 1 million barrels of oil per day, valued at over $9 billion dollars per year for the reporting corporations.

These energy efficiency improvements have been attained primarily through the application of no- or low-cost measures. These actions range from the initiation of energy management awareness programs to relatively low-cost improvements, such as the use of insulation in process equipment and the installation of improved fuel use controls on boilers and other energy-intensive process equipment.

In the United Kingdom, some industries have set their own voluntary targets, and many data are available on individual company successes. For example, over the ten years from 1971 through 1980, Imperial Chemical Industries (ICI) has reduced energy use per unit of output 35%, 10% have been achieved since 1978. Pilkingtons, the glass manufacturers, improved energy efficiency by 20% between 1974 and 1980.

The U.K. has been perhaps the most successful country in encouraging the appointment of energy managers in factories. Over the last seven years, the government has vigorously promoted the energy manager concept and there are now over eight thousand energy managers divided into over seventy regional groups with a national coordinating committee.

As a final example of the national potential for improved energy efficiency, we may examine briefly the results obtained from a recent study in

Tunisia[1]; the study will be discussed in detail later. Among the findings of the study, a widespread lack of careful energy accounting and a resultant lack of awareness of the possibilities for energy saving were apparent. There was rarely any focus for energy data, energy conservation, and energy management. It was clear that much improvement in energy efficiency can be achieved with little or no investment. The potential for improvement obviously varies from plant to plant, but typical improvements of 15 to 20% should be achieved within two years through a combination of better management and moderate capital investment.

We should also note that, for most countries, the impact of new plant commissioning can be very significant. There is a need for attention to be paid in developing countries to the energy efficiency of new plant designs, which can often contribute much greater savings to the economy than savings achievable in the existing plants. This is evident when we examine the contribution to industrial sector output of new plants over the next twenty years, as illustrated in Exhibit A.

The potential for savings in Tunisia is illustrated in Exhibit B. The cumulative savings from 1982 through 1986 from energy management efforts in existing plants alone is evaluated at about 50 million dollars at world market prices. The resources for promoting better energy management, in terms of manpower and equipment, which can be justified by the 50 million dollars are clearly substantial, but without a major effort to focus attention and action on energy problems, the undoubted potential for conservation will not be realized. In our experience, this situation is typical for many developing countries.

3. OVERVIEW OF THE SEMINAR

The Seminar will concentrate on the role of energy management in the industrial sector, and will also consider the possibilities in other sectors, such as buildings, transportation, and the electric utility sector.

Session Two will introduce the problem areas relating to energy demand in West Africa, and will review the demands for electricity, oil and non-traditional fuels, especially with respect to imports of energy. A panel discussion will follow the formal presentations.

Session Three will present the results of prior work in the field of industrial energy management in a number of developing countries to illustrate, through actual studies, the potential benefits of effective energy management.

Session Four will continue with case studies in the transport, buildings, and electric utility sectors.

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[1]Industrial Energy Study for Tunisia; Final Report, September 1982, by E/DI Europe Ltd. for USAID and the Ministry for National Economy, Tunis.

EXHIBIT A

AGE DISTRIBUTION OF PLANTS

4% GROWTH 1 % DECAY

1980	PRE - 1980		
1990	PRE - 1980		1980 - 1990
2000	PRE - 1980	1980 - 1990	1990 - 2000

8% GROWTH 1 % DECAY

1980	PRE - 1980		
1990	PRE - 1980	1980 - 1990	
2000	PRE - 1980	1980 - 1990	1990 - 2000

12% GROWTH 1 % DECAY

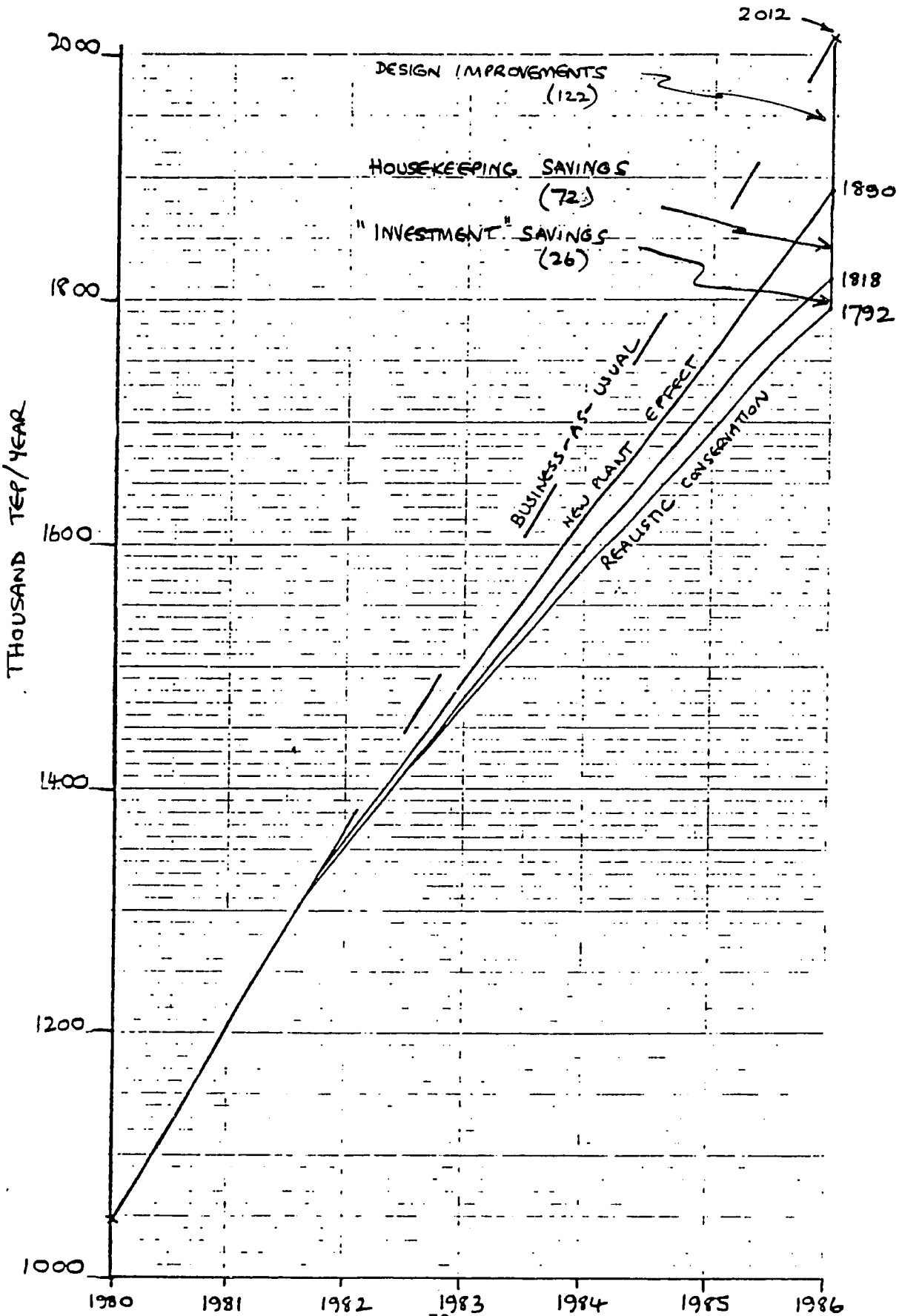
1980	PRE - 1980		
1990	PRE - 1980	1980 - 1990	
2000	PRE - 1980	1980 - 1990	1900 - 2000

OLD <——————————— NEW ———————————>

Source: Energy Development/International, Ltd.

EXHIBIT B

PROJECTED DEMANDS



Session Five is a review of the barriers and incentives connected with energy conservation, and will include discussion of such issues as energy tarification, regulatory aspects, technical information, training programs, capital requirements for investments, etc.

Session Six will cover the role of the donor agencies in supporting energy conservation projects, and a panel discussion will follow the formal presentations.

Having introduced the topic of energy conservation thoroughly, and having reviewed some of the policy-related factors which can effect conservation programs, Session Seven will go into details of industrial plant energy audits, and will illustrate the procedures used to establish energy use patterns and to identify energy conservation opportunities. Examples of the use of microcomputers for energy management work, both for data base storage and handling and for engineering calculations, will be given. Session Eight will continue this theme.

In order to reinforce the audit techniques and procedures covered in the previous sessions, Session Nine will consist of a field visit to the phosphate processing complex of OTP. The seminar participants will be divided into several groups and will conduct practical audit work, such as collecting operating data on the plant itself, and measuring combustion efficiency and heat losses with portable instruments. A review of the field work will be conducted on the following morning.

Session Ten is to be devoted to a detailed technical discussion of the potential for energy efficiency in the electric utility sector, while Sessions Eleven and Twelve will deal with the detailed technical aspects of energy management in the buildings and transport sectors, respectively. A field trip to demonstrate energy conservation in the buidings sector is being planned for Session Thirteen.

Session Fourteen will cover the economic analysis of energy efficiency measures at the micro level, including the use of microcomputers for calculations of the return on capital investments, and will also discuss the economics of conservation from a national perspective, thus linking the development of energy policies with economic analyses at the plant level.

The final session, Session Fifteen, will include discussion of the findings and recommendations of participants, and will be used to establish the consensus of opinions for follow-up action.

SESSION THREE: THE ROLE OF ENERGY EFFICIENCY

1 CASE STUDY: INDUSTRIAL ENERGY PROJECT, TUNISIA

The findings and conclusions presented here for Tunisia are used to illustrate the typical situation in developing countries, and are intended to show how energy efficiency may be improved through a properly structured study. The remarks are, in our experience, broadly applicable to many countries and are not unique to Tunisia.

1.1 PROJECT OBJECTIVES

This project was carried out to assist the Government of Tunisia to improve their energy planning capability and to stimulate improved energy efficiency in the industrial sector. The basic objectives were:

1. To improve the collection of industrial energy data, starting with the collection of basic data at the individual plant level, in order to provide accurate and timely data on which to base regulatory and investment policies and programs.

2. To analyze data taken from selected plant audits with a view to identifying energy conservation opportunities.

3. To train Tunisian personnel, in particular at the plant level, to perform practical plant energy audits and to implement in-plant energy efficiency improvements.

1.2 INDUSTRIAL CONSERVATION TRAINING COURSES

Two cycles of training courses were conducted for a total of 21 engineers from industrial plants, the state electricity and gas utility and the national oil company. The course consisted of lectures on industrial energy conservation principles and techniques, and a series of one-day visits were made made to industrial plants to reinforce the classroom lectures with practical demonstrations of the principles involved and of the use of portable diagnostic instruments.

1.3 AUDIT WORK

An integral part of the training effort was the conduct of audits in selected plants by the Tunisian engineers themselves. The participants were divided into small groups of 4 or 5 engineers and these groups carried out specific tasks in the plants, such as performing heat and material balances around kilns, furnaces, and boilers. At all times, the training of the engineers was given an equal priority to the identification of energy conservation opportunities. Full reports of the audit work were prepared and the findings discussed with representatives of the plants. In all plants, it was possible to develop recommendations for immediate action to improve energy efficiency.

1.4 GENERAL FINDINGS OF THE AUDIT WORK

Several comments may be made regarding energy management in general, as observed in the broad range of industrial facilities visited. With some notable exceptions, the general standard of energy consumption monitoring and energy management was poor; closer control of operations could lead to significant energy savings in the short term. In general:

1. There is a widespread lack of careful energy accounting, and a resultant lack of awareness of the possibilies for energy saving.

2. Where data are assembled regularly, reports are often incorrect, inconsistent, and incomplete; there is a need for rigorous checking of all data.

3. Important energy-related data are often missing and no attempt is made to relate energy consumption to production, a fundamental prerequisite for improving efficiency.

4. There is a need for top management to demonstrate a firm commitment to energy efficiency.

5. Energy and production data are often quoted in diverse units and confusion between such units as litres and kilogrammes, cubic metres and tonnes, etc., can often occur. In some cases, data records are kept without quoting units, which can lead to further confusion. It is recommended that complete energy reports be prepared regularly with all energy consumptions converted to a common unit for comparison purposes.

6. On occasion we observed a surprising degree of confusion about the grade of fuel oil used and its calorific value. Quality control of fuel purchases appears nonexistent, and control of quantity of fuel delivered often leaves much to be desired.

7. When asked about equipment performance or efficiency, plant personnel often quoted design data and were unable to quantify with any certainty the current situation.

8. Accurate measurement is essential to establish the priorities for energy efficiency improvement, but the standard of instrumentation for measuring important flows and temperatures is generally poor.

9. A questioning attitude by the plant engineers is generally absent and an analytical approach to energy data is lacking.

10. A regular, comprehensive and reliable monthly report on energy consumption should always be prepared in a format which would allow comparisons to be made on energy efficiency from one month to the next.

11. A significantly improved standard of maintenance and housekeeping is necessary in many of the plants to improve the operating performance and to contribute to improved energy efficiency. Safe and clean working conditions are essential for efficient plant operation.

12. There appears to be a general lack of qualified engineering personnel to identify and implement energy efficiency measures.

13. There is a general lack of information on basic calculations and standard engineering data.

14. Above all, there is a widespread lack of focus for energy data, energy conservation, and energy management. There is a need for a clear definition of responsibilities for energy matters and it is recommended that an energy manager be considered for all the plants.

It is most important to appreciate that the findings listed here for Tunisia are quite typical of our observations in a number of developing countries and, indeed, are often found to apply to developed countries, too. The findings are by no means applicable only to Tunisia: the situation is frequently worse in many countries.

1.5 SPECIFIC FINDINGS FOR THE PLANTS

Specific findings and recommendations were discussed fully in a series of comprehensive reports of audits carried out at the selected plants. The potential for improved energy efficiency obviously varies from plant to plant, but typical improvements of 15 to 20% should be achieved on average within two years through a combination of better management and moderate capital investment.

In some of the plants, a great deal of improvement could be made with little or no investment. For example, high excess air rates were frequently found on boilers, furnaces, and kilns. In most cases, we believe that simple adjustments could save as much as 10% of the fuel. In many plants, a poor standard of instrumentation contributes to poor energy efficiency.

The reports prepared for each of the seven plants include specific recommendations for improving operating efficiencies, such as improved instrumentation, additional insulation of hot lines and tanks, better control

EXHIBIT C

ENERGY AUDIT TRAINING MANUAL

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Exhibit D
Summary & Results - Tunisia

HOUSEKEEPING	MINOR INVESTMENTS	MAJOR INVESTMENTS
• Improve site cleanliness, safety • Initiate proper record-keeping • Improve instrument and burner maintenance • Control combustion at boiler and furnaces	• Install automatic control on air/fuel for ladle heating (PBP <2 years)	• Install stack gas recuperators on reheat furnaces (savings 12.5%, PBP 2 years)
• Initiate monthly reports on energy consumption • Improve operation of fuel oil storage and handling system (e.g., better temperature control)	• Recover heat from boiler blowdown (PBP <2 years) • Improve condensate recovery (PBP <2 years) • Modify steam system to supply LP steam to deaerator	(none identified)
• Improve site cleanliness and maintenance • Initiate proper monthly energy monitoring (improve data reliability) and improve energy management Reduce water content in slurry (20% savings) Repair combustion control instruments	• Replace electric heating of fuel oil by steam heating (PBP 1 year)	(Plant is old and quarry reserves are limited; technology is outdated)
• Improved format for monthly report • No focus for energy management	• Improve clinker cooler operations (PBP not established)	(Plant is new, with best modern technology)
• Initiate proper record keeping • No focus for energy management (appoint energy manager) • Reschedule plant operations (40-50% savings) • Remove one of two air fans • Reduce losses/breakage	• Recycle hot exhaust kiln gases to dryers (12% savings, PBP <2 years) • Trials of supplementary ceramic fibre insulation (savings 4%, PBP 1 year)	(New plant, but lacks adequate instrumentation)

Exhibit D (cont'd)

HOUSEKEEPING	MINOR INVESTMENTS	MAJOR INVESTMENTS
• Reduce material losses • Improve maintenance and scheduling • Initiate proper record keeping • Study rail transport and potential losses • Improve control of fuel oil storage and handling	• Reduce water in filter cake entering dryer • Modify control system tgo control on direct measurement of phosphate exit temperature	• (none identified)
• Initiate proper record keeping • Improve maintenance • Eliminate steam leaks	• New burners for black liquor burner • Insulation on steam lines, hot fuel lines, etc. • Improve condensate recovery	• Eliminate static letdown of steam at power plant; install new turbogenerator
• Improve cleanliness, maintenance • Reduce breakages • Initiate proper record keeping • Eliminate flue gas leakages • Improve boiler combustion control	• Modify wiring system to allow selective shutdown of motors, drivers • Modify kiln gas recycle to dryers to increase heat recovery	(None identified)

EXHIBIT E
PLANT DATA

SUBSECTORS/ PLANTS MATERIALS OF CONSTRUCTION	PLANT NUMBER	OUTPUT DATA YEAR	QUANTITY	PRIMARY PRODUCT	ELEC.	NAT. GAS	GASOIL	FOD	F.O. LEGER	F.O. LOURD	OTHER	TOTAL ENERGY	SPECIFIC CONSUMPTION TEP/T
Cement													
●	B	1980	436618 T	clinker	13450	-	-	-	-	74133	-	87583	0.201
●	A	1980	721350 T	clinker	23254	-	1139	-	-	66554	-	90947	1.126
●	G	1980	482500 T	clinker	22516	39892	689	-	-	-	-	63097	0.131
●	51	1981	769624 T	clinker	30316		780	-	-	68276	9	99381	0.129
			2,410,092 T		89,536	39,892	2,608	0	0	208,963	9	341,008	0.141
Bricks													
●	C	1980	97147 T	bricks	2312	-	204	-	-	6172	-	8688	0.089
●	07	1980	178223 T	bricks	3636	-	904	-	-	12353	-	16943	0.095
●	09	1980	155540 T	bricks	2272	-	579	-	-	5728	-	8579	0.055
●	F	1980	89302 T	bricks	1200	5346	534	-	-	-	-	7080	0.079
●	23	1981	55360 T	bricks	641	-	307	-	-	3131	-	4079	0.074
●	24	1981	55000 T	bricks	860	-	271	-	-	2609	-	3740	0.068
●	14	1981	n.a.	bricks	2391	-	-	-	2777	4576	1767	11511	n.a.
●	37	1980	39985 T	bricks	642	-	17	-	-	1571	-	2230	0.056
●	48	1981	30000 T	bricks	570	-	23	-	-	1761	-	2454	0.082
			500,557 T		14,574	5,346	2,939	0	2,777	37,901	1,767	65,304	0.077
●	35	1981	4500 T	ref bricks	344	-	51	-	-	789	-	1184	0.263
Glass													
●	15	1980	17656 T	glass containers	1956	171	386	-	-	4520	1166	8199	0.464
Others													
●	03	1981	64500 T	lime	341	-	26	-	-	-	3082	3449	0.053
●	26	1980	56000 T	lime	345	-	37	-	-	-	2975	3357	0.060
●	25	1981	835000 M^2	tiles	771	-	122	900	-	4061	-	5854	0.007 TEP/M^2
●	34	1980	3600 T	porcelain	334	-	30	1714	-	-	-	2078	0.577
●	03	1980	131462 T	reinforced concrete prod.	826	-	148	28	-	1741	-	2743	0.021
●	22	1981	8209 T	plaster	169	-	90	-	-	210	-	469	0.057
●	28	1980	22100 T	asbetos tiles and pipes	956	-	-	385	-	-	-	1341	0.061
	29	1981	28000 T	asbestos cement pipes	1015	-	47	-	613	-	-	1675	0.060
TOTAL SUBSECTOR ENERGY USE					111,167	45,409	6,484	3,027	3,390	285,185	8,999	436,661	

EXHIBIT E (continued)
PLANT DATA

SUBSECTORS/ PLANTS	PLANT NUMBER	OUTPUT DATA YEAR	QUANTITY	PRIMARY PRODUCT	ELEC.	NAT. GAS	GASOIL	FOD	F.O. LEGER	F.O. LOURD	OTHER	TOTAL ENERGY	SPECIFIC CONSUMPTION TEP/T
Chemicals													
•	01	1980	70148 T	SSP, blended fertilizers	423	-	89	-	-	-	3	515	0.007
•	H	1980	3'7416 T	TSP	2159	-	-	-	-	22030	-	24189	0.076
•	38	1980	-	TSP, sulphuric phosphoric acid & Fert.	2319	12063	158	133	-	-	-	14673	-
•	33	1981	418074 T	TSP	-	-	226	-	-	17130	-	17427	0.042
•	39	1981	514974 T	DAP	2547	12580	154	-	-	-	-	15281	0.030
•	40	1980	62611 T	MAP	571	707	-	-	-	-	-	1278	0.020
•	32	1980	59965 T	mix, fertil.	935	-	129	-	-	1966	-	3030	0.051
			1,524,033	mix, fert. & related prod.	9,026	25,350	755	133	-	41,126	3	76,393	0.135
•	41	1980	19730 T	alum. fluoride	1958	3072	63	-	-	-	-	5093	0.258
•	36	1981	-	indus. gases (oxygen, CO_2 acetylene)	1696	-	-	-	-	-	957	2653	-
TOTAL SUBSECTOR					12,680	28,422	818	133	-	41,126	960	84,139	
MECHANICAL, METALLURGICAL, ELECTRICAL													
Basic Steel													
•	D	1980	177937 T	steel billets (for rolling, etc.)	30933	-	414	4025	-	21629	76480	133481	0.750
Others													
•	31	1980	2847 T	elec. cables	534	-	8	100	-	-	1	643	0.226
•	19	1980	12000 units	gas bottles	216	-	-	-	-	-	64	280 (2.3 TEP/ 1000 bottles)	
•	05	1980	19200 T	lead	1306	-	-	421	1580	-	5021	8328	0.434
•	04	1980	70338 units	household appliances	924	-	39	318	-	868	12	2161 (0.031 TEP/ unit)	
•	13	1980	8777 units	assembly of cars, trucks & buses	736	-	-	547	-	-	-	1083 (0.159 TEP/ unit)	
•	02	1980	2300 T	castings	192	-	28	154	-	-	322	696	0.290
•	42	1980	4787 T	iron & steel mouldings	15[illegible]	-	-	354	-	-	582	2440	0.510
•	44	1980	-	household fittings & ironmongery	1270	-	-	95	290	-	9	1664	-
TOTAL SUBSECTOR					37,415	-	489	6,014	1,870	22,497	82,491	150,776	

EXHIBIT E (continued)
PLANT DATA

SUBSECTORS/ PLANTS	PLANT NUMBER	OUTPUT DATA YEAR	QUANTITY	PRIMARY PRODUCT	ELEC.	NAT. GAS	GASOIL	FOD	F.O. LEGER	F.O. LOURD	OTHER	TOTAL ENERGY	SPECIFIC CONSUMPTION TEP/T
MINING													
●	J	1980	4328667 T	enriched phos. rock	40703	-	7852	1250	-	92150	-	141955	0.033
TEXTILES													
●	11	1980	13.6×10^6m	finish.textil.	106	-	-	191	-	5672	36	6005	(0.442 TEP/ 1000 metres)
●	12	1980	16.1×10^6m	denim textiles	2550	-	-	32	-	2490	193	5265	(0.327 TEP/ 1000 metres)
●	43	1980	-	cloth&thread	2365	-	-	-	11	591	-	2967	-
TOTAL SUBSECTOR					5,021	-	-	223	11	8,753	229	14,237	
PAPER													
●	1	1980	23808 T	paper	15546	-	127	259	-	27301	-	43233	1.816
FOOD PROCESSING													
Dairy Products													
●	10	1980	41×10^6L	proces. milk, yogurt	1657	-	316	13	-	1550	5	3541	(86 TEP/10^6 litres)
●	17	1980	56×10^6L	proces. milk, cheese, yogurt	1328	-	267	47	-	974	8	2624	(47 TEP/10^6 litres)
					2,985	-	583	60	-	2,524	13	6,165	
Baking, Biscuits													
●	20	1981	2210 T	biscuits	228	29	-	-	-	-	-	257	0.116
●	30	1980	3200 T (flour)	bread & cakes	24	-	51	101	-	-	-	176	(0.055 TEP/t flour)
					252	29	51	101	-	-	-	433	-
Sugar													
●	E	1980	60615 T	sugar	209	-	-	26	20	16296	509	17060	0.281
Drinks													
●	45	1980	-	beer, soft drinks, ice	1444	-	295	53	-	1758	43	3593	-
●	46	1981	1.8×10^6L	alcohol	59	-	28	19	-	827	4	937	
					1,503	-	323	72	-	2,585	47	4,530	

EXHIBIT E (continued)
PLANT DATA

SUBSECTORS/ PLANTS	PLANT NUMBER	OUTPUT DATA YEAR	QUANTITY	PRIMARY PRODUCT	ELEC.	NAT. GAS	GASOIL	FOD	F.O. LEGER	F.O. LOURD	OTHER	TOTAL ENERGY	SPECIFIC CONSUMPTION TEP/T
Others													
●	21	1981	539 T	chocolate	163	-	-	147	-	-	-	310	0.575
●	27	1981	3704 T	tomato concent.	141	-	-	-	-	657	-	798	0.215
●	47	1980	-	preserved. fruits&tomatoes	147	-	171	-	-	999	-	1317	-
●	49	1980	73988 T	flour&semolina	1543	-	56	19	-	-	-	1618	0.022
●	50	1981	9291 T	couscous	492	-	-	-	21	978	-	1491	0.160
TOTAL SUBSECTOR					7,435	29	1,184	425	41	24,039	569	33,722	
MISCELLANEOUS													
●	08	1980	8200 T	misc. house-hold articles	1519	-	66	-	-	-	10	1595	0.195
●	16	1980	160000 units	tyres	802	-	-	-	24	1667	5	2498	(15.6 TEP/ 1000 units)
					2,321	-	66	-	24	1,667	15	4,093	

EXHIBIT F

HEAVY FUEL OIL CONSUMPTION -- CUMULATIVE

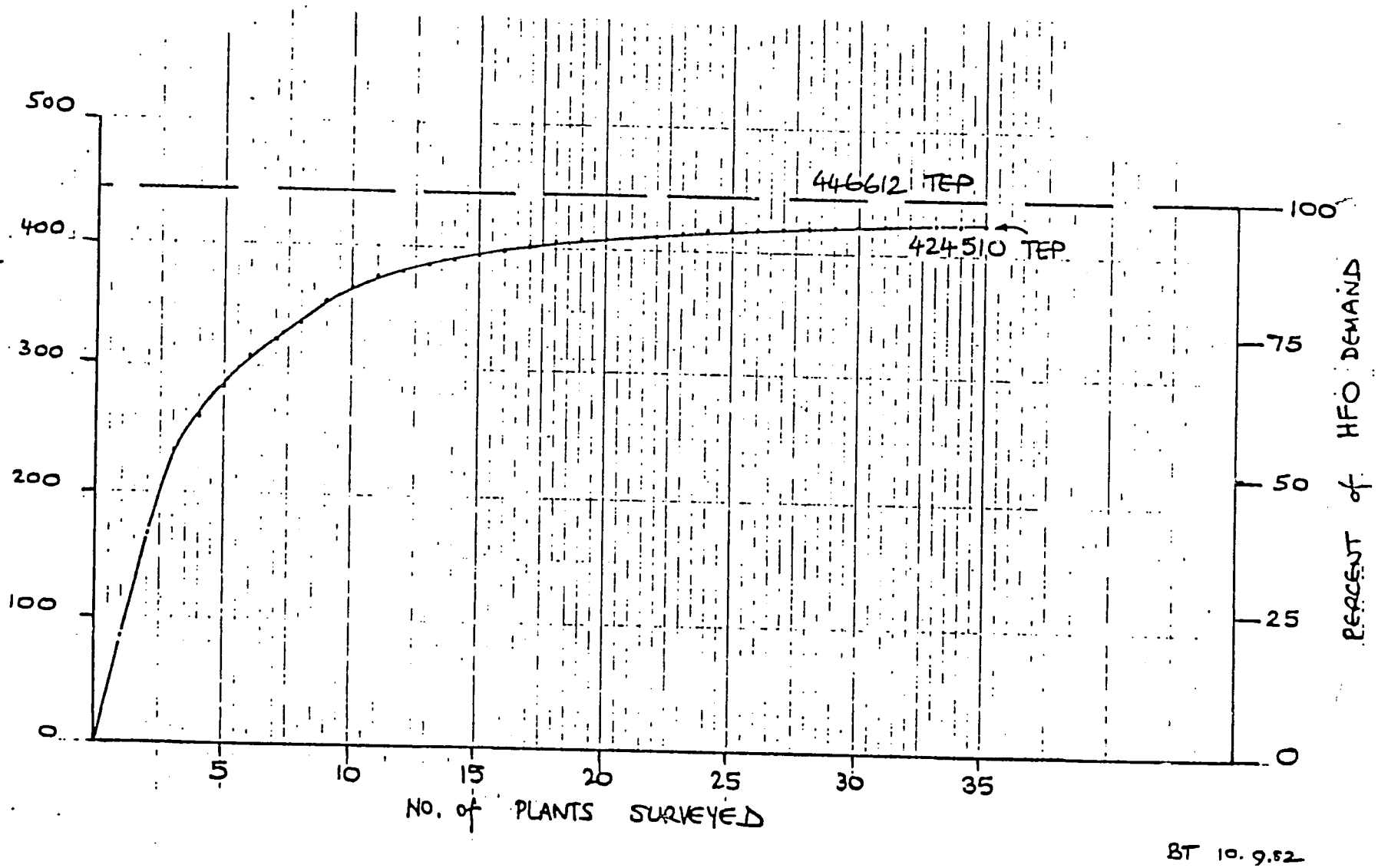

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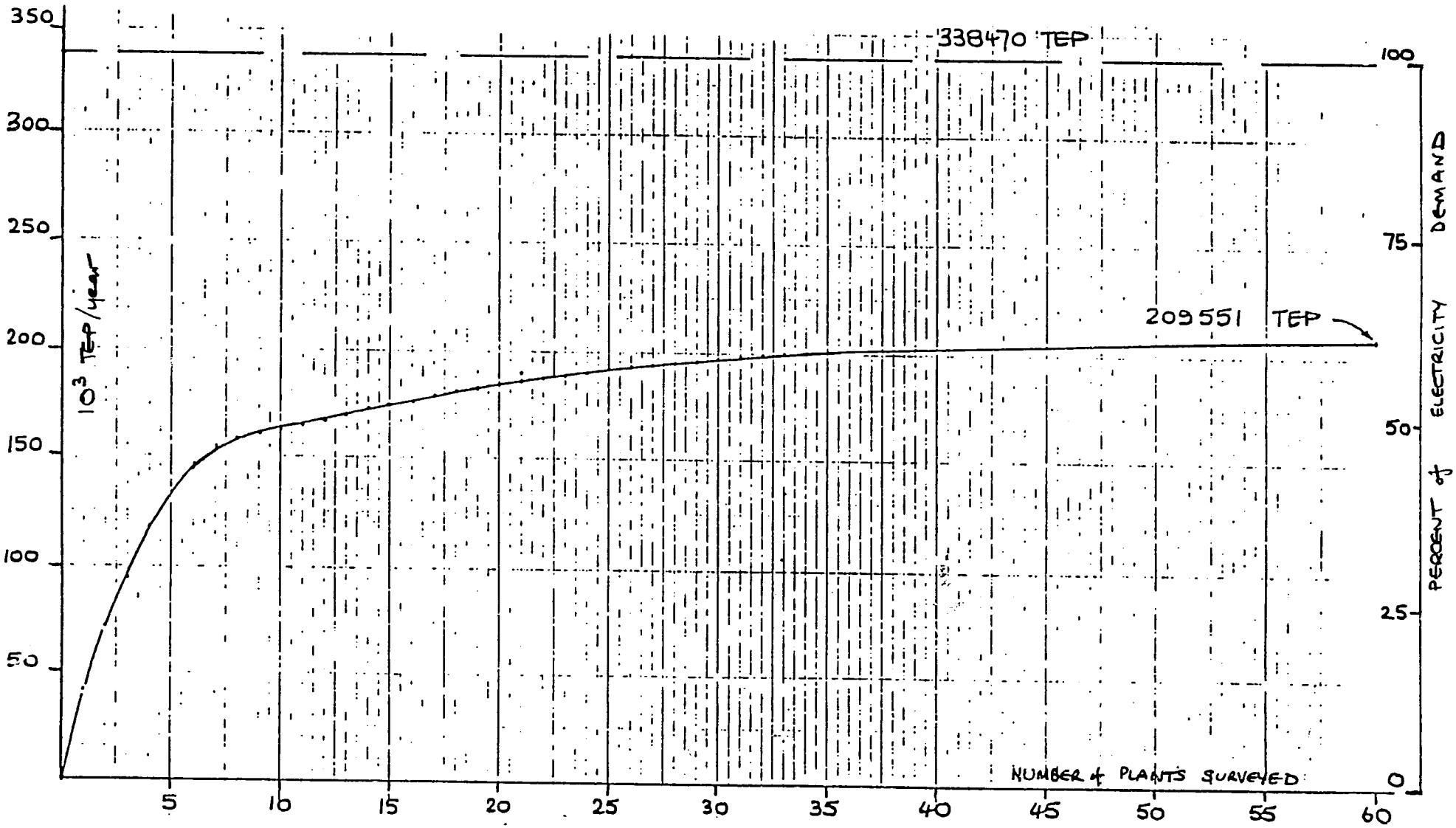
EXHIBIT G
CUMULATIVE ELECTRICITY CONSUMPTION



of fuel-to-air ratios, and the installation of waste heat recovery systems (see Exhibit D).

1.6 ENERGY DATA COLLECTION

To assemble comprehensive data on industrial sector energy consumption, it was decided to collect data on the supply side from the distributors of oil products, gas, and electricity, and on the demand side from a total of 60 industrial consumers. Data on energy consumption and industrial production available from the national statistics institute (INS) were also examined. Examples of the data collected from plants are given in Exhibit E.

1.7 ENERGY USE BY THE INDUSTRIAL SECTOR

An examination of the data from plants and distributors show that the sample of 60 plants represents a coverage of over 80% of the energy consumed in the industrial sector. For the fuels used by large factories, coverage was considerably higher: for heavy fuel oil, the sample represented 95% and for natural gas 98% of industrial sector use of the respective fuels, and somewhat less for electricity (see Exhibits F and G).

An estimate of the energy consumed in the industrial sector was made for 1980, with the following result:

	10^3 TEP	%
Materials of construction	417.1	39.8
Chemicals	96.4	9.2
Mechanical, metallurgical, electrical	166.1	15.8
Mining	178.9	17.1
Textiles	42.9	4.1
Paper	44.7	4.3
Food Processing	89.3	8.5
Miscellaneous	12.1	1.2
	1047.5	100.0

It was also estimated that industry represents at least one third of the national consumption of commercial fuels, and between 25 and 30% of the total national energy demand.

Although the plant survey covered the 60 largest plants, the energy patterns derived from this project are believed to represent the sector as a whole. In any case, it may be concluded that policy initiatives and plant-level work aimed at relatively few large energy consumers could have a significant impact on the national energy situation. Policies and programs for improving the efficiency of the major energy consuming plants should receive a high priority.

The percentage of selling price represented by the cost of energy was calculated for major products (see Exhibit H). Other types of data analysis

Exhibit H
Energy Costs in Relation to Product Prices

Products	Energy Cost/Selling Price (%)
Steel (reinforcing bars)	35
Lime	31
Plaster	28
Cement	24-25
Bricks	24
Glass bottles	18
Paper	17
Enriched phosphate rock	12
Sugar	8
Couscous	7
TSP	5
Milk	3
Bread	3
Tomato concentrate	3
DAP	2
Household appliances	2
Textiles	2
Flour	1
Camionette	0.3

Source: E/DI Europe Ltd., based on data from Tunisia (1980, 1981).

Exhibit I
Energy Consumption and Output Per Employee

		Employees	Energy Consumption TEP/Employee	Output Per Year TEP/ Employee
I	MATERIALS OF CONSTRUCTION			
	Cement	650	135	672
		650	140	1110
		540	117	894
		511	194	1506
		2351	145	1025
	Bricks	220	39	442
		500	34	356
		250	34	622
		250	28	357
		145	28	382
		174	22	382
		700	16	N/A
		96	23	417
		150	16	200
		2484	26	393
		105	11	43
	Glass	508	36	35
	Others	150	23	430
		130	26	431
		278	21	-
		283	7	13
		1130	2	116
		96	5	86
		310	4	71
		150	11	190
II	CHEMICALS	230*	2	305
		570	42	557
		600	24	-
		490	36	853
		110	28	545
		555	28	928
		75	17	835
III	MECHANICAL, METALLURGICAL, ELECTRICAL			
	Steel	2400	56	74

Exhibit I (Cont.)

		Employees	Energy Consumption TEP/Employee	Output Per Year TEP/ Employee
	Others	174	4	16
		420	1	-
		530	16	36
		1000	2	-
		1600	1	-
		404	2	6
		580	4	8
		900	2	-
IV	MINING	13500	11	321
V	TEXTILES	700	9	-
		970	5	-
		950	3	-
		2620	5	
VI	PAPER	1700	25	14
VII	FOOD PROCESSING			
	Dairy	327	11	-
		435	6	-
	Baking, biscuits	128	2	17
		48	4	-
	Sugar	435*	39	139
	Drinks	970	4	-
		56	17	-
	Others	64	5	8
		108	7	34
		300	4	-
		220	7	336
		69	22	135
VIII	MISCELLANEOUS	330	8	-
		270	6	30

*Includes seasonal workers

were carried out; for example, Exhibit I shows a table of energy consumption and output per employee, which can be used as a guide for national planning purposes.

1.8 PROJECTED ENERGY DEMANDS

An estimate of industrial energy consumption was made for 1986 using subsector growth rates taken from reports on the National Plan. Assuming no change in energy use patterns and in the current energy efficiencies, the total industrial sector demand may be expected to increase to over 2 million TEP by 1986 from the level of about 1 million TEP in 1980.

An examination of fuel substitution possibilities was made and an estimate of the potential for natural gas was made. With a very vigorous gas conversion program, it was estimated that industry could be using almost 900,000 TEP per year by 1986/87.

1.9 POTENTIAL FOR ENERGY CONSERVATION

The prospects for energy conservation obviously vary from plant to plant. For the seven plants audited this project, comprehensive reports were prepared which included specific recommendations for improving plant operating efficiency, and these recommendations were discussed extensively with plant managements.

At a "macro level", examination of the energy data was conducted for each industrial subsector. An example of the analysis for the brick industry is shown in Exhibits J and K, indicating the adverse impact of low capacity utilization, which appears to be quite important. From the results of the audits and the visits to the other plants in the survey and of a review of specific energy consumption data, estimates of the conservation potential were made for each subsector. Through a program of "vigorous conservation", it was estimated that industry demand could be cut by about 13% compared with the "business-as-usual" estimation by 1986/87. By "vigorous conservation", we mean a major program of housekeeping and energy management improvements throughout the industrial sector, and investment in all conservation measures showing reasonable payback periods (say 3 years or better). For new plants, we imply a thorough examination of design parameters and the incorporation at the design stage of cost effective energy-saving measures to a greater extent than typically included in conventional plant designs.

The "vigorous conservation" case presents a very difficult challenge for industry and may take longer than 1986/87 to be fully realized. We therefore, suggested a more realistic scenario for quantifying the probable impact of conservation by 1986. Briefly, this requires that serious efforts be made in the largest of the existing plants to improve energy management (in all 60 plants covered by the current survey, for example) and assumes that these efforts achieve 70% of the full potential by 1986. We also suggest that 50% of cost-effective capital investments are actually effected in existing plants by 1986, and that new plants are commissioned with energy efficiencies 15% better than current subsector averages.

EXHIBIT J

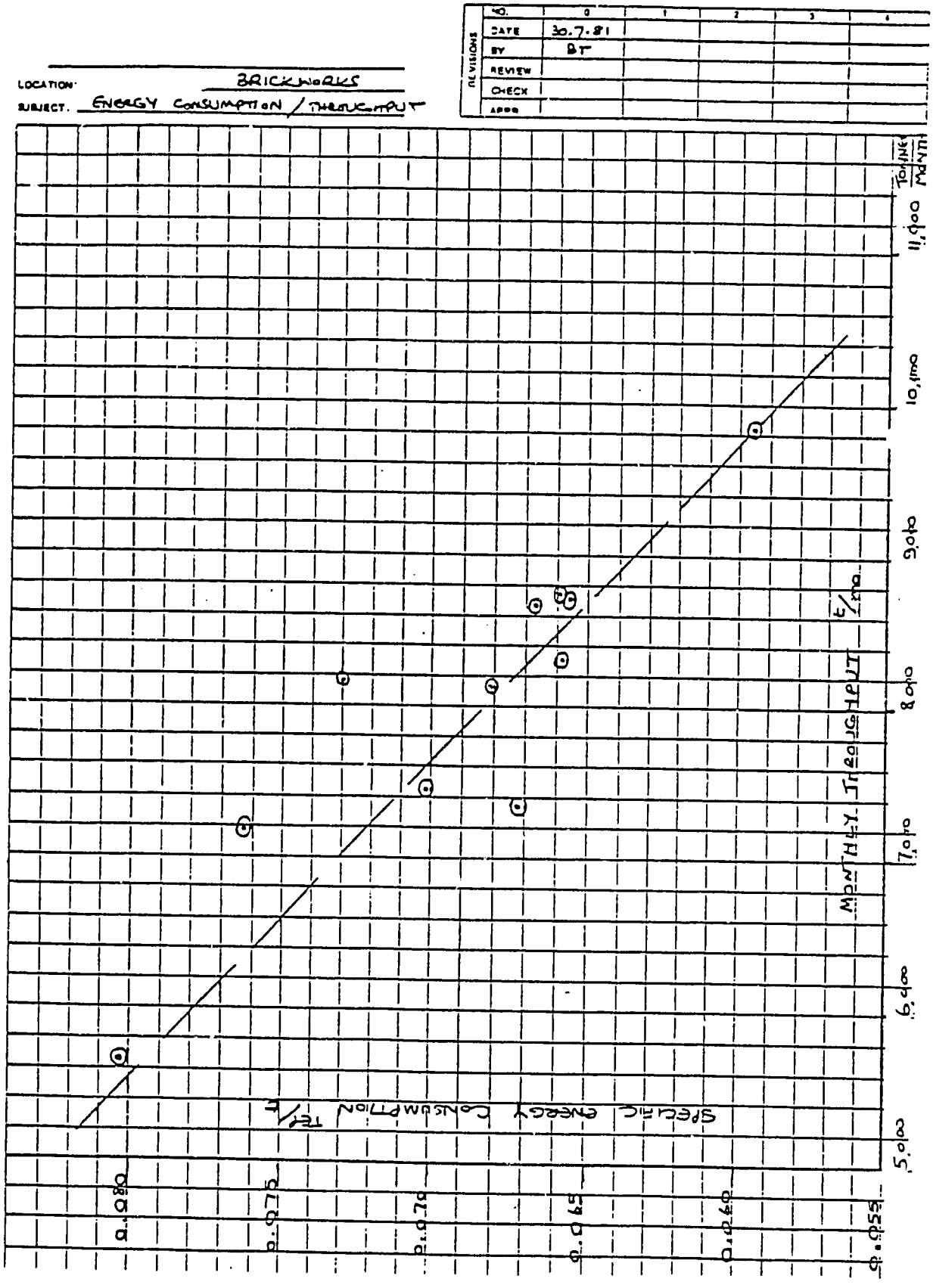
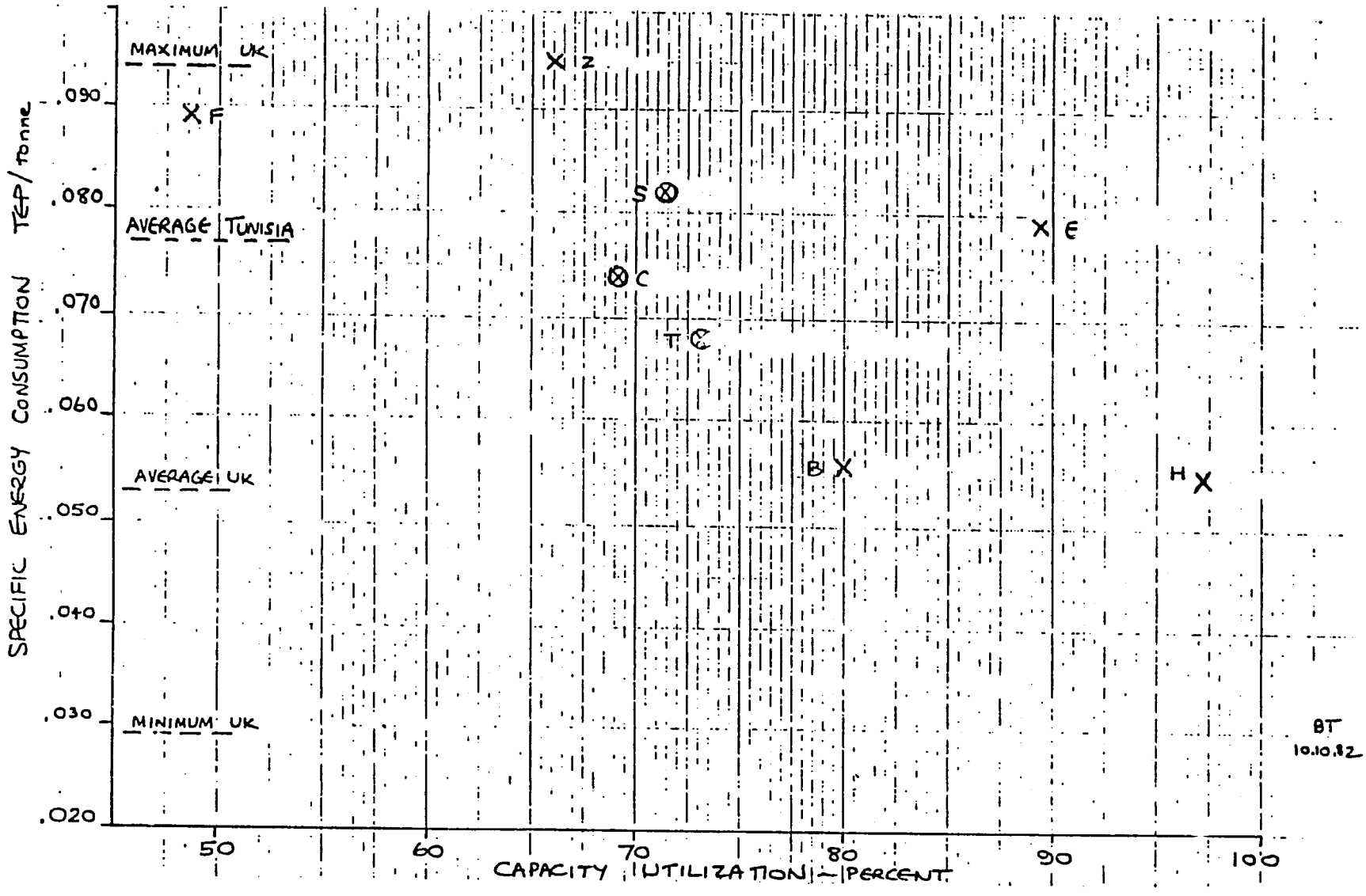

LOCATION: BRICKWORKS
SUBJECT: ENERGY CONSUMPTION / THROUGHPUT
REVISIONS
NO. 0 1 2 3 4
DATE 30.7.81
BY BT
REVIEW
CHECK
APPR
Specific Energy Consumption TEP/t
0.080
0.075
0.070
0.065
0.060
0.055
Monthly Throughput t/mo
5,000
6,000
7,000
8,000
9,000
10,000
11,000
Tonnes/Month

EXHIBIT K
BRICKWORKS PERFORMANCES



The benefits obtainable under this scenario were estimated to reach about 220,000 TEP per year by 1986 over the "business-as-usual" case:

	10^3 TEP
Housekeeping contribution in existing plants	72
Contribution from investments in existing plants	26
Contribution from improved efficiency of new plants	122
	220

The contribution from improvements in new plant efficiency are clearly important and most of these savings will probably be obtained with relatively minor efforts by Tunisian industry. This is because technical improvements to plants will occur through the normal competitive pressures of the market place. A more active involvement of plant engineers seeking higher levels of efficiency could probably contribute even more significant savings.

For the "realistic" scenario, the cumulative savings from 1982 through 1986 — excluding the contribution from new plant improvements — amount to about 50 million dollars at world market prices. About one-third represents the contribution of capital investments of around 24 million dollars over a four year period to the end of 1986 (see Exhibit B).

The resources for promoting conservation in terms of manpower and equipment which can be justified by the 50 million dollars are clearly substantial. The potential also supports our strong recommendation that energy managers be appointed at the plant level, as full-time staff for all large plants and part-time at others. Without a major effort to focus attention on energy problems, an effort in which energy managers have a key responsibility, the undoubted potential for conservation will not be realized.

1.10 RECOMMENDATIONS FOR DATA COLLECTION

Comprehensive data are essential for energy planning at the national level. To provide timely and accurate energy data which are not currently available, it was recommended that a regular annual report be obtained from major energy consumers, and that reports be obtained from the distributors of petroleum fuels, electricity and gas on their sales of energy products to the industrial sector.

The annual report from industrial companies should be concise and should include energy and production data. To be of use for planning purposes and for monitoring energy consumption in the industrial sector, the data must be collected promptly each year. A specific individual should be nominated by each factory to complete the report, preferably the energy manager. The report should include a simple calculation of specific energy consumption and a comparison with the previous year made to bring energy efficiency to the attention of all concerned.

The assembly of data and its analysis could best be performed in future years with the aid of electronic data processing. A complex computerized

system could be counterproductive, and we strongly recommend an interactive microcomputer system be utilized.

1.11 RECOMMENDATIONS FOR FUTURE WORK IN TUNISIA

The potential for improved energy efficiency in the industrial sector has been shown to be very large indeed by the current project. To realize the potential savings available, the government of Tunisia needs to create a permanent industrial energy conservation capability including an ability within the private sector to conduct audits and implement recommendations. However, the attainment of significant savings cannot rely solely on a technical approach: the development and implementation of effective government policy must be given its due priority.

We therefore recommend that the government set up a permanent program:

(1) To encourage and assist industry to use energy more efficiently through improved operating practices and through investment in new equipment.

(2) To support energy policy development by creating and maintaining an industrial energy data base for monitoring consumption and for the analysis of policy options.

The program relies on positive but limited government intervention. We recommended an "Industrial Energy Efficiency Group" (IEEG) be formed, with two sections:

(1) A Technical Section to be responsible for technical assistance services such as plant surveys, brief audits, development and management of plant-level conservation programs, equipment specifications, and special studies. This section should act as a catalyst for action by the enterprises themselves rather than a resource which can carry out all the necessary work.

(2) A Policy and Analysis Section responsible for regular data collection and analysis, coordination of training programs, preparation and dissemination of publicity materials and technical information, and the support necessary for developing national energy policies and legislative initiatives.

We believe it is most important that the two sections work closely together; each can be highly effective as part of a combined operation. We do not believe either section working alone would be as effective, and it would be a mistake to proceed with a program relying on the activities of one or other of the sections in isolation.

It is essential the IEEG be given authority to act independently and be allocated the necessary resources of manpower and equipment. Strong leadership is essential too, as the work of the group will be a blend of technical work and public relations, with much of its success relying on the establishment of credibility with industrial enterprises.

2. VISITS TO INDUSTRIAL PLANTS IN TOGO

In preparation for this seminar a series of plant visits were made in and around Lome. The visits were used to select a suitable plant for the planned field trip, and to gain a general idea of the present energy situation in the Togolese industrial sector. The plants visited were:

(1) CIMAO clinker manufacture
(2) SNS steelworks
(3) CIMTOGO clinker grinding plant
(4) Brasserie du Benin brewery
(5) SOTOMA brickworks and marble processing plant
(6) OTP phosphate processing complex

Brief summaries of the data collected and our observations are attached.

Plant visited: Les Climents de l'Afrique de l'Ouest (CIMAO)

Date: 16 Dec 1982

Contact: Messrs. Philippe, Lawson

Activites: This plant was commissioned in 1980 and produces cement clinker using local materials. It is jointly owned by the Governments of Togo, Ghana and the Ivory Coast. There are about 500 employees. The plant consists of two Polysius-designed 4-stage suspension preheater kilns, each with a capacity of about 600,000 tonnes per year. Raw materials are obtained from adjacent quarries and held in a covered stockpile close to the kilns. Moisture content averages about 14%, but can range from about 8% in the dry season to 18% in the rainy season. The raw materials are processed in ball mills (one for each kiln) in which heat is recovered from kiln exhaust gases; a supplementary burner for drying is also installed. The 4-stage suspension preheaters and kilns are conventional modern designs, with clinker cooling accomplished in exterior orbital cooler pipes. Clinker is transferred to storage silos prior to transport by rail to CIMTOGO for grinding and blending for the manufacture of cement, or to the port at Lome for direct export. Total investments, including the railway and port facilities, amounted to 67.5 billion CFA francs.

Main energy consuming equipment: This is a modern conventional cement plant. Major energy use is as follows:

(1) Electricity (raw material grinding and kiln rotation)
(2) Heavy fuel oil (kiln firing)

Electricity is purchased from the grid, and fuel oil is received by the railway system.

Observations:

(1) Fuel oil is held in heated storage tanks and is also preheated prior to firing in the kilns. A thermal fluid system is used and a small boiler is always on-line to heat this fluid to about 120°C. The fuel oil tank is held at about 70°C, which appears rather high (50°C would probably be sufficient). The fuel oil tank also appears to be uninsulated.

(2) The thermal fluid boiler has a fully automatic Klöckner pressure jet burner system, but there is no means of measuring the stack temperature or stack gas oxygen content. There is, therefore, no way of checking combustion efficiency. Of course, the quantity of fuel burned in the thermal fluid boiler is only about 190 kg/h, which is under 2% of the total plant fuel oil consumption.

(3) The fuel is preheated from around 70°C to 90°C immediately prior to the main kiln burners (Paillard MY Simplex, pressure jet burners).

(4) The oxygen content of the kiln exit gases is monitored continuously and is normally maintained at a maximum of about 1.5%. One kiln was operating at 0.5% during our visit. The CO content of the gases is also monitored and should be at a very low level if combustion is properly controlled. Readings were very low on our visit.

(5) The standard 4-stage SP system operates effectively, kiln gases entering stage 1 at 1200°C and leaving stage 4 at 300°C.

(6) All electricity is purchased from the grid: no electricity is self-generated. The supply was said to be quite reliable, with few voltage reductions or power cuts.

(7) The kilns are stopped every 3 months or so for refractory brick repair. This seems to be rather frequent and should be checked.

Energy consumption data: Data for a typical month were obtained (October 1982):

Clinker produced	71,367 tonnes
Electricity consumed	5.336 million kwH
Fuel oil consumed	7,033 tonnes (PCI 9850 kcal/kg)

Thus electricity use is equivalent to about 75 kwh per tonne of clinker, and overall fuel use is 970 kcal/kg of clinker. For the kilns only, fuel use is about 915 kcal/kg. These figures are quite reasonable in comparison to international standards, although the fuel figure of 970 kcal/kg is somewhat high (probably due to the relatively high moisture content of the raw materials).

Remarks:

This plant utilizes the latest modern cement-making technology and appears to operate well up to international standards. While it is usually possible to make some energy savings in all plants, the potential for energy efficiency improvement is not believed to be very great in this plant. However, it should be noted that the kilns are currently operating at around 70-75% of maximum capacity; for maximum energy efficiency, the plant should be run as close to maximum capacity as possible.

Finally, it should be noted that a monthly report is produced for the plant, and that both electricity and fuel oil consumptions are checked regularly and specific energy consumptions are calculated each month.

Plant visited: Societe Nationale de Siderurgie (SNS)

Date: 16 Dec. 1982

Contact: M. Sikpa

Activites: This plant is an integrated steel mill, producing reinforcing steel bars primarily from local scrap. The Swiss-designed plant was commissioned in January 1979, and was built at a cost of about 14 billion CFA francs. It is owned by the Government of Togo. The plant consists of a scrap preparation section, an electric arc furnace for steel making, and a reheat furnace and rolling mills. The annual capacity of the arc furnace is about 20,000 tonnes, and that of the rolling mills is 40,000 tonnes, but production is currently running at under 9,000 tonnes per year. About 30% of production is used in Togo, and up to 70% is exported to Upper Volta, Benin, and Niger.

Main energy consuming equipment: The main energy forms consumed are:

(1) Electricity in the arc furnace
(2) Gasoil in the reheat furnace

Electricity is purchased from the grid: the plant is located about 200 meters from a new power plant, which has two 30 MW gas turbines in service (and four 10 MW diesel generators being installed). Gasoil is supplied by road tankers.

Observations: Unfortunately the plant was shut down during our visit, but is is possible to make the following comments:

(1) The steel mill may be divided into two main sections, the steel-making section and the rolling mills.

(2) The steel-making section includes feed preparation, where local scrap (and a minor amount of imported scrap) is cut into small pieces prior to loading into the arc furnace. The furnace itself has a capacity of 15 tonnes and can operate up to 5 hours per day in full three-shift operation. The heating cycle for the furnace is about 4 hours. Three electrodes are fitted.

(3) The composition of the steel produced is adjusted by addition of various chemicals and additives. Carbon content may be controlled by oxygen lancing, oxygen being supplied in cylinders.

(4) The arc furnace may be tipped to pour the molten steel into ladles. The ladles themselves are preheated using gasoil burners; the ladle lids were not well insulated. The ladles transfer molten steel to the casting section, where ingots are cast and later stockpiled outside the rolling mill building. Ingots typically weigh 150 kilogrammes.

(5) Prior to rolling, the ingots are reheated in a furnace fired with gasoil. The reheat furnace requires a heating period of about 2 days from a cold start and is supposed to operate continuously. The ingots are heated to about 1200°C in the furnace.

(6) The reheat furnace is a conventional pusher furnace fired by gasoil. It appears that the furnace could be fired on heavy fuel oil but "supplies" were stated to be a problem. This should be investigated, as the heavier fuels are cheaper than gasoil.

(7) The furnace has North American burners, with separate forced draft primary and secondary air ducts. There is no automatic fuel/air ratio control, and no measurement of oxygen/carbon dioxide in the stack gas. The stack gas temperature is not measured. There is, therefore, no means of checking combustion efficiency.

(8) The furnace insulation appears to be ordinary brick and, thus, heat loss should be checked when the plant is operating normally.

Energy Consumption Data: Data were obtained from the plant and from the power station. We noted several discrepancies, including the fact that ingot production was said to be about 3,500 tonnes greater than rebar production, and yet the stack of ingots seen on-site was only perhaps 100 to 200 tonnes. We do not believe the data are reliable, but report these in any case in Exhibit A, together with some calculated ratios, such as electricity consumptions per tonne of product.

It will be seen that the electricity consumption in the arc furnace fluctuates quite broadly, while oxygen consumption is extremely variable, according to the data provided. The electricity and gasoil consumptions for the rolling mills are also extremely variable; better records should be kept as a start to improving energy management.

Remarks

In general, we would recommend a much greater attention to the collection of reliable energy and production data by plant management. The plant itself did not have electricity consumption data for the rolling mills separately from the arc furnace consumption, for example. We understand that the new management team took over in September and it is, therefore, hoped that data (and energy management) will improve. The potential for energy saving cannot be judged at this time; plant tests are recommended as soon as steady operation is achieved. It is particularly important that the reheat furnace be operated at high throughput whenever possible: it is preferable for the ingots to be stockpiled and the furnace to be run at maximum rate for say 1 to 2 months and then shut down while the stock is rebuilt. In our judgment, this plant uses reasonably modern technology, but does not appear to have been designed for optimum energy efficiency as it lacks good instrumentation in many areas.

EXHIBIT A - 1982 DATA FOR SNS

	January	February	March	April	May	June	July	August	September	Totals
STEELMAKING SECTION										
Ingot production (tonnes)	1640	1634	1061	plant down	1521	1284	441	1272	1320	10,173
Electricity consumed (10^3 kwh)	1089	1137	795		1068	929	318	898	1016	7250
Oxygen consumed (10^3 CFA francs)	2406	4410	10,572	4301	3292	4111	10,397	6034	8409	53,932
Electricity (kwh/t)	664	696	749	-	702	724	721	706	770	713
Oxygen (francs/t)	1467	2699	9964	-	2164	3202	23,576	4744	6370	5301
ROLLING SECTION										
Product (tonnes)	487	1049	1035	511	602	1097	714	171	976	6642
Ingots processed	4181	9708	8956	4661	5990	10,416	5964	2019	9516	63,430
Ingots/tonne	8.59	9.25	8.65	9.12	9.95	9.49	8.35	11.81	9.75	9.55
Electricity consumed (10^3 kwh)	362	441	279	234	381	464	277	270	384	3092(1)
Electricity (kwh/t)	743	420	270	458	633	423	388	1578	393	466
Gasoil consumed (metered,lit)	45,440	90,850	83,279	44,781	65,200	92,826	50,024	32,303	95,117	599,830
Gasoil (litres/t)	93.3	86.6	80.5	87.6	108.3	84.6	70.1	188.9	97.5	90.3
Hours operational	102	226	167	136	163	252	98	40	184	1368
Tonnes/hour	4.77	4.64	6.20	3.76	3.69	4.35	7.29	4.28	5.30	4.86
Good product as % of total tonnage processed	94.2	91.0	92.3	92.0	86.9	91.0	96.0	78.5	88.0	-

(1) These figures obtained by difference from the total consumption reported by the power plant and the electric arc furnace consumption figures.

Plant visited: CIMTOGO

Date: 17 Dec 1982

Contact: M. Brenner

Activites: This plant is owned 50% by the Togolese government and 50% by private interests, and was originally commissioned in 1971. The plant grinds cement clinker and blends this with gypsum, imported pozzolanic material, sand, and other additives to produce a range of finished cements in bags. The plant produces sufficient cement for the entire Togo market, and also exports finished cement. Clinker from CIMAO is loaded into ships through the jetty located adjacent to the CIMTOGO plant.

The plant was originally constructed with one grinding mill to produce 150,000 tonnes/year, operating entirely on imported clinker. Expansions in 1977 and 1980 have resulted in a current grinding capacity of 850,000 tonnes/year. It is intended that all the Togolese portion of the CIMAO plant production will be ground by CIMTOGO (planned to be up to 300,000 to 350,000 t/y) to satisfy the local markets currently about 220,000 t/y, as well as for exports to Upper Volta and Niger, currently running at about 40,000 t/y.

Main energy consuming equipment: Almost all the energy used in the plant is electricity for grinding mills, although some gasoil is used in a rotary dryer for the imported pozzolan. The electrical power factor is greater than 0.85.

Observations:

(1) The plant appears to be well maintained and efficiently operated. Cements are produced to French standard specifications.

(2) Quality problems are sometimes experienced due to density (quality) variations in the CIMAO clinker. This can have some effect on energy use as the energy used for grinding can be adversely affected.

(3) Grindings aids have been tested but have not been found useful.

(4) As the plant is not running at full capacity, grinding is often carried out at night to minimize electricity costs:

23 CFA francs/kwh day rate
19 " " " night rate

(5) The pozzolan drier is a rotary type, with once-through air flow (no recycle). A Saake rotary cup burner is installed, rated at 500 kg/hr maximum.

(6) Plant problems are currently related to economics rather than energy. Cement production for 1983 is expected to be about 260,000 t/y, although capacity is 850,000 t/y. CIMAO clinker prices are high, and the local cement price is controlled by the government.

Energy consumption data: Data on electricity consumption were provided by the plant:

	Consumption (kWh)	Production (tonnes)	kWh/t
1979	10,534,000	297,615	35.4
1980	10,561,000	303,042	34.8
1981	9,804,000	278,472	35.2
First 9 months, 1982	-	207,974	-

In addition, it appears that about 15 litres of gasoil are consumed per tonne of pozzolan processed in the dryer, that is, about 655 tonnes per year of gasoil:

$$260{,}000 \text{ t/y} \times 20\% \text{ pozzolan} \times \frac{15}{1000} \times 0.84 \text{ SG} = 655 \text{ t/y}$$

A figure of 20% pozzolan content is assumed for the calculation, although it was stated that up to 25% pozzolan can be included in finished cement. The total of 655 tonnes/year seems rather high and should be checked, as control appears be be maintained solely on the product exit moisture content and not on the exit gas relative humidity. There is no combustion efficiency monitoring, but the burner has automatic air/fuel ratio control.

The cost of the electricity represents around 3% of the final cement selling price.

Remarks:

The plant appears well operated and efficient in its use of energy. Potential savings are probably quite limited, therefore.

Plant visited: Brasserie du Benin

Date: 20 Dec 1982

Contact: M. Ayayi Ajavon

Activites: This plant is primarily a brewery, although it also produces soft drinks. The plant is jointly owned by private German and Togolese interests, and was initially set up in 1966. It has been expanded on several occasions since then, the latest being in 1981, and currently there are 470 employees. Several types of lager and Guinness are brewed. There are two boilers of 10 t/h steam capacity, although only one is normally in operation at a time. Each boiler operates for about one week. The boilers are fired about 50% of the time on gasoil and 50% on heavy fuel oil. There are five 50 CV ammonia compressors for the main refrigeration system, as well as a number of air compressors, gas liquifiers, pumps, etc.

The process is a conventional brewing process, with fermentation followed by cooking, and then filtration of the product. Roasted malt is imported. Carbon dioxide produced during the brewing is collected, compressed, and liquified: it is used primarily for the manufacture of soft drinks. The beer is packed in cans (one line, 25,000 cans/hour) or bottles (one line, 12,000; one line, 30,000 bottles/hour).

Main energy consuming equipment: Heavy fuel oil and gasoil are used in the boilers, and electricity is used throughout the plant to drive ammonia and air compressors, bottling lines, pumps, lights, etc. Some diesel oil is used occasionally for the emergency electricity generator sets (three 340 KW), although the grid electricity supply is generally very reliable.

Observations:

(1) The boilers are designed for 8-bar steam generation and are fitted with Saake rotary cup burners. Fuel and water are metered, and full instrumentation is fitted, including automatic stack dampers and fuel/air ratio control. Forced draft fans are fitted.

(2) Regular checks of boiler efficiency are carried out by the plant technical staff. We were able to use a portable stack gas analyzer and check the boiler efficiency with the plant technician for various firing rates (1 lowest; maximum setting would be 10):

Firing position	1	1	5.5	5.5	8
Oxygen %	6.1	6.2	5.7	5.8	4.3
Temperature °C	160	164	210	206	222
Efficiency %	82.8	82.5	80.4	80.6	80.6

These figures are good, and show that the boiler is well adjusted for automatic air/fuel ratio control over a wide firing range. It may be possible to improve combustion conditions by reducing the oxygen content to say 2 or 3%, resulting in an efficiency improvement of about 1 to 2 percentage points.

(3) The boiler, as well as being well instrumented, was properly maintained, clean, and well insulated. Heat loss from the structure is thus properly controlled.

(4) The general level of lighting is good where necessary, and it was noted that lights were turned off at idle work stations. Most lighting is fluorescent.

(5) Maximum condensate recovery is practiced.

(6) All utility piping was color-coded and tanks and lines were properly insulated where necessary.

(7) Water evaporated from the cookers (evaporators) amounts to about 18%, and this is vented to atmosphere. There appears little prospect of heat recovery being economically viable.

(8) Water recycle is practiced in the bottle-washing machines, with the final used water rejected to drain.

Energy consumption data: Some energy data were provided, but corresponding production figures were not supplied at the time. The figures for November 1982 were:

Consumptions

Water	127,000 M^3
Electricity	457,000 kWh
Gasoil and fuel oil	205,000 litres

It was stated that the plant runs typically at a production rate of around 500,000 hectolitres/year.

Remarks:

This is a well run factory and we doubt that significant further energy savings can be made. The boiler operation is particularly good, and the regular monitoring of performance and adjustment of firing conditions is a model of good energy management.

Plant visited: SOTOMA

Date: 21 Dec 1982

Contact: Messrs. Akitani and Djato

Activites: This factory produces marble items from roughly quarried blocks, and also manufactures bricks. A section for the production of ceramic tiles is currently shut down due to adverse market conditions. The marble quarries are located about 120 and 200 km from the factory, and the activities at the factory consist of various types of stone cutting and polishing. Electricity is used for the machines.

Of major interest from an energy point of view is the brickworks section. A clay quarry 15 km from Lome and another close to the plant are used for the raw materials. Four batch brick kilns are installed, preceded by a large drying chamber into which kiln exhaust gases can be blown to hasten the drying of the raw bricks, hourdis, and tiles. The brick kilns are fired using cotton linters (residues) and some coke and husks from coconut palms. Wood is used only to start the fires. Until a few months ago, the kilns were fired using heavy fuel oil: conversion to cotton residues means that fuel costs have been reduced by about 90%, and a locally available waste product is being used effectively.

The brickworks, whose capacity is about 60 tonnes/day, uses the conventional brickmaking process. Clay and sand are mixed with water and extruded into the required form. Individual bricks are wire cut and stacked on pallets for drying. After drying, the bricks are fired for about 24 hours.

Main energy consuming equipment: In the brickworks, essentially all the energy consumed is in the form of cotton linters for firing the brick kilns. Minor amounts of electricity are used for materials handling, such as clay and sand mixing.

Observations:

(1) The brick kilns (clamps) are of standard design and are now becoming rather old. The batch firing method is not the most efficient means of brick manufacture available, but is appropriate for small-scale brick production and is an effective way of using a locally available waste product as a fuel.

(2) The consumption of fuel for brickmaking was about 60 litres oil per tonne when fuel oil was used (approximately 6000 kcal/tonne). About 6 tonnes of cotton linter are used per furnace per batch of bricks fired, representing a similar specific energy consumption.

(3) Cotton linter waste is available at a rate of about 18,000 tonnes/year, and the brickworks currently uses about 2,500 tonne/year at a cost of 5000 CFAF/t to produce 18,000 tonnes of bricks. The original plant design capacity was 27,000 tonnes/year, but the age of the equipment is such that this is no longer possible.

(4) There is no appreciable amount of carbon in the clay used for the bricks in Togo and, therefore, all energy input comes from the fuel fired in the kilns.

(5) A high brick reject rate is caused by overfiring parts of the brick stacks, but the operation is still economically viable.

(6) The marble handling section is essentially a craft industry using entirely electricity. The potential for savings is negligible. No lights were left on, and machines were switched off when not attended. There may be some potential for improving the cutting techniques by using diamond-tipped saws rather than simple steel cutters.

Energy consumption data: A figure of 21,700 kwh of electricity was quoted for a recent month, and the cotton linter consumption was stated to be about 2,500 tonnes/year.

Remarks:

This plant provides an excellent example of the effective use of locally available waste materials as a source of energy. The cost of fuel has been reduced to such an extent that we do not believe that conventional attempts to economize on fuel use will be economically viable. At the present time, the ready availability of cheap fuel is assured, and conservation efforts are hardly relevant.

Plant visited: Office Togolais des Phosphates (OTP)
Processing Complex

Date: 17 Dec 1982

Contact: M. Moukaela

Activites: This plant, which is owned by the government, beneficiates phosphate rock mined about 35 km away from the site, which is placed on the coast for acess to water used in the processing. Essentially all the production is exported by ship.

The phosphate rock is mined open cast and is brought to the plant by train: about 25 to 30 trains per day discharge around 20,000 t/d of rock (63-66 BPL quality) which is processed to raise the phosphate content to 78-80 BPL. About 25 years of reserves remain in the ground. The process consists of slurrying in seawater the rock which arrives in a powdery form direct from the mines, removing very large oversized particles in a vibratory sieve, and then removing large and fine cuts of steriles in two stages of hydrocyclones before drying the required "heart cut" in fuel-oil-fired rotary driers.

The removal of steriles is carried out in five similar processing lines* as follows. The slurry, containing 200 to 300 gm/litre solids in about 2400 M^3/hr seawater, is passed through a sieve to remove all particles greater than about 3 mm diameter. A "top cut" of fines under 25 microns is removed in the first stage hydrocyclone. After the removal of heavier particles in the second stage hydrocyclone, the slurry containing 70% solids is passed to centrifuges where a fresh-water rinse is applied to remove salts to meet a specification of 500 ppm chlorides (maximum). The consumption of fresh water is about 800 litres per tonne of production, and is pumped from 7 wells. The centrifuge exit water is filtered and some phosphate is recovered to join the main centrifuge outlet stream, which is designed to contain around 16% moisture.

This material is then fed to rotary driers fired by heavy fuel oil. The phosphate is dried to a moisture content of 2% maximum, at which point it is stored and then shipped to customers.

Main energy consuming equipment:

The major energy consumption is in the form of heavy fuel oil for the rotary driers. Electricity use is quite low, as no grinding of phosphate rock is required. Electricity is used for slurry pumping, conveyor belts, drier rotation, etc.

*Normally 3 or 4 lines in service, with 1 to 2 lines undergoing maintenance.

Observations:

(1) The general appearance of the site appears well organized and maintained. Most of the time was spent in the drying area, as this is where most of the energy is used.

(2) A brief examination of the drying lines showed that the three oldest driers are poorly insulated. Drier 1 was not operating, but both Driers 2 and 3 were operating with flames passing from the combustion sections into the rotating drying sections.

(3) Driers 1, 2, and 3 have induced-draft systems while Driers 4 and 5 have forced-draft fan systems.

(4) Some gas temperature readings were taken around the driers. The exit gas temperatures were recorded as shown by the plant instruments, but the outside temperature of the ductwork seemed particularly hot on Driers 2 and 3. The following data were obtained:

	Drier 2	Drier 3	Drier 4	Drier 5
Hot air to rotating dryer section (°C)	920	820	(instruments not working)	570
Exit gas temperature (°C)	77	100	"	67

The inlet temperatures on Driers 2 and 3 appear excessively high and are evidence of poor flame shape and inadequate mixing of the dilution air introduced at the outlet of the combustion section.

(5) Saake rotary cup burners were fitted to the driers. No measurement of exit gas humidity is taken. Control is maintained based on the phosphate product moisture content, determined regularly in the plant laboratory.

(6) Heavy fuel oil is stored in tanks which appear uninsulated and are painted black. These tanks are heated by steam, raised in a nearby boiler (which was not visited, as the boilerplant was closed to visitors at the time).

(7) The yield of phosphate product is fairly steady at about 60% of the inlet phosphate rock, as received from the mines.

(8) The water content of the drier feed and product streams is monitored regularly. Plant records indicated that the feed moisture was generally in the range 17.3 to 18.9%, with one or two low figures and around 16.6 and high figures around 19.5 being noted. It is clear that the inlet moisture content is not averaging close to the 16% design figure. Drier outlet moisture contents were in the range 1.8 to 2.0%.

Energy consumption data: Data for a typical month were obtained (November 1982):

Production	203,421	tonnes
Fuel oil consumed	3,173,379	litres
Electricity consumed	1,870,143	kwh
Fuel use	15.6	litres/tonne
Electricity use	11.5	kwh/tonne

Remarks:

Comprehensive plant records are kept and specific energy consumptions are reported regularly. However, no attempts to relate energy use to throughput or to moisture contents appear to be made. The critical factor affecting fuel use is clearly the drier input moisture content. If this could be reduced to 16%, the design figure, substantial savings could be achieved.

We would, therefore, recommend that a careful study of drier operation be carried out, and test runs performed over a reasonable period of time to collect comprehensive data on all relevant parameters (e.g., air and fuel flow rates, phosphate processing rate, gas and product temperatures, inlet and outlet moisutre levels, exit gas humidity, etc.). Detailed heat and materials balances should then be calculated, and heat losses in the exit gases and from the structure should be estimated. The effectiveness of the control system should also be examined. It may prove possible to reduce energy consumption by improving the drier operating procedures.

It is also possible that some processing changes could be economically viable. For example, the final freshwater washing step should be examined. Currently, this rinse occurs in the final centrifuge bowl immediately prior to entry of the phosphate to the drier. Alternatives should be investigated with the objective of reducing the water content of the drier feed. The economics of an additional water separation stage could also be examined (e.g., additional second-stage centrifuges, series operation of existing centrifuges, additional vacuum filtration equipment, etc.).

The final product specification of 2% moisture also deserves attention. A small relaxation in this figure could have a significant effect on fuel use, as well as resulting in reduced product loss during loading of ships (reducing windblown phosphate losses).

Finally, it should be remarked that a thorough investigation of the phosphate processing operations will require adequate time for on-site observations. However, a major study appears justified in view of the large consumption of fuel oil. It may also be worthwhile to examine the potential for fuel substitution (e.g., using wood-based fuel), although it is doubtful if the reconstruction of the plant for alternative fuels will be economically viable--particularly after operation of the existing plant has been optimized.

SESSION V
ENERGY CONSERVATION PERSPECTIVES

1 TRAINING PROGRAMS

1.1 INTRODUCTION

A comprehensive industrial energy management training program would typically have the following complementary primary objectives:

1. The training of engineers, managers and government officials in the basic techniques of industrial energy management.
2. The training of plant level engineers in the performance of practical plant energy audits, in the collection of energy-related data, and in the practical application of the techniques of energy conservation.
3. The improvement in awareness of engineers, managers and government planners in the potential for improved energy efficiency in the industrial sector, and in their appreciation of its limitations and costs.
4. The establishment of comprehensive and accurate energy data systems at the plant level, which will contribute to improved energy management within the plants and will provide national energy planners with reliable data on which to base policy decisions.
5. The performance of detailed energy audits at selected industrial facilities in order to quantify conservation potential and to develop specific action plans to achieve this potential, in addition to providing a training experience for engineers.

In the national context, effective industrial energy management requires the training of significant numbers of local engineers to become familiar with the general concepts of energy analysis and conservation, and with the technologies for improved energy efficiency which are applicable to their particular industry. It must be recognized, however, that formal training is merely the beginning. The ability of local engineers to conduct audits and conservation studies similar to the examples applied in the training program will depend on their gaining further experience of conditions in industry, and will come with the confidence that exposure to different plants and different problems will develop. A good training program would provide some assistance in this respect through incorporating an extended "follow-up" assistance effort: any training program must allow sufficient time for the development of local personnel.

1.2 PERSONNEL TO BE TRAINED

In addition to factory "energy managers" and to plant level engineers in general, any national training program should include personnel from oil, gas, coal and electricity companies, which are often state-owned. In our view, these personnel have a key role to play in disseminating energy conservation principles throughout the industrial sector of the country concerned. While plant engineers have specific responsibilities within their own companies, we feel that utility and fuel company personnel can work independently across a broad range of industries, providing the catalyst for company and plant specific conservation programs. Where a plant is

considering what kind of conservation activities should be started, such personnel could be made available to assist in the initial energy audits and the planning of the conservation program most appropriate to that plant.

In addition, we suggest that a training program include a series of brief lectures for plant supervisors and company management to explain the basic principles of industrial energy conservation, the basic techniques of energy audits, and the relevant financial and economic considerations. We also believe that company financial officers should have some appreciation of the role that industrial energy management can play in the operation of the company. It is important that production managers be fully conversant with energy management procedures. It is through these "abbreviated" courses that we would hope to initiate a link from the plant engineers carrying out detailed conservation work to their managements.

1.3 THE STRUCTURE OF THE TRAINING PROGRAM

Based on our experiences in several developing countries and in the United Kingdom and the United States, we have developed some guidelines for an industrial energy management training program. This program draws extensively upon our work in Tunisia, the People's Republic of China, Kenya, the Sudan and Turkey.

We feel strongly, however, that a training program should be a continuing exercise to disseminate energy awareness, the practical techniques of data collection and analysis, and the development of company conservation programs throughout the industrial sector of a country. For this reason, we consider the program described here is a good start, but is insufficient to achieve truly national results in a meaningful way: that is, for there to be built up a local ability to conduct energy audits and energy conservation studies with a view to establishing permanent energy conservation programs in a large number of companies. For this to occur, a continuing effort is necessary over several years. Indeed, training is a vital activity which should be considered as an ongoing necessity to achieve improved energy efficiency in industry. This training must be supplemented by such activities as demonstrations of new technologies, establishment of incentives for capital investment, and the creation of appropriate tarification policies for energy products.

We would thus recommend that a similar training program be conducted regularly, with up to about 20 participants each time. The results of the first training program should be used to modify the subsequent program (in terms of emphasis in obvious areas of need, for example, specific to the country in question).

Before discussing the details of each element in the program, it should be pointed out that we have prepared a training program for engineers irrespective of the industries which the engineer represents. In the experience of E/DI Europe, which covers many industries in many countries, it is our view that the greater part of energy conservation work is common to all industries. The principles of measurement, data organization and analysis,

cost-benefit evaluations and company/national conservation programs should, therefore, be taught to all. Assignments within specific industries and technical lectures and visits oriented to specific industries can be given from time to time throughout the program, of course, but we would prefer to emphasize the common approaches to energy management, rather than the relatively minor differences. Successful energy conservation is rarely a question of technology; it is almost always a question of systematic data collection and analysis, and of properly organized management.

Of course, there may be exceptions to this approach which are necessary due to local conditions, especially where significant progress in industrial energy management may have already been made. For this reason, the "diagnostic" phase is important (see below) for it is through this task that the design of a program most suited to the needs of a particular country can be made. Any program must take fully into account the level of energy awareness and standard of energy management already attained, and must address the priorities of the country and of specific industries where appropriate.

1.4 DIAGNOSTICS AND PLANNING

In the first month of a training program, the scope of the work must be properly defined. For one country alone, we would suggest a visit by a team of, say, two experts for one to two weeks in the country should be sufficient, with some preparatory work conducted by correspondence. The resumes of propsective training course participants would be reviewed and recommendations for the final list would be made to the appropriate host government agency. The invitation list for course participants would of course include the introductory "management" seminar.

Within this phase, the timing and logistics for all elements of the program and the specifics of course content would be decided as far as possible, bearing in mind the desirability of coordinating the training program with any other energy management efforts currently in progress in the country. Some flexibility in the timing of assignments and plant visits must, of course, be maintained.

This phase will also include discussion of the lectures and course content with host government representatives to define those parts of the training program which could be given by local personnel, and to agree on the detailed course content appropriate to the level of knowledge and experience of the actual participants. The experience gained by local personnel in giving lectures themselves should prove invaluable for the ongoing training effort which we see as essential in future years.

1.5 MANAGEMENT SEMINAR

An introductory seminar of about one week should be given for management personnel from utility companies, fuel supply companies, government agencies and industrial plants. This provides the opportunity to review with senior engineers, managers, and financial officers the proposed industrial energy

management training program, emphasizing to them the potential benefits of energy conservation throughout the industrial sector. A brief introduction should be given to the techniques of energy auditing and energy management in general; it is hoped that the seminar will develop an improved awareness of the need for conservation, and above all the need for senior management support for the efforts of plant engineers and energy managers.

1.6 TRAINING SEMINARS

Lectures on industrial energy conservation principles and techniques should be given to plant engineers, energy managers, and other suitable personnel. The topics to be covered in these lectures should include at least the following:

1. Introduction to the training program and industrial energy management in general - background, objectives, etc.
2. A review of energy consumption and the energy situation in the country or region in question.
3. The detailed structure of the training program (lectures, plant visits, audit assignments, overseas training, etc.), including objectives of each task, procedures, logistics, responsibilities of participants, etc.
4. Basic principles of energy conservation.
5. Basic information - alternative fuels and their characteristics, common units of measurement and conversion factors, heating values, etc.
6. Energy audits - the purpose of audits, the scope of an energy audit, data forms and questionnaires, data analysis, benefits of audits, procedures to be adopted, instruments (portable, fixed).
7. Basic unit operations - we concentrate on the most important operations (combustion, steam generation), but include discussion of at least the following:

- Combustion
- Heat transfer
- Evaporation
- Drying
- Distillation
- Boilers and steam systems
- Electrical demand management
- Co-generation
- Plant compressed air systems

The lectures include discussion of basic theoretical principles, practical applications, calculation methods (vigorous and "short-cut"). They are illustrated by a variety of calculation exercises for the participants to carry out themselves, by practical industry case studies, and with films appropriate to the topic under review.

8. Process analysis - a brief review of the need for analysis of the specific processes used in different industries, with illustrations of international comparisons of specific energy consumptions in a range of industries and the limitations of this approach.
9. Industrial lighting, and the significant potential for conservation in this area.

10. Space conditioning of offices and other industrial buildings, including audit forms and parameters affecting energy use.

11. Check lists of conservation measures generally applicable in the industrial sector, arranged according to the unit operations previously discussed.

12. Conservation measures for specific industries, and the need for target setting, to be illustrated by actual case studies from developing and developed countries.

13. Typical company and plant conservation programs, including case studies and guidelines on how to develop effective programs.

14. Economic aspects of energy conservation, including the common calculation procedures employed for payback, rate of return, etc.

In conjunction with the lectures indicated above, a series of one-day visits are normally made to selected plants (say three or four nearby plants). These visits are intended to reinforce the classroom lectures with practical demonstrations of the principles involved, and are used in preparation for the longer visits to be carried out at a later stage of the program. These visits, therefore, serve as an introduction for participants to

- the use of audit forms and techniques for obtaining data
- the identification of problem areas in energy use, by data analysis and by inspection of the physical plant
- the handling of portable instruments for the diagnosis of plant performance.

The program participants are usually divided into two groups for each visit, with participants alternating between these groups for the different visits:

Group 1 concentrates on data collection and the use of audit forms. The duties of this group include obtaining basic data on energy consumption and levels of production, obtaining details of the manufacturing processes in use and major production units/equipment, and inspecting the plant briefly (primarily to gain a general impression of operating practices and efficiency and to relate the data collected to the corresponding physical plant).

Group 2 is assigned to inspect specific sections of the factory, where they observe the location of important measuring points and the availability (or lack) of data on key operating parameters (flows, pressures, temperatures, etc.). The use of portable instruments is demonstrated to this group.

It is important to note that no conclusions are drawn from the data collected in the initial visits.

1.7 AUDIT ASSIGNMENTS

For the next phase of the training, participants are divided into groups of six or seven in order to undertake "short audits" in selected plants. The objectives of the short audits are:

- To train local engineers in energy audit procedures and the techniques of data collection and analysis (including the use of portable instruments)
- To collect the energy consumption data for selected major industrial consumers
- To identify and quantify specific energy conservation opportunities in the plants.

Due to time limitations, the scope of these audit assignments will necessarily be limited. However, they serve as practical experience for the course participants, who should then be better able to develop more detailed audits wherever justified in their own companies.

Details of the programs for the short audits are usually developed during the earlier one-day visits. Each training group will itself be split into two during the audit work, some engineers to concentrate on examination of energy-related records and the completion of comprehensive audit forms, and some to carry out test runs in the plants.

Plant engineers should be placed as far as possible in groups covering their particular industry, with the balance of each group composed of fuels and utility company and government personnel. Each group spends about one week on a plant carrying out a specific assignment related to energy auditing and the identification of conservation measured. The work should include in-plant data collection and time should also be allowed for the group to work with their instructors (two to each group) to make at least a preliminary analysis of the data in the second week. The participants must have the opportunity to play an active role in the writing of the final report.

2 APPROACH TO CONSERVATION PROGRAMS

Action by national governments to stimulate energy conservation can usually be justified by the significant potential benefits. The types of action which governments can take include sponsoring plant audits and training programs. Indeed, the training element of the Tunisia project was paramount. International agencies are often prepared to provide grants or loans on preferential terms to enable developing countries to conduct industrial conservation programs.

Of course, the problem of achieving improved energy efficiency is not solely that of the developing countries. A recent study reported that the potential existed in the U.K. to save 14% of current energy use with projects offering three-year paybacks or better. Very few of the companies surveyed in the study had implemented the full variety of technically possible energy saving measures. Three main barriers to conservation were highlighted.

1. The knowledge barrier. Many of the companies interviewed had not recognized many technically possible and financially attractive opportunities for energy savings. Many had also made little use of the sources of information and advice that are available.

2. Energy management. There is clear evidence that the companies with the most sophisticated energy management systems had made the most progress in achieving energy savings. The effect on management attitudes of even the simplest energy monitoring and target setting system was particularly noticeable.

3. Capital budgeting. The financial appraisal of conservation investments was usually crude, based on short payback periods which ignore some of the special features of energy conservation investment—notably long life, low risk and savings linked to fuel price inflation--which more sophisticated financial analysis would bring into reckoning.

The report, therefore, recommended the improvement of the status which managements give to energy conservation; the upgrading of government information and advisory services; boosting publicity on conservation and an examination of selective financial aid to industry, possibly involving longer term bank lending and "pay as you save" schemes. These findings and recommendations have broad applicability in developed and developing countries.

At the plant level, managements must undertake initial audits to determine how much energy is used in each important processing stage, and should initiate proper energy consumption monitoring. Areas for improving efficiency should be examined and the necessary cost-benefit evaluations performed. Above all, management must take a vigorous interest in energy conservation. Effective energy management within an industrial enterprise requires:

1. the commitment of all concerned
2. communication throughout the compa
3. an organization (or structure) which results in properly defined responsibilities and authorities
4. the involvement of personnel at various levels in setting goals for improvement
5. leadership in the work of improving efficiency (such as that provided by an "Energy Manager")
6. technical and economic expertise, to fully evaluate and exploit conservation opportunities.

In conclusion, it is particularly important to stress that energy conservation is not a negative concept. It is essentially the improvement of the efficiency with which energy is used, enabling economic development and the improvement of living standards to be pursued. We must recognize, however, that changes in attitudes and changes in the established way of doing things are brought about only slowly. Opportunities for saving energy are often not taken up even when a first-class financial case exists. We must conclude that even more must be done to stimulate both interest and action.

SESSION SEVEN
ANALYZING ENERGY EFFICIENCY IN THE INDUSTRIAL SECTOR

1 CONSERVATION AT THE PLANT LEVEL

Before discussing the procedures for energy auditing which are used to identify the opportunities for energy savings, we should understand some of the basic principles which apply to energy conservation work in general:

1. The manner and extent of all energy use should be examined.
2. An essential element of energy conservation is the systematic measurement of plant energy and material flows.
3. To carry out accurate energy and material flow measurements, it is necessary to use properly calibrated and maintained instruments.
4. The maximum amount of useful work should be obtained at each stage of temperature or pressure reduction.

Energy audits in industrial plants are used, as we shall see, to determine energy use patterns and to evaluate the existing efficiency of energy use. Based on these energy audits, it is usually possible to identify energy conservation opportunities in the following categories:

1. Housekeeping measures: the improvement of efficiency using little or no capital investment, effective in the short term.
2. Minor capital investments: relatively simple modifications to the plant, with savings obtainable in the medium term.
3. Major capital investments: substantial replacement or modification of plant, with savings obtainable in the medium to long term.

Some typical conservation measures within these categories are:

Housekeeping
- energy consumption monitoring
- closer control of operations
- improved maintenance
- elimination of leaks
- improved scheduling

Minor capital investments
- improved insulation
- better levels of instrumentation
- condensate recovery
- additional heat exchangers
- higher eficiency lighting
- combustion air preheating
- power factor improvement
- electricity load leveling

Major capital investment
- replacement of boilers
- replacement of obsolescent plant

- conversion to different processes
- rebuilding furnaces with recuperators

As a general rule, measurable improvements in the plants will be the result of the accumulated effort of many small actions, rather than the result of one or two spectacular major capital investments. The contribution of housekeeping is important and it is true that energy efficiency improvements through housekeeping are relatively easily obtained in many plants by better management. Regrettably, it is also true that housekeeping successes are relatively easily lost unless the drive for efficiency is maintained over the long term.

2 INTRODUCTION TO AUDITING

An integral element of a national energy program is a knowledge of disaggregated industrial energy demand. Effective incentives for efficient energy use cannot be designed without a detailed knowledge of energy consumption patterns within the industrial sector. At the plant level, an effective energy management program must be related to a numerical target or objective. To define such targets for reducing waste and improving energy efficiency, each plant needs to know exactly what energy it uses: a procedure for defining energy use and for updating records periodically is essential. Such a procedure is provided by an energy audit, which includes:

1. Monitoring the type and quantity of fuels and electricity consumed
2. Relating energy consumptions and costs to the output of the plant
3. Identifying the activities and major processing stages where energy is used
4. Identifying the opportunities for energy savings

The purpose of an energy audit is thus to provide plants with accurate means of recording energy consumption and costs, to provide plants with the information necessary for identifying real opportunities for energy savings, and to provide comprehensive and accurate data appropriate for national energy planning activities. An energy audit should be viewed as a critical examination of the plant.

There are, of course, many "levels" of energy audits, ranging from simple data surveys to highly detailed examinations of existing data coupled with special plant test runs designed to provide new data. An initial audit for a plant will probably take about 2-3 days on average, depending on the complexity of the plant and the availability (and accuracy) of data on existing operations. This kind of brief audit cannot be very sophisticated, but is most useful in revealing inadequacies in metering and measurement. The aim of the brief initial audit is to obtain data and energy savings quickly; accuracy will be gained in the light of experience.

A more comprehensive plant energy audit usually follows the first brief audit, and can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried

out. The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

In order to carry out this kind of audit work successfully, engineers with wide experience in operating industrial plants are essential. Two basic areas of experience are needed within an audit team:

1. Experience and familiarity with "plant services," such as steam generation and compressed air systems;
2. Experience of the "process" side of plant operations, e.g., cement production, chemical processes, etc.

The availability of process expertise is important for the conduct of any detailed audit. Where outside experts are used to carry out the work, it is also important that one or more counterparts from the plant itself work closely with these experts, to assist them in gaining a rapid understanding of the plant operations, and to learn for themselves the techniques used for data collection and analysis.

3 INFORMATION OBTAINED IN AN AUDIT

The information to be collected during the audits will fall into the following categories:

1. Energy consumption by type of energy, by department, by major items of process equipment, by end-use (e.g., lighting, process heat)
2. Material balance data (raw materials, intermediate and final products, by-products, etc.)
3. Energy cost and tariff data
4. Process flow diagrams
5. Data on the supply of auxiliary services (e.g., cooling water, compressed air, steam)
6. Sources of energy supplies (e.g., electricity from the grid or self-generation)
7. Potential for fuel substitution, process modifications, and the use of cogeneration systems (combined heat and power generation)
8. Energy management procedures and energy awareness training programs within the establishment.

An example of the data collection questionnaire used in a comprehensive audit is shown in Exhibit L. While questionnaires are an integral part of auditing, they do not in themselves constitute the whole audit. The forms represent a systematic way of collecting certain basic data that experience has shown are relevant in virtually all audits. However, questionnaires must

Exhibit L
Extended Energy Audit Questionnaire

A. Identification

1. Name of company
2. Full postal address
3. Telephone
4. Persons interviewed
5. Their positions/titles
6. Head office
7. Branch of industry in which the factor is classified:

- [ ] Mining
- [ ] Textiles
- [ ] Food Processing
- [ ] Other
- [ ] Construction Materials
- [ ] Mechanical/Electrical
- [ ] Oil Refining
- [ ] Paper
- [ ] Chemicals
- [ ] Electricity Generation

8. Date of factory commissioning
9. Number of employees

B. Processing Activities

10. Provide a flow sheet of the plant indicating major operations.

11. List the different process units (manufacturing stages) including units for the production of utilities (e.g. boiler, electricity generation, oxygen plant, compressed air).

12. List all major products:

Product	Units	Plant Capacity	Actual Production	Corresponding Value of Sales

C. Energy Supplies/Consumption

13. Complete table for all energy supplies consumed; if no use, enter zero.

Energy Type	Calorific value	Quantity/year	Units	Cost per year	Current price	Sourc
purchased electricity						
natural gas						
coal						
coke						
wood						
charcoal						
LPG						
Distillate* fuel oil						
Residual* fuel oil						
Others (specify)						

*Specify grade/specification of fuel oil.

14. Is electricity generated at the factory? ☐ Yes ☐ No

15. If yes, what type of generator is installed?

☐ diesel ☐ gas turbine ☐ steam turbine ☐ waste heat boilers

☐ other

16. What self-generating capacity is installed? kW

17. How much electricity was generated by the plant last year? kWh

19. Is self-generation capacity to be increased? ☐ Yes ☐ No

(Give details.)

D. Combined Heat and Power Generation (Co-Generation)

20. Is there a co-generation system installed in the plant?

21. If yes, give details of the system

energy source	heat production	steam	electricity production
Uses?			
Type of equipment			

22. When was the system installed?

23. Are there plans to install co-generation systems or to increase the capacity of an existing system?

E. Electricity Consumption

24. What is the total installed capacity of motors and other equipment?

kW

25. Specify voltage levels utilized.

26. Give the latest annual consumptions:

Electricity	kWh Consumed
Purchased:	
Self-generated:	

27. Are there data available on daily and seasonal variations in electricity consumption?

28. Is there a daily load curve available? ☐ Yes, copy attached ☐ No

29. What is the average power factor for the plant?

30. Estimate the breakdown of electricity use by completing the following table:

	Quantity (incl. units)	Percent of total Electricity
Motive power (motors) Heating Lighting Others (specify)		

Note: rough estimates are acceptable if accurate data not available.

F. Boilers

31. How many boilers are installed?

32. Any increase or changes planned?

33. Complete the following table for each boiler:

	Units	Boiler	Boiler	Boiler
Type/model	-			
Steam capacity				
Steam pressure				
Steam temperature				
Fuel type	-			
Fuel consumed				
Steam produced				
Estimated efficiency				

34. What is the source of boiler feed water?

35. What water treatment is used?

36. What is the water quality after treatment?

37. What is the consumption rate of water? Quantity - Units -

38. What percentage of condensate is re-used?

39. What is the peak demand for steam?

G. Energy Utilization

40. What process units/departments are the major consumers of energy?

Major units	Energy used - Type, quantity	Specific energy consumption	Efficiency	* Alternative fuels

*with or without modification of the plant

41. How much energy is used in heating/cooling buildings?

42. How much energy is used for mechanical handling and transport within the factory?

43. Are fuel oil tanks heated? ☐ Yes ☐ No

44. If so, how are they heated?

45. How is the system controlled?

H. Energy Management

46. Who is responsible for energy management?

Name

Position

Full time/part time

Qualifications, experience

47. Is there an "energy team"? ☐ Yes ☐ No If so, how many?

48. Is there an "energy committee"? ☐ Yes ☐ No

49. If yes, list the members of the committee and their titles.

Name	Title	Name	Title

50. What are the tasks and responsibilities of the energy committee?

51. How is energy consumption examined and controlled:

- ☐ by senior management only?
- ☐ by each plant within the company?
- ☐ as a routine matter, or from time to time?

  - when was the last complete review performed?

52. What analysis of energy consumption is carried out?

- ☐ According to department (e.g. offices, process plant)
- ☐ By major equipment (e.g. furnaces, boilers)
- ☐ By end-use (e.g. lighting, process heat, rotation equipment).
- ☐ By major product line.
- ☐ By total monthly consumption.

53. What units of measurement are used?

54. Are the consumptions of different forms of energy converted into a common unit of energy, e.g. kilocalories, Btu, kWh? ☐ Yes - unit ☐ ☐ No

55. Does the analysis include study of the relation between energy used and level of production? ☐ Yes ☐ No

56. Describe briefly the records kept of energy consumption.

57. Is current energy consumption compared with energy consumed in previous periods, or with other similar factories? Explain:

58. Are adjustments to energy consumption made for variations in product quality, in the quality or type of raw materials, in climatic conditions, in capacity utilization, etc.? Explain:

59. Are specific, quantitative objectives set by management:

- ☐ for total energy consumption?
- ☐ for specific energy consumption?
- ☐ for energy savings (e.g., percentage reduction)?
- ☐ for improvements in specified processes or manufacturing stages?

60. What action has been taken to educate personnel in energy conservation procedures?

61. Is there a formal system of preventive maintenance? (Give details.)

I. Energy Conservation Problems and Activities

62. Summarize the major energy problems as viewed by plant management.

63. What constraints to improvement of energy efficiency exist?

64. What studies have been performed in relation to improving energy efficiency?

65. Summarize major energy conservation activities <u>already initiated</u> or <u>planned</u> (specify timing):

66. What is the potential for using non-conventional energy forms or renewable resources (e.g., wood, solar, wind, biomass, biogas)?

be supported by observations made during inspection of the plant and by measurements taken with fixed or portable instruments on important energy consuming equipment such as boilers and kilns. The audit is not complete until the data collected from these various sources have been analyzed and a final report, including recommendations, has been prepared and presented to management.

4 DIAGNOSTIC INSTRUMENTS

The instruments typically used in plant audit work will include portable equipment to supplement existing plant flow, temperature and pressure measurements, and will be used by the audit engineers to assist in the diagnosis of operating performance. Some typical instruments are as follows:

1. For combustion processes, stack gas analysis equipment to determine oxygen levels, CO, gas temperature, etc. Today, these can be electronic instruments giving a continuous readout of key parameters calculating combustion efficiency automatically. A smoke pump is also useful.
2. For direct temperature measurement, miniature digital thermometers with a selction of probes and leads.
3. For non-contact temperature measurement, an infra-red pyrometer.
4. For air and gas flow measurement, a pitot tube and manometer.
5. For electrical measurements, clip-on voltmeter, ammeter, power consumption meter and power factor meter

In addition, it is sometimes useful to have a portable relative humidity meter for the analysis of drying processes, as well as miscellaneous collection of pressure gauges and recorders for temporary installation in the plant during extended audits.

5 BASIC PROCEDURES

The details of procedures to be adopted will vary according to the scope of the proposed audit and to the size and type of facilities. In general, however, the following procedures are common to audit work:

Step 1: Plan the entire project. This includes setting audit objectives; dividing the facility into operating departments (or cost centers, as appropriate); selecting the audit team members; assigning responsibilities.

Step 2: Collect basic energy consumption and production data from the departments/cost centres, using the forms provided in this manual (or similar).

Step 3: Carry out plant test runs to gather additional data on the operating performance of specific equipment, departments or cost centers.

Step 4: Calculate energy balances and efficiencies.

Step 5: Identify improved energy management procedures, and estimate energy savings, if appropriate.

Step 6: Identify improved maintenance and operating procedures, estimate energy savings obtainable, and assign responsibilities to specific individuals for implementation of all worthwhile measures.

Step 7: Identify minor cost improvements, estimate cost of implementation, calculate energy-saving potential, and prepare schedules for implementing all attractive capital investments (specify who will do what, and when).

Step 8: Identify major cost improvements, estimate costs, calculate energy saving potential, and prepare detailed schedules of items showing attractive payback.

Step 9: Prepare a report to management summarizing the findings and recommendations of the audit, and including all data collected and procedures used in technical appendices. The report may include recommendations for energy efficiency improvement targets, based on the data gathered during the audit work and the analyses performed.

6 EXAMPLES OF ENERGY CONSERVATION MEASURES

6.1 HOUSEKEEPING

Turning to the practical side of energy management, it is useful to examine some typical results obtained recently in Tunisia. The first category of improvements is housekeeping:

A. Energy reporting

At El Fouledh steelworks, a great deal of energy and production data are available, but most of the data are never put together in one regular report. By collecting information from several departments, it was possible to reconstruct the energy situation, by department within the works, for 1980. An example of part of the report is given as Exhibit M. It is only by tabulating energy information regularly, and by arranging the report in a format which makes comparisons easy, that one can start to investigate energy efficiency at the plant level (and at the department level within the plant).

B. Future efficiencies

At the phosphate rock beneficiation complex at Metlaoui, several small furnaces are used to heat fuel oil tanks and lines. Measurements were taken with portable stack gas analyzers under various firing conditions: some results are shown in Exhibit N. Flue gas losses were calculated at about 25 to 30%; excess air rates were around 60%. Better control of the plant should provide an excess air rate of under 20% (and flue gas losses closer to 20%). The calculation of furnace efficiencies is relatively simple, and the principles are shown in Exhibits O and P.

Exhibit M

6. DEPT. LAMINOIRE (Rolling Mills)

			J	F	M	A	M	J	J	A	S	O	N	D	1980
MATERIALS															
LI (Bar)		T	10344	10262	11597	11824	11883	10782	8063	8515	9692	10068	7794	11569	122315
LI (F.)		T	4668	4095	4731	4601	1395	3626	3626	4091	4319	4640	2784	4339	46915
Total			15012	14357	16328	16425	13278	14408	11689	12606	14011	14708	10578	15908	169230
ENERGY															
No. 1 line															
FO Lourd		T	647	622	697	726	753	675	574	591	578	623	495	649	7628
		TEP	634	610	683	711	738	662	563	579	566	611	485	636	7475
FOD	10^3	L													18
		TEP	–	–	–	–	–	–	–	–	–	–	–	–	15
Electricity	10^3	kWh	1270	1222	1243	1116	1100	1115	1025	1026	998	1142	969	1224	13450
		TEP	109	105	107	96	95	96	88	88	86	98	83	105	1157
Total TEP			743	715	790	807	833	758	651	667	652	709	568	741	8647
TEP/t prod.		10^{-3}	71.8	69.7	68.1	68.3	70.1	70.3	80.7	78.3	67.3	70.4	72.9	64.1	70.7
No. 2 line															
FO Lourd		T	420	368	428	377	139	429	462	498	492	482	302	477	4875
		TEP	412	361	419	369	136	420	453	488	482	473	296	467	4778
FOD	10^3	L													11
		TEP	–	–	–	–	–	–	–	–	–	–	–	–	8
Electricity	10^3	kWh	887	758	856	698	349	725	726	674	697	786	476	715	8347
		TEP	76	65	74	60	30	62	62	58	60	68	41	61	718
Total TEP			488	426	493	429	166	482	515	546	542	541	337	528	5504
TEP/t prod.		10^{-3}	104.5	104.0	104.2	93.2	119.0	132.9	142.0	133.5	125.5	116.6	121.0	121.7	117.3
General															
Gasoil pmpe battit.	10^3	L													105
		TEP	7	8	7	8	7	8	7	8	7	8	7	8	90
Pompe Batt		kWh	60	71	50	46	52	50	75	54	77	73	45	34	687
P. laminoirs		kWh	132	132	132	132	132	132	132	132	132	132	132	132	1584
Total 10^3		kWh	192	203	182	178	184	182	207	186	209	205	177	166	2271
		TEP	17	17	16	15	16	16	18	16	18	18	15	14	195
Grand total		TEP	1255	1166	1306	1259	1022	1264	1191	1237	1219	1276	927	1291	14436
TEP/t prod.		10^{-3}	83.6	81.2	80.0	76.7	77.0	87.7	101.9	98.1	87.0	86.8	87.6	81.2	85.3

Exhibit N

TABLE SHOWING THERMAL FLUID BOILER FLUE GAS CONDITIONS AND TEST DATA

Date Time	% CO_2	% O_2	Smoke No.	Flue gas T°C	Ambient T°C	Firing rate litre/h	Flue gas loss % fuel CV	% CO_2	% O_2	Smoke No.	Flue gas T°C	Ambient T°C	Firing rate litre/h	Flue gas loss % fuel CV
27.11.81 14.45	16-17	0.6	6	480	25	-	25.44	-	-	-	-	-	-	-
16.10	-	-	-	-	-	-	-	10	9	5	358	25	-	25.58
28.11.81 09.10	-	-	-	-	-	-	-	10	9	7	331.5	20	-	23.0
09.40	-	-	-	-	-	-	-	9	9	7	333	21	164	25.98
10.20	-	-	-	-	-	-	-	8.5	9	6	359.5	23	187.5	29.16
10.40	-	-	-	-	-	-	-	9	9	-	357	-	201	27.89
11.10	-	-	-	-	-	-	-	8	9	6	351	23	196	30.3
							Average	9.08	9	5.8	348.3	22.4	-	27.05

EXHIBIT O

RELATIONSHIP BETWEEN EXCESS AIR, CO_2, O_2, AND CO IN FLUE GAS

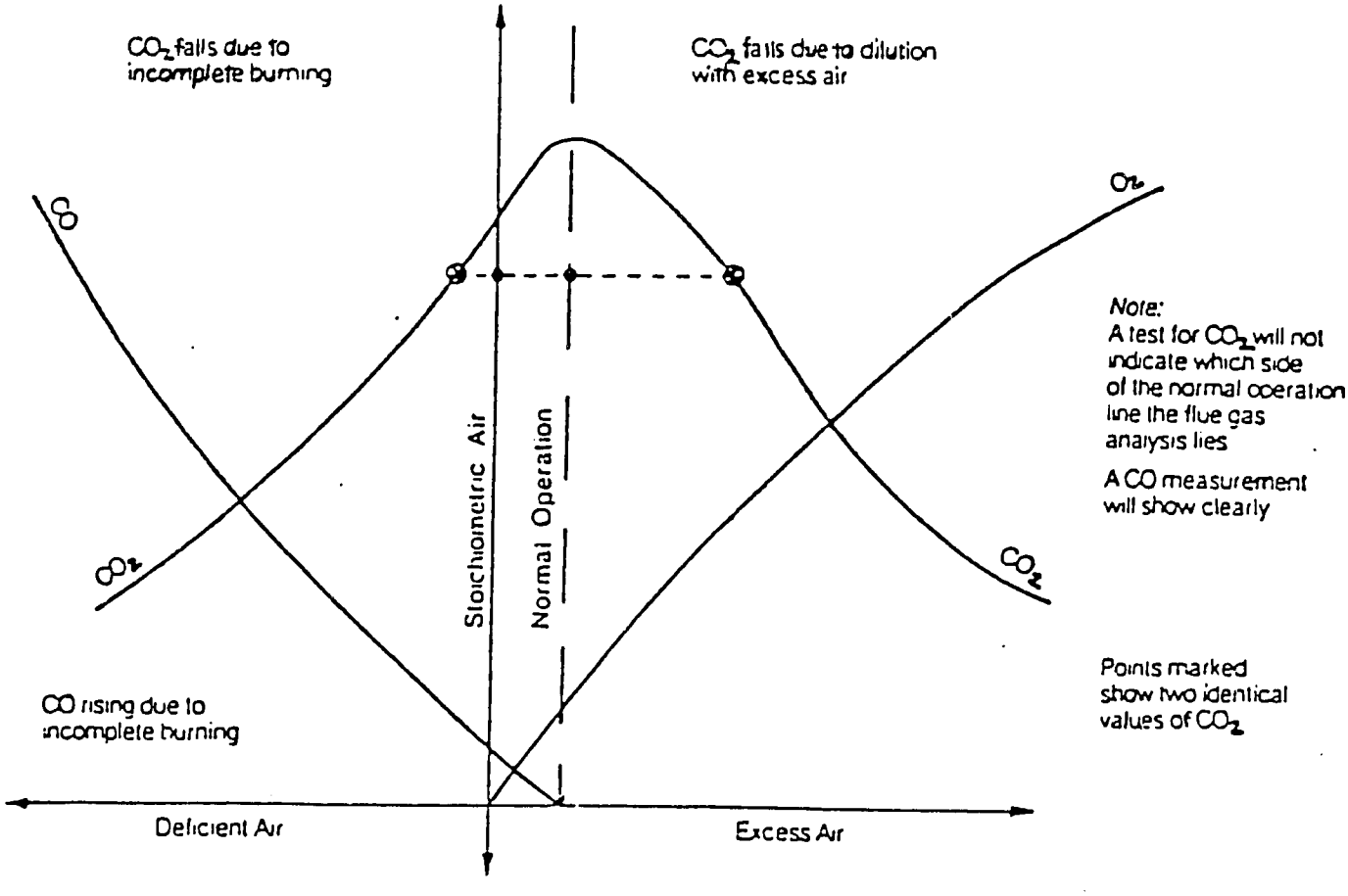
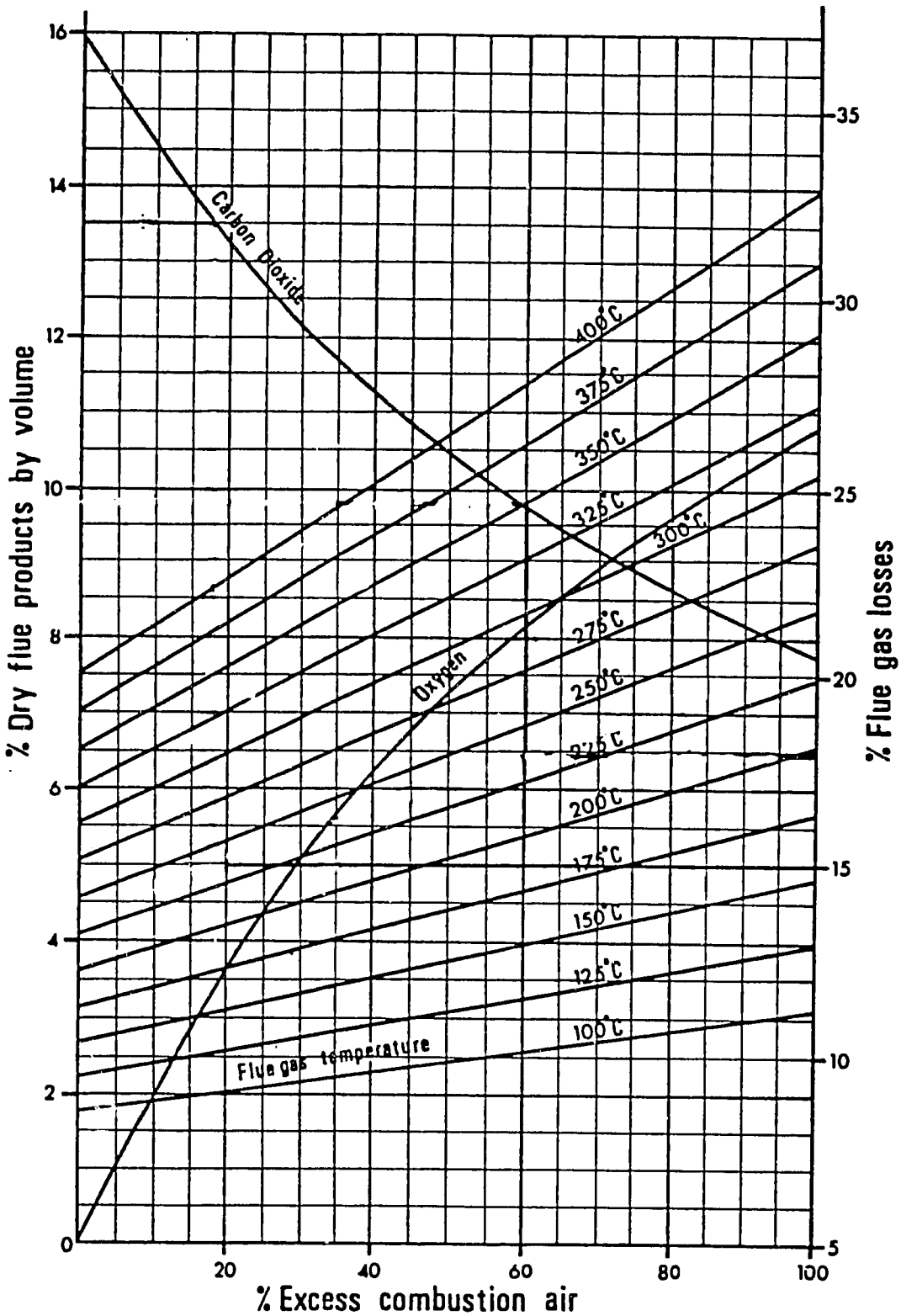


EXHIBIT P

HEAVY FUEL OIL



Flue gas losses—heavy fuel oil. Based on gross calorific value and an ambient temperature of 20°C

Exhibit Q

TEST RESULTS : TABLE SHOWING EXTENT OF UNLAGGED THERMAL FLUD AND HOT FUEL OIL SERVICES

PLANT AREA CONSIDERED	Approx. pipework length m	Size of pipe mm	Surface temp. as measured 0°C	Heat loss bare pipe kc/m h	Heat loss after insulation kc/m h	Energy saving kc/m h	Annual energy saving kc/10^6	Equivalent annual boiler input kc/10^6	Annual energy cost saving Dinar	Budget cost for insulation Dinar
Standby oil tank storage compound;	24	38	150	340	34.7	305.3	58.6	83.14	945	140
Unlagged thermal fluid services	30	20	160	231	34.5	196.5	47.16	66.89	760	111
Large oil tank compound;	4	75	65	124	13.2	110.8	3.54	5.03	57	36
Unlagged thermal fluid and oil services	8	38	160	372	37.2	334.8	21.42	30.4	345	47
Preheated fuel oil pipework downsteam of rotary kiln	24	15	85	77	14	63	12.1	17.15	195	91.2
Pumping and heating unit	24	10	85	55	12.5	42.5	8.16	11.5	131.6	75
								TOTAL	2433.6	500.2

The average payback period is about 0.2 years.

C. Plant scheduling

Data obtained at brickworks in Tunisia illustrate the effect that proper scheduling of operations can have on energy efficiency. Exhibit J is a graph of specific energy consumption against throughput for one's works on which monthly data for 1980 have been plotted. The exhibit shows that high throughputs give rise to high energy efficiencies: this is the expected result, because much of the energy used in brickworks is lost through the walls of the kilns, irrespective of throughput. Exhibit J therefore suggests that rescheduling of operations to maintain a high utilization of plant capacity could lead to energy savings of perhaps 25-40%, with no capital investment needed.

Exhibit K shows data for a number of brickworks and a similar situation may be seen for the sector as a whole. Potential energy savings are significant.

D. Steam leaks

An example of the sizable waste of energy that can be represented by steam leaks was observed at a paper plant. Steam escapes to the atmosphere from a safety valve on a tank used for digesting the raw material for pulp manufacture. In the original plant design, the steam was passed through heat exchangers to preheat process water. However, the heat exchangers began to leak and were left out of service, while steam was vented to atmosphere. Using simple measurements, the loss was estimated at 58,000 tonnes of steam per year: assuming only 50% of the energy loss could be recovered for other uses in the factory (perhaps for preheating process water, as was designed), the savings would be close to 400,000 dollars per year. These savings clearly justify the repair of the heat exchangers originally installed.

6.2 MINOR INVESTMENTS

A typical area for minor capital investments is the improvement of insulation on hot or cold lines and vessels. In the course of audit work in several factories, measurements of the surface temperature of uninsulated hot oil lines were taken and estimates made of the heat losses and the cost of insulation. Exhibit Q is an example of the results of this exercise; the average payback period is about 0.2 years.

Other minor investments identified in the Tunisian project included the installation of fixed stack gas analyzers, which would lead to the improved operation of furnaces, boilers and kilns (see also Section 6.1B above).

6.3 MAJOR INVESTMENTS

A typical example of an energy conservation measure requiring major capital investment is the recommendation for installation of stack gas recuperators at the steelworks. Two furnaces are used for reheating steel billets, and no attempt is made to recover the energy lost in the furnace stacks. A

study showed that recuperation of heat to preheat combustion air could result in an annual saving of over 500 tonnes of heavy fuel oil for each furnace (equivalent to a cost saving of about 110,000 dollars per year). A cost estimate for a recuperator system was made:

		Dollars
(a)	New burner equipment sized for preheated air at 300°C	19,600
(b)	Multi-tube recuperator, with combustion air blow-off facility as over temperature protection - flue gas temperature 750 to 930°C, combustion air 300°C	75,000
(c)	Freight, installation and commissioning of the combustion system, including drawings, pipework and duct modifications	47,000
(d)	Freight, installation, refractory modification, etc., required for recuperator	44,000
	TOTAL ESTIMATED COST PER FURNACE	185,600

The simple payback period for the recuperator system on each furnace is thus under two years (based on fuel oil at world market prices).

Another example of a major capital investment was identified at a paper works. Here, steam is raised in two boilers, one operating at 20 atmospheres to provide steam for general process uses, the other at 43 atmospheres to provide steam for the generation of electricity. Due to a limitation in the steam offtake system from the turboalternator, the total amount of steam available at 43 atmospheres cannot be utilized, and up to 40% of the steam is passed through a pressure reducing station to produce 20 atmosphere steam for general process uses. An estimate of the savings obtainable by installing a turboalternator in place of the reducing station was made: about 3.6 million kwh could be generated each year, valued at over 180,000 dollars annually. The cost of a suitable turboalternator set is 120,000 dollars, giving a simple payback period better than one year.

7 THE ECONOMICS OF CONSERVATION

The case for investment in energy management and energy conservation measures must be based on sound economic principles. All conservation opportunities should be assessed using the standard techniques such as discounted cash flow (DCF) rate of return, although rapid assessments of profitability may be made (with care) using the simple payback method. As an indication of the attractiveness of typical energy conservation measures, Exhibit R presents some paybacks observed in a study of over 2200 plants. The use of the DCF techniques will be discussed later in connection with microcomputer programs.

EXHIBIT R

TYPICAL PROFITABILITY OF ENERGY CONSERVATION INVESTMENTS

Generic Measures	Payback Period (years)
Improve insulation of buildings	4
Improve control of temperature (thermostats, timeclocks)	0.4
Insulate steam pipes, hot air ducts, hot water pipes, etc.	0.8
Maintain boiler, improve combustion control	1
Replace existing lighting by improved system	2
Clean luminaires, paint walls lighter color	4
Improve compressed air system, repair leaks, etc.	1
Improve process plant insulation	0.8
Improve process plant control systems	0.8
Return condensate, utilize flash steam	1
Replace boilers	2
Recover waste heat for process heating (incl. recuperators)	1.5
Re-line furnaces, major maintenance of heaters	1.5
Use of waste products as fuel	0.5
Specific Technologies	
Heat recovery from the absorption stage of sulphuric acid plant	1.4
Process heat integration at chemical plant	2
Heat wheel for heat recovery in textile plant	3.2
Heat recovery on a slab reheating furnace	1.5
Replacement of old boiler by coal-fired fluid bed system	4
Rotary air preheater on aluminum melting furnace	2.4
Wet to semi-wet cement plant conversion	5
Self-recuperative burners on forge furnace	3
Recuperative burners on continuous reheat furnace	1.5
Heat recovery by heat pumps in a dairy	2
Coal-fired fluid bed cogeneration system	1.7

Based on studies of over 2200 plants in the U.K. and on technology demonstration projects being monitored by the U.K. Department of Energy.

8 THE USE OF MICROCOMPUTERS FOR INDUSTRIAL ENERGY EFFICIENCY WORK

8.1 INTRODUCTION

The use of computers for calculations in industry has, of course, been well developed over a period of many years. The capability of microcomputers has increased to such an extent in the last few years that a large proportion of the tasks traditionally performed on main frame computers can be carried out using small desk-top microcomputers. In addition, the close interaction of user with microcomputer allows many simple calculations to be performed very rapidly. Indeed, the microcomputer often improves the turnaround time (from submission of input to receipt of output) significantly over that achieved by main frame systems.

The relatively low cost and convenience of the "personal microcomputer" represents a very important advance. The microcomputer can be a highly cost-effective aid to the plant energy manager and the energy planner, both of whom can exploit the computer-user interaction to the full in their daily tasks.

There are, of course, a large number of possible applications for a microcomputer in industry. These may be divided into several broad categories:

1. Data management
2. Engineering calculations
3. Financial analyses
4. Special applications

A few examples of each type of application will serve to illustrate the potential for productive utilization of microcomputers for energy management and energy planning.

8.2 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 by users, in addition to which there are many ready-made software packages available commercially.

Another type of program of great utility in all areas of data management is the "electronic spreadsheet," of which Visicalc is probably the most well known. This program is extremely versatile and is readily usable by engineers after only a few minutes' practice. For example, 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:

EXHIBIT S: EXAMPLES OF DEMAND PROJECTIONS BY VISICALC

Growth rate reduced from 14.5 to 10.5%

	1980	PCT	PCT GR	1896	PCT
MATCON	417.1	39.819	10.5	759.30	41.468
CHEM	96.4	9.2029	10.2	172.65	9.4291
MECMET	166.1	15.857	14.3	370.38	20.228
MINING	178.9	17.079	4.9	238.38	13.019
TEXT	42.9	4.0955	9.3	73.144	3.9947
PAPER	44.7	4.2673	10.2	80.057	4.3722
FOODPR	89.3	8.5251	5	119.67	6.5357
OTHER	12.1	1.1551	6.3	17.458	0.95343
TOTAL	1047.5	100.		1831.0	100

Basic figure for consumption modified from 417.1 to 505.3 x 10^3 TEP

	1980	PCT	PCT GR	1896	PCT
MATCON	505.3	44.492	10.5	919.86	46.187
CHEM	96.4	8.4882	10.2	172.65	8.6689
MECMET	166.1	14.625	14.3	370.38	18.597
MINING	178.9	15.752	4.9	238.38	11.969
TEXT	42.9	3.7774	9.3	73.144	3.6726
PAPER	44.7	3.9359	10.2	80.057	4.0197
FOODPR	89.3	7.8630	5	119.67	6.0088
OTHER	12.1	1.0654	6.3	17.458	0.87656
TOTAL	1135.7	100.		1991.6	100

EXHIBIT T: BLANK FORM FOR PLANT DATA

This line:
Name of person interviewed or contacted for information and his telephone number.

This line:
Date factory was visited, identity of interviewer, and spare line for entry of special codes by user.

Subsector of manufacturing industry in which the plant is classified.

Major product manufactured

Year to which data refer

Identification number for filing/retrieval purposes

```
PLANT ENERGY DATA FORM  YR .. CODE .....

COMPANY ................. SITE .........
CONTACT ............... TEL ............
DATE-VISIT ....... INTVWR ..... XX .....
SUBSEC ......... EMP .... VALPRO .......
MAJPROD ......... PRODN ....... UN .....

ENERGY CONSUMPTION FIGURES
ENERGY TYPE   CONSUMPTION   EQUIV TEP
ELEC-PURCH(M KWH) .......    E1 ......
NAT-GAS---(M NM3) .......    E2 ......
DOM-FO-(M LITRES) .......    E3 ......
LIGHT-FO-(TONNES) .......    E4 ......
HEAVY-FO-(TONNES) .......    E5 ......
COAL-----(TONNES) .......    E6 ......
                         TOTAL TEP ......

PARAMETERS
SPECIFIC-CONSN ...... TEP/UNIT OUTPUT
ENRGY/EMPLOYEE ...... TEP/EMPLOYEE
ENRGY/VAL-PROD ...... TEP/UNIT CURRENCY
VALUE-PROD/TEP ...... UNIT CURRENCY/TEP
```

Identifies specific factory

Number of employees

Value of production

Units in which production is expressed

Production of main product

Energy consumption expressed as the equivalent tonnes petroleum (1 TEP = 10^7 kcal)

Space for various parameters, such as specific energy consumption, energy consumed per unit of production value, etc.

	1980	PCT	PCT GR	1986	PCT
ATCON	417.1	39.82	14.5	939.88	46.72
HEM	96.4	9.20	10.2	172.65	8.58
ECMET	166.1	15.86	14.3	370.38	18.41
INING	178.9	17.08	4.9	238.38	11.85
EXT	42.9	4.10	9.3	73.14	3.64
APER	44.7	4.27	10.2	80.06	3.98
OODPR	89.3	8.53	5	119.67	5.95
THER	12.1	1.16	6.3	17.46	0.87
OTAL	1047.5	100.00		2011.62	100.00

The annual growth rates may be subject to considerable inaccuracy, and he planner may wish to know what the industrial sector demand would become f the construction materials subsector were actually to grow at 10.5% per ear. By setting up a matrix using the Visicalc program, the user can simply mend the subsector growth rate from 14.5% to 10.5%, and the computer will utomatically recalculate the projected demands and other dependent figures ithin a few seconds. Other key data can be changed by the user, and the ensitivity of the projections to these changes can be observed immediately. xhibit S shows some typical microcomputer outputs illustrating this particu- ar application of Visicalc.

Another major type of data handling activity is the storage and etrieval of large masses of data. An example of this application to energy anagement is the collection and analysis of plant-level energy data carried ut for the 60 factories in Tunisia. Visits were made to all the plants in urn, and a questionnaire was completed for each by the survey engineers. ata collected included energy consumption figures for each energy form and orresponding production figures. A simplified form was developed for the torage of the most important data using a microcomputer: Exhibit T shows he blank form, and the input data are indicated in Exhibit U.

Many of the items are automatically calculated by the computer. The ackage used for this work was a Versaform, a product of Applied Software echnology. This calculation feature is quite useful, especially for the onversion of the common physical units of consumption into the standard nergy unit, "tonnes equivalent petroleum" (TEP). Much time is saved, and he calculation is carried out accurately and correctly for every plant, vir- ually eliminating the possibility of errors in computing the total plant nergy consumption. Several key parameters of energy intensity and energy fficiency are also calculated and displayed on the form. Exhibit V shows he data forms completed for two typical plants, and Exhibit W is a summary isting of all plants included in the file for Tunisia.

With the Versaform software, it is possible to prepare a number of use- ul reports by searching the data files in different ways. For example, a earch for all plants in the "materials of construction" sector may be made Exhibit X) and a report showing specified key data for all brickworks within hat sector may be produced. This report is shown as Exhibit Y. The options

EXHIBIT U

TYPICAL INPUT DATA AND CALCULATED VALUES

Input data above line

```
PLANT ENERGY DATA FORM  YR 80 CODE 00007

COMPANY BRIQ.ZARROUK..... SITE KALAA-SGH
CONTACT AMRI,DIR.USINE. TEL (3)31.015...
DATE-VISIT 2/3/82. INTVWR TEAM. XX ...S1
SUBSEC MAT.CONS. EMP 500. VALPRO 3279...
MAJPROD BRICKS... PRODN 178223. UN T....

ENERGY CONSUMPTION FIGURES
ENERGY TYPE    CONSUMPTION   EQUIV TEP
ELEC-PURCH(M KWH) 11519..    E1 3686.1
NAT-GAS---(M NM3) 0......    E2 .....0
DOM-FO-(M LITRES) 1057.2.    E3 902.95
LIGHT-FO-(TONNES) 0......    E4 .....0
HEAVY-FO-(TONNES) 12735..    E5  12353
COAL-----(TONNES) 0......    E6 .....0
                       TOTAL TEP  16942
PARAMETERS
SPECIFIC-CONSN 0.0951 TEP/UNIT OUTPUT
ENRGY/EMPLOYEE 33.884 TEP/EMPLOYEE
ENRGY/VAL-PROD 5.1668 TEP/UNIT CURRENCY
VALUE-PROD/TEP 0.1935 UNIT CURRENCY/TEP
```

All these items
calculated automatically
by the computer

TYPICAL PLANT FORMS

PLANT ENERGY DATA FORM YR 81 CODE 00003

COMPANY SA.DOM.POTINVILLE SITE HAMMAMLIF
CONTACT DE.LABAREYRE... TEL (1)247.431..
DATE-VISIT 24/2/82 INTVWR TEAM. XX ...S1
SUBSEC MAT.CONS. EMP 150. VALPRO 1018...
MAJPROD LIME..... PRODN 64500.. UN T....

ENERGY CONSUMPTION FIGURES

ENERGY TYPE	CONSUMPTION	EQUIV TEP
ELEC-PURCH(M KWH)	1064...	E1 340.48
NAT-GAS---(M NM3)	0.....	E2 0
DOM-FO-(M LITRES)	30.....	E3 25.623
LIGHT-FO-(TONNES)	0.....	E4 0
HEAVY-FO-(TONNES)	0.....	E5 0
COAL-----(TONNES)	4280...	E6 3081.6
	TOTAL	TEP 3447.7

PARAMETERS

SPECIFIC-CONSN	0.0535	TEP/UNIT OUTPUT
ENRGY/EMPLOYEE	22.985	TEP/EMPLOYEE
ENRGY/VAL-PROD	3.3867	TEP/UNIT CURRENCY
VALUE-PROD/TEP	0.2953	UNIT CURRENCY/TEP

PLANT ENERGY DATA FORM YR 80 CODE 00300

COMPANY BRIQ.EL.HAMMA.... SITE EL.HAMMA.
CONTACT MONCEF.JENNI... TEL .....
DATE-VISIT 9/81... INTVWR BT... XX ...S1
SUBSEC MAT.CONS. EMP 250. VALPRO .....
MAJPROD BRICKS... PRODN 89302.. UN T....

ENERGY CONSUMPTION FIGURES

ENERGY TYPE	CONSUMPTION	EQUIV TEP
ELEC-PURCH(M KWH)	3750...	E1 ..1200
NAT-GAS---(M NM3)	5400...	E2 ..5346
DOM-FO-(M LITRES)	624.6..	E3 533.47
LIGHT-FO-(TONNES)	0.....	E4 0
HEAVY-FO-(TONNES)	0.....	E5 0
COAL-----(TONNES)	0.....	E6 0
	TOTAL	TEP 7079.5

PARAMETERS

SPECIFIC-CONSN	0.0793	TEP/UNIT OUTPUT
ENRGY/EMPLOYEE	28.318	TEP/EMPLOYEE
ENRGY/VAL-PROD	.....	TEP/UNIT CURRENCY
VALUE-PROD/TEP	0	UNIT CURRENCY/TEP

EXHIBIT W

CODE	COMPANY	SUBSEC	MAJPROD	PRODN	TOTAL	SPECIF
00001	STEC	CHEMICALS	FERTILIZR	66000	511.87	0.0078
00002	FONDERIES REUNIES	MECMET	CASTINGS	2300	647.10	0.2813
00003	SA DOM POTINVILLE	MAT CONS	LIME	64500	3447.7	0.0535
00004	LE CONFORT	MECMET	APPLIANCE	70338	1555.7	0.0221
00005	SMMT	MECMET	LEAD	19200	8302.1	0.4324
00006	EL ANABIB	MAT CONS	CONCRETE	131462	2743.7	0.0209
00007	BRIQ ZARROUK	MAT CONS	BRICKS	178223	16942	0.0951
00008	COMPT NAT PLASTIQ	MISC	ARTICLES	8200	1595.1	0.1945
00009	BRIQ M'HENNI	MAT CONS	BRICKS	155540	8578.4	0.0552
00010	TUNISIE LAIT	FOOD PROC	MILK	30987	3548.1	0.1145
00011	SITER	TEXTILES	TEXTILES	13600	5968.5	0.4389
00012	SITEX	TEXTILES	TEXTILES	15200	2625.8	0.1728
00013	STIA	MECMET	VEHICLES	8777	1082.6	0.1233
00014	UNION GENERALE	MAT CONS	BRICKS		10272	
00015	SOTUVER	MAT CONS	GLASS	17656	7033.2	0.3983
00016	SONAP	MISC	TYRES	160000	2493.1	0.0156
00017	STIL	FOOD PROC	MILK	56000	2597.1	0.0464
00019	SOC GEN INDUSTRL	MECMET	CYLINDERS	120000.	280.02	0.0023
00020	SOTUBI	FOOD PROC	BISCUITS	2210	228.16	0.1032
00021	SOTUCHOC	FOOD PROC	CHOCOLATE	539	310.11	0.5753
00022	PLATRES TUN MEKN	MAT CONS	TILES	8209	468.70	0.0571
00023	CERAM DE L'QUEST	MAT CONS	BRICKS	55360	4079.1	0.0737
00024	CERAM TUNIS IENNE	MAT CONS	BRICKS	55000	3739.6	0.0680
00025	CERAM TUNISIENNE	MAT CONS	TILES	835000	5854.4	0.0070
00026	CIM ARTIF TUNISNE	MAT CONS	LIME	56000	3356.4	0.0599
00027	ALI MAJOUL + CIE	FOOD PROC	TOMATO CN	3704	798.78	0.2157
00028	SIOCOAC	MAT CONS	PIPES	16100	7964.1	0.4947
00029	CIM AMIANTE TUNSN	MAT CONS	PIPES	28000	1674.8	0.0598
00030	PATISS QUARDA	FOOD PROC	BREAD	3200	125.32	0.0392
00031	S MAT EL CHAKIRA	MECMET	CABLES	2847	634.33	0.2228
00032	GRANUPHOS	CHEMICALS	FERTILIZER	59965	3030.5	0.0505
00033	SIAPE	CHEMICALC	TSP	418074	17428	0.0417
00034	MAN TUN CERAMIQUE	MAT CONS	PORCELAIN	3600	2048.6	0.5691
00035	REFRACTAIRES DE T	MAT CONS	REFRACT	4500	1183.5	0.263
00036	STOA	MECMET	GASES	1830	2642.3	1.4439
00037	SOC LA BRIQUE TUN	MAT CONS	BRICKS	39985	2229.5	0.0558
00038	ICM	CHEMICALS	TSP	49488	14515	0.2933
00039	SAEPA	CHEMICALS	DAP	514974	15281	0.0297
00040	ENGRAIS DE GABES	CHEMICALS	MAP	62611	127.7	0.0204
00041	ICF	CHEMICALS	AL FLUOR	19730	5093.3	0.2582
00042	SOFOMECA	MECMET	CASTINGS	4787	2426.8	0.5070
00043	SOMOTEX	TEXTILES	THREAD	8595	2966.3	0.3451
00044	ATEL MEC SAHEL	MECMET	IRONMGY		1671.6	
00045	SFBT	FOOD PROC	BEER	295359	3299.1	0.0112
00046	REGIE ALCOOLS	FOOD PROC	ALCOHOL	1800	906.57	0.5037
00047	COOP AG IZIDIHAR	FOOD PROC	PRESERVES		1146.0	
00048	SFAX CERAMIQUE	MAT CONS	BRICKS	30000	2330.8	0.0777

EXHIBIT W (Continued)

1/13/82

CODE	COMPANY	SUBSEC	MAJPROD	PRODN	TOTAL	SPECIF
00049	STPA	FOOD PROC	FLOUR	48878	1562.2	0.0320
00050	COUSCOUS DU SUD	FOOD PROC	COUSCOUS	9291	1491.0	0.1605
00051	CIM D'OM KHELIL	MAT CONS	CLINKER	192406	24843	0.1291
01000	CIM ARTIF TUNISNE	MAT CONS	CLINKER	436618	87583	0.2006
02000	BRIQ FOUCHANA	MAT CONS	BRICKS	97147	8689.1	0.0894
03000	BRIQ EL HAMMA	MAT CONS	BRICKS	89302	7079.8	0.0793
04000	CIM BIZERTE	MAT CONS	CLINKER	721350	90946	0.1261
05000	CIM GABES	MAT CONS	CLINKER	482500	62408	0.1293
06000	S T SUCRE	FOOD PROC	SUGAR	60615	17061	0.2815
07000	SNPCA	PAPER	PAPER	23808	43106	1.8106
08000	SIAPE	CHEMICALS	TSP	317416	24190	0.0762
09000	C P GAFSA	MINING	PHOS ROCK	4.329	134103	30978
10000	EL FOULEDH	MECMET	STEEL	177937	134549	0.7562
					======	
					826546	
					======	

60 forms read, 60 details scanned,
60 items selected, 60 processed.

EXHIBIT X

1/13/82

CODE	COMPANY	SUBSEC	MAJPROD	PRODN	TOTAL	SPECIF
00003	SA DOM POTINVILLE	MAT CONS	LIME	64500	3447.7	0.0535
00006	EL ANABIB	MAT CONS	CONCRETE	131462	2743.7	0.0209
00007	BRIQ ZARROUK	MAT CONS	BRICKS	178223	16942	0.0951
00009	BRIQ M'HENNI	MAT CONS	BRICKS	155540	8578.4	0.0552
00014	UNION GENERALE	MAT CONS	BRICKS		10272	
00015	SOTUVER	MAT CONS	GLASS	17656	7033.2	0.3983
00022	PLATRES TUN MEKN	MAT CONS	TILES	8209	468.70	0.0571
00023	CERAM DE L'QUEST	MAT CONS	BRICKS	55360	4079.1	0.0737
00024	CERAM TUNIS IENNE	MAT CONS	BRICKS	55000	3739.6	0.0680
00025	CERAM TUNISIENNE	MAT CONS	TILES	835000	5854.4	0.0070
00026	CIM ARTIF TUNISNE	MAT CONS	LIME	56000	3356.4	0.0599
00028	SICOAC	MAT CONS	PIPES	16100	7964.1	0.4947
00029	CIM AMIANTE TUNSN	MAT CONS	PIPES	28000	1674.8	0.0598
00034	MAN TUN CERAMIQUE	MAT CONS	PORCELAIN	3600	2048.6	0.5691
00035	REFRACTAIRES DE T	MAT CONS	REFRACT	4500	1183.5	0.263
00037	SOC LA BRIQUE TUN	MAT CONS	BRICKS	39985	2229.5	0.0558
00048	SFAX CERAMIQUE	MAT CONS	BRICKS	30000	2330.8	0.0777
00051	CIM D'OM KHELIL	MAT CONS	CLINKER	192406	24843	0.1291
01000	CIM ARTIF TUNISNE	MAT CONS	CLINKER	436618	87583	0.0894
02000	BRIQ FOUCHANA	MAT CONS	BRICKS	97147	8689.1	0.0894
03000	BRIQ EL HAMMA	MAT CONS	BRICKS	89302	7079.8	0.0793
04000	CIM BIZERTE	MAT CONS	CLINKER	721350	90946	0.1261
05000	CIM GABES	MAT CONS	CLINKER	482500	62408	0.1293
					======	
					365495	
					======	

60 forms read, 60 details scanned,
23 items selected, 23 processed.

EXHIBIT Y

1/13/82

CODE	COMPANY	MAJPROD	PRODN	TOTAL	SPECIF
00007	BRIQ ZARROUK	BRICKS	178223	16942	0.0951
00009	BRIQ M'HENNI	BRICKS	155540	8578.4	0.0552
00014	UNION GENERALE	BRICKS		10272	
00023	CERAM DE L'QUEST	BRICKS	55360	4079.1	0.0737
00024	CERAM TUNIS IENNE	BRICKS	55000	3739.6	0.0680
00037	SOC LA BRIQUE TUN	BRICKS	39985	2229.5	0.0558
00048	SFAX CERAMIQUE	BRICKS	30000	2330.8	0.0777
02000	BRIQ FOUCHANA	BRICKS	97147	8689.1	0.0894
03000	BRIQ EL HAMMA	BRICKS	89302	7079.8	0.0793
			======	======	
			700557	63940	
			======	======	

60 forms read, 60 details scanned,
9 items selected, 9 processed.

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.

Other applications for data files and searching facilities include lists of equipment manufacturers, fuel heating values, insulation and refractory characteristics, process data and specific energy consumptions.

8.3 ENGINEERING CALCULATIONS

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

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

(i) furnace efficiency based on stack gas analyses and temperatures, taking into account fuel characteristics.
(ii) boiler efficiency, same as above and also including the effect of blowdown and condensate return.
(iii) heat losses from structures, such as boilers, process vessels, cement and brick kilns.
(iv) heat losses from pipes.
(v) fuel combustion calculations, to calculate stoichiometric air requirements for different fuels, stack gas volumes and calculated compositions from fuel analyses.
(vi) pump, compressor and turbine calculations, such as work output and efficiency.
(vii) pitot tube calculations, for estimating gas flow rates from instrument readings.
(viii) heat exchanger calculations and sizing of heat recovery systems.
(ix) estimation of steam and compressed air losses from leaks.
(x) 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 heating, ventilation, and air conditioning (HVAC) programs, based on standard calculational procedures such as American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) methods. Appendix A gives some examples of engineering programs written specifically for audit work using the Visicalc system.

8.4 FINANCIAL ANALYSES

Much energy management work leads to the identification of conservation opportunities, often requiring capital investment. The evaluation of these investments is necessary, using simple payback techniques or preferably using discounted cash flow methods. A typical discounted cash flow (DCF) rate of return calculation will be discussed in Session Fourteen. Further discussion of rate of return calculations is given in Appendix B.

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 can be used for this work.

8.5 SPECIAL APPLICATIONS

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

(i) linear program models for optimizing oil refinery and petrochemical plant operations
(ii) fuel blending calculations (e.g., gasoline blending by octane number, fuel oil blending to viscosity and sulphur specifications)
(iii) transportation models for optimizing the operation of distribution depots and delivery fleets
(iv) Monte Carlo simulation models (e.g., for estimating the capacity of storage tanks or inventory levels)
(v) electric utility system dispatch models for day-to-day operations, and capacity planning models for optimizing new plant construction
(vi) electricity and gas tariff analyses

Many such applications are the subject of commercial software, while there are also many proprietary and company-specific programs for particular tasks. Increasingly, companies are turning to user-oriented microcomputer systems rather than main frame computers for regular calculations.

Finally, mention should also be made of the special applications of microcomputers as remote terminals linked to energy management control systems or main frame data banks. Microcomputers have been used to monitor and control building heating and lighting systems, for example, in combination with telephone lines and modems.

8.6 SOFTWARE NEEDS AND AVAILABILITY

As indicated in the previous section, there are many commercially available software packages for microcomputers. However, there are relatively few such packages for carrying out energy-related calculations, and it is thus the responsibility of the users either to utilize commercial software such as Visicalc and Versaform for energy calculations or data handling or, where this software is inadequate, to write their own programs for specific nergy-related applications.

sets of data, making it possible to develop a library of useful programs on one or two disks which are easily stored and easily transported from one computer location to another.

With respect to the availability of commercial software, the major microcomputer manufacturers provide lists of software developed by them and suitable for their machines, and there are a very large number of specialist software companies throughout the world who write programs for the main microcomputer systems. The price of software will obviously vary quite considerably, depending on its capabilities, but most commonly used software is priced in the range from $150 to $500. Visicalc, for example, is typically available at a price at the lower end of this range, while Versaform is priced nearer to top end.

8.7 ASPECTS OF IMPLEMENTATION

There are a number of factors which must be taken into account when considering the implementation of microcomputer systems for energy management work. Software availability has already been mentioned. There is also the question of the hardware itself. Some manufacturers have well-developed dealer networks and can provide good after-sales service and backup, both in terms of repair of defective equipment and in terms of programming support and training.

The minimum hardware requirement for typical energy management work may be summarized as follows:

1. Microcomputer (say 48 - 64K RAM)
2. Monitor (a TV set is normally acceptable)
3. Printer (the dot-matrix type being quite adequate for engineering work)
4. Disk drive and control card (at least one drive unit, preferably two)

The cost of this hardware can be quite variable from country to country and manufacturer to manufacturer. A very rough guide to the price of a complete package with two disk drives would be $3,500.

Depending on the software systems to be used, various add-on "cards" (printed circuit boards) may be necessary. For example, the Versaform package is written in the Pascal language and therefore a special card, incorporating 16K extra RAM capacity, will usually be needed for a typical microcomputer, permitting it to run Pascal in addition to the Basic language which is usually standard. A Pascal card for the Apple II system will probably cost about $200.

Having purchased the basic hardware and software, the potential user will need to learn how best to operate the microcomputer system. For the optimum use of the microcomputer for energy efficiency work, some training may be desirable for plant engineers. Assuming that the plant engineer has a solid technical background, it may be appropriate for training to be given as follows:

1. "energy management" training, to teach the principles of energy conservation work, to review the technical basis of common unit operations (e.g., combustion).

2. an introduction to microcomputers, to encourage familiarity with the capabilities of the particular system and the main feature of its operation.

3. training and practice in the use of the available software packages.

4. some training in the writing of new programs (in BASIC and possibly FORTRAN) to cover the gaps which will undoubtedly exist due to limited availability of appropriate software.

Following the initial training, the plant engineer must be encouraged to practice using the microcomputer. There is no substitute for practical experience.

While most medium to large plants, and some small plants, will be able to benefit from the use of a microcomputer for technical work, applications in the area of data base management are less obviously beneficial. In general, data base management will usually prove to be most useful to government agencies for energy planning work, for monitoring the impact of existing energy policies, and for developing new policy initiatives.

Of course, without due consideration to the provision of reliable data and proper thought to the use to which the data will be put, there is little justification for a microcomputer-based system. However, if the right data are available, the closer user interaction achievable with a microcomputer will be found to be extremely valuable for the energy planner and policy maker, and thus the microcomputer system is much superior to the conventional main frame system usually used by a national statistical bureau for many types of work involving the evaluation of options and decision-making.

SESSION NINE

FIELD VISIT TO THE OPT PLANT, APRIL 4

INTRODUCTION

In the course of the Seminar, a field trip was made to the phosphate benefication plant of the Office Togolais des Phosphates, a state-owned enterprise. About 40 seminar participants were present.

Following a comprehensive introduction to the plant by management (see Appendix C), a tour of the plant was made, from all the rail wagon unloading points to the final product storage and shipment facilities. The processing activities at each stage were described. After lunch, the opportunity was taken to demonstrate the use of various portable diagnostic instruments to the seminar participants. The main instruments used by the participants themselves were:

(1) Combustion gas analyser - to check stack gas composition and temperature for a boiler, and thus calculate combustion efficiency, and

(2) Infrared pyrometer - to determine the external temperature profile of several rotary dryers and thus calculate heat loss by radiation and convection, and to determine the surface temperature of the fuel oil storage tank and thus heat losses from the tank to atmosphere.

In addition, a group of the participants collected key energy and production data from the plant records. These data, the data collected on the plant using the instruments, and various observations on the operations are described in the notes which follow.

1.1 OVERALL ENERGY USE

(a) Data taken from information collected at the plant office.

(b) Important to monitor "specific energy consumptions" regularly - a monthly report should be produced with such figures for all operating departments (including the railway transport). Operations should be followed similarly on a daily basis: much of this is already done at the OTP plant, but the general point should be made that this kind of monitoring is most important for efficient operation of industrial facilities.

(c) Typical data as follows:

		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Raw material	10^3T	306.000	420.400	423.700	420.900	320.200	298.100
Product	BPL	79.590	79.410	79.440	79.560	80.180	---
Fuel Oil	10^3L	2334.800	3173.400	3162.800	3114.900	2181.300	2031.900
Electric	10^3KWH	5334.100	5529.100	6051.800	5514.400	4557.400	3826.200
Product	10^3T	152.359	203.400	201.600	197.900	143.900	138.300
Litres/tonne		15.330	15.600	15.690	15.740	15.160	14.690
KWH/tonne		35.000	27.200	30.000	27.900	31.700	27.700
Water in	%	17.540	17.600	17.510	17.240	17.200	17.210
Water out	%	1.930	1.920	1.940	1.940	1.940	1.980
Yield product/feed		0.498	0.484	0.476	.470	.449	.464
Water removed	10^3T	28.800	38.700	37.800	36.600	26.500	25.400
Fuel liters/tonne water		80.950	81.980	83.750	85.150	82.270	79.840

(d) The combustion control approach better than at the first visit in December, when the firing control appeared poorer. The above figures confirm this improving trend (fuel liters/tonne water removed were 79.84 in March, 85.15 in January, a difference of 6%).

(e) Electricity use also shows a gradual decline (March 27.7, October 35.0, a difference of 21%). Suggests that savings over the medium to long term of perhaps 10-15% <u>might</u> be obtained through good supervision and management.

(f) Poorer fuel efficiency seems to occur at higher throughputs, suggesting that operations should be carefully monitored. Steadier performance might be obtained by running the plant at more constant throughput, with savings on the order of 5% of fuel used at present.

(g) Overall efficiency of dryer system over 70%, which is reasonable:

$$80.95 \frac{\text{liters fuel}}{\text{t water}} = 760 \frac{\text{kcal}}{\text{kg water}}$$

(fuel calorific value - PCS - assumed 9600 kcal/kg or 9400 kcal/litre)

Evaporation of water, say 560 kcal/kg

Efficiency 560/760 = 74%

(85.15 litres/tonne = 70% efficiency)

(h) At dryer inlet, the phosphate contains over 17% water (figures up to about 18.6% can be observed) and the product runs around 1.9 - 1.95% water. Thus a change of 1% water at the feed inlet represents a change in fuel use of say 6 to 7%. Operation of centrifuges is thus most important and deserves priority attention. Questions: Is there anything that can be done to reduce water content, perhaps by changing operation of centrifuges (faster rotation?) or by putting centrifuges in series, or adding centrifuges in parallel to reduce throughput of each? Are there additives available to reduce surface tension and thus allow better water removal?

(i) Slightly different processes used in other plants - e.g., Metlaoui, Tunisia, use a vacuum filtration separation after the hydrocyclones to produce a dryer feed of 14-15% water. Can a slipstream of phosphate be treated in a small vacuum filter at the plant? The economics of this need checking (figures of 13% and 15% moisture observed at Moroccan plants).

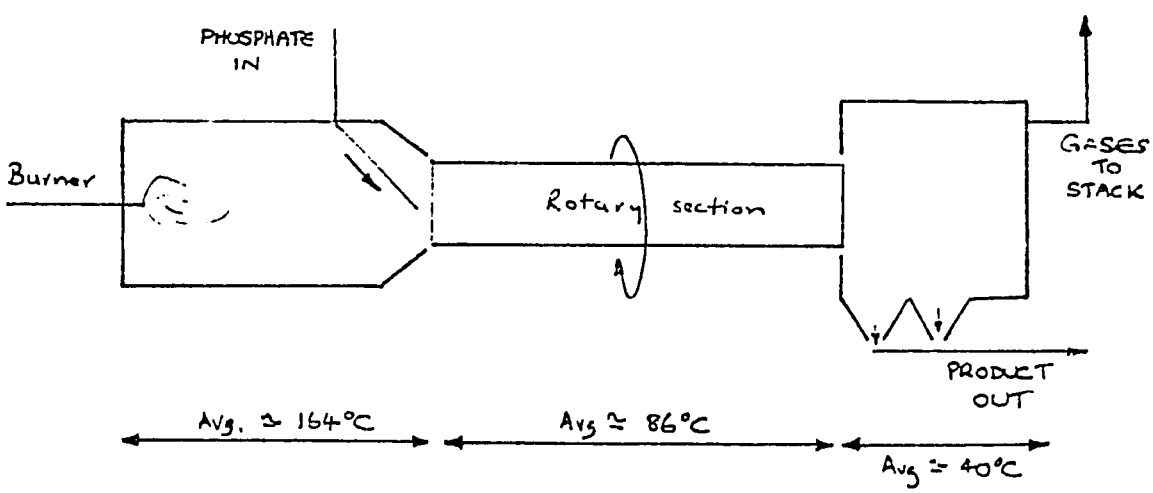
(j) Product moisture seems extremely low (Tunisia = 3%). Is 2% level really necessary? Slightly higher moisture at dryer could save fuel, avoid some dust losses, and yet still allow shipping specifications to be met. Needs careful study.

(k) Dust losses from stacks not measured, but looks significant. Better removal system possible? Savings might be as much as 5%?

(l) Large number of instruments broken, thus not possible to monitor performance of individual dryer lines. Flow rates of phosphate, temperatures, water contents, etc., should be measured regularly and optimum performance of <u>each</u> dryer should be the objective.

1.2 DRYER HEAT BALANCE

(a) As an exercise, we measured dryer surface temperatures to estimate heat losses. Typical temperatures were as follows for line 3:



Heat losses were calculated to be about 330,999 kcal/hour (method described in seminar manual). Note that surface temperatures on dryer 4 were consistently 5-10°C higher, resulting in heat losses about 10% higher (say 360,000 kcal/hour).

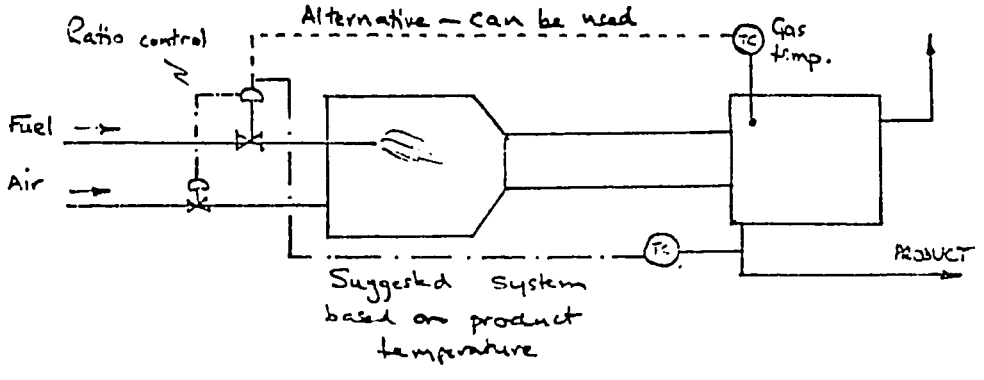
(b) An approximate heat balance may be made to illustrate the general principles involved. Very rough temperature and specific heat numbers were used, and the combustion air rate was assumed to be about 300% of stoichiometric air:

	10^6 Kcal/hr	%
Heat in (fuel = 1140 litres/hour)	10.73	(100)
Out - water evaporation for 80 t/hr product	8.17	(76)
- stack gases at say 80°C	0.38	(4)
- phosphate product at say 80°C	1.20	(11)
- radiation/convection losses	0.33	(3)
	10.08	(94)
unaccounted/errors	0.06	(6)

Obviously this should be computed for each drier using accurate measurements of flows and temperatures and should allow for the energy input in the hot fuel oil (although this is quite small), etc.

1.3 CONTROL OF OPERATIONS

The control system for each dryer was not examined, although it was noted that the plant operator did not appear to have any knowledge of the product moisture content - someone else has the information. Due to the inevitable delay in getting moisture results, it is not possible to control the fuel to the dryer according to the outlet phosphate temperatures? This is done in similar drying operations and is normally quite reliable. Careful testing needs to be done. Air rates should also be checked and tests carried out at lower air and fuel rates.



(Some dryers have FD and ID fans, allowing good air control. Dryer 3, for example, has ID fan only and combustion control is thus more difficult). Such tests may have already been carried out by the plant - results would be interesting.

1.4 FUEL OIL TANKS

(a) Quick tests on the small tank indicated a surface temperature of as much as 65°C, suggesting losses of perhaps 150 t/year of fuel for heating the tank contents. The operation of this system should be carefully checked - oil should be stored at the minimum temperature possible, perhaps 45°, and only heated to 90 - 100°C at the burner itself, as is already done.

(b) The value of insulating the bottom 2 - 3 meters of the tanks should be investigated. The black color also leads to heat losses - why not paint?

1.5 BOILER

(a) The small thermal fluid boiler was checked and the following typical figures found:

Stack	170°C	(normal)
Oxygen	6.9 - 7%	(a little high)
Efficiency	90%	

Some reduction in oxygen level might be possible resulting in an improved efficiency (1 or 2%).

(b) The back of the boiler, some parts of line, and valves and fittings, should be properly insulated. Worth checking.

1.6 OTHER ITEMS

(a) Lights - investigate benefits of replacing mercury vapor lamps by high pressure sodium or similar. Small savings possible, but may not be economic.

(b) Transport energy use of 0.22 liters per tonne looks alright but could be studied.

1.7 GENERAL COMMENT

Operations appear to be well controlled in general. Some energy savings could be achieved by careful investigation of all stages of the process, but it is unlikely that very large savings will be found for any one stage. Better supervision/control <u>might</u> ultimately lead to savings of 5% or so.

SESSION THIRTEEN

ECONOMIC ANALYSIS OF ENERGY EFFICIENCY MEASURES

THE USE OF A MICROCOMPUTER FOR DCF CALCULATIONS

A brief discussion of DCF calculations and the use of a microcomputer to perform them appears in Appendix B.

APPENDIX A
EXAMPLES OF ENGINEERING CALCULATIONS

This Appendix gives examples of the use of microcomputer programs to carry out some engineering calculations commonly applied in energy management work. The calculations are:

1. Boiler/furnace efficiency
2. Heat losses from hot structures to atmosphere
3. Heat losses from pipes
4. Gas flow measurement by pitot tube

For each program, a comprehensive discussion of the basis for the calculation method is provided, and examples of typical input and output are shown. The programs have been applied to the Apple II system, which is quite typical of the many personal microcomputers available at moderate cost to plant engineers.

A.1 BOILER/FURNACE EFFICIENCY CALCULATION ("COMBUSTION EFF")

1 INTRODUCTION

This calculation involves estimating the various sources of loss from the boiler or furnace and then calculating the thermal efficiency by difference:

% thermal efficiency = 100 - (sources of loss) %

Nine different sources of loss have been identified:

1. Unburnt combustible material in fly ash
2. Unburnt combustible material in slag or ash withdrawn from the bottom of the combustion zone (in the program this is referred to as "slag ash")
3. Sensible heat in fly ash
4. Sensible heat in slag ash
5. Sensible heat of dry flue gas
6. Latent heat of moisture in flue gas
7. Unburnt combustible carbon monoxide in flue gas
8. Radiation and convection heat loss from the structure of the boiler or furnace
9. Sensible heat in blowdown water.

Items 1 and 4 are applicable only for solid fuels such as coal and coke; item 9 applies only to boilers.

Apart from the radiation and convection heat loss (item 8), the program calculates all the individual sources of loss. Item 8 is entered by the user: a program to calculate such losses follows in this Appendix, but a typical value of 3% can be entered if the actual value is not known.

2 HOW THE PROGRAM IS ORGANIZED

The program uses the Visicalc "electronic spreadsheet" system: it is, therefore, necessary to load Visicalc into the microcomputer prior to loading the "COMBUSTION EFF" diskette.

The worksheet is divided into several "fields", in which the various elements of the program have been placed. These elements are shown in Exhibit A.1.1, and are:

1.	Numerical input data	(A1 - E36)
2.	Identification information	(A37 - E48)
3.	Calculation results	(A50 - E82)
4.	Standard input data	(J1 - R8)
5.	Typical fuel calorific values	(J20 - M47)

The required input data are listed in Exhibit A.1.2. Some items are dependent on the characteristics of the fuel being fired: typical values are shown on the worksheet itself (J1-R8 and J20-M47) and also in Exhibit A.1.4.

3 CALCULATION BASIS

The basic equations used in the calculation procedure are listed in Exhibit A.1.3.

4 WORKED EXAMPLE

Exhibit A.1.4 presents a typical worked example of the combustion efficiency program applied to a coal-fired boiler.

Note that the Visicalc program operates by changing the input data. Whenever COMBUSTION EFF is loaded, a set of input and output figures will appear, as these are the data used for the previous calculation. The user must make sure that all the input data are changed to correspond to the new calculation to be performed.

EXHIBIT A.1.1 "COMBUSTION EFF" WORKSHEET

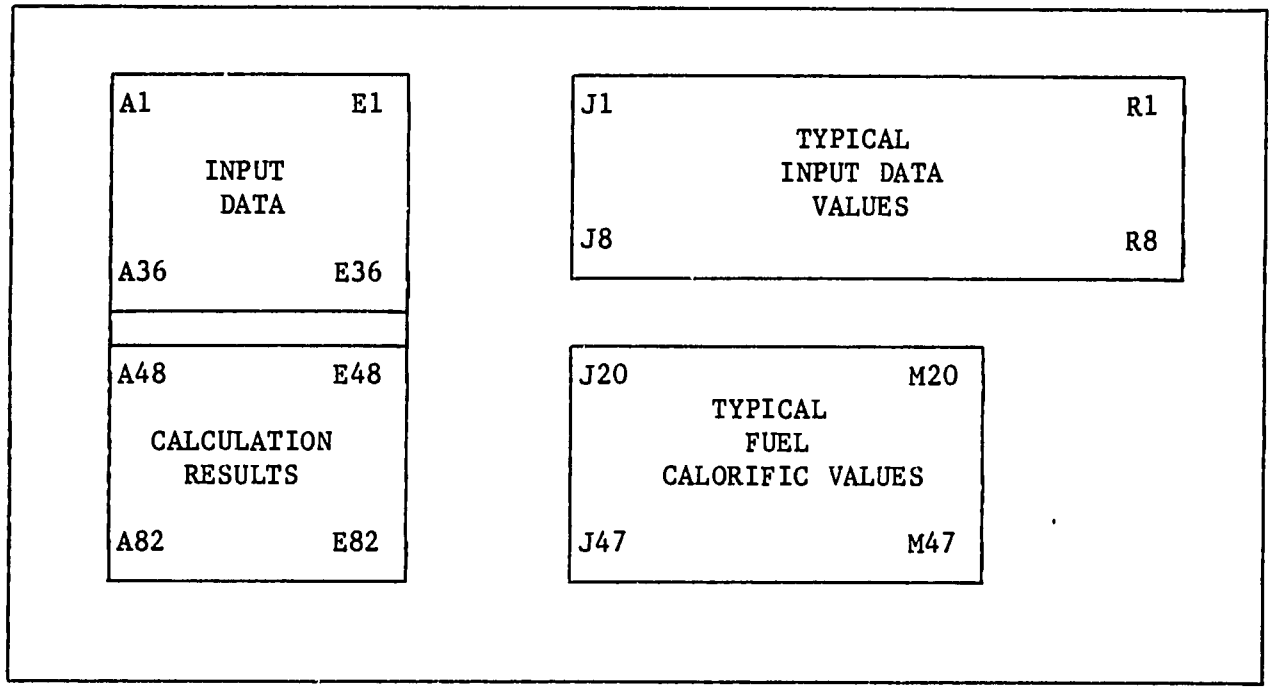


EXHIBIT A.1.2

INPUT DATA

	Symbol	Notes
Weight fraction ash in fuel	A_{fuel}	(1) (2)
Fraction of ash in fuel to fly ash	F_{FA}	(2)
Weight fraction combustibles in slag ash	C_{SA}	(2)
Weight fraction combustibles in fly ash	C_{FA}	(2)
Gross heating value of fuel, kcal/kg	CV_G	(1)
Flue gas temperature, °C	T_{FG}	(3)
Ambient temperature, °C	T_A	
Slag ash exit temperature, °C	T_{SA}	(4)
Oxygen in dry flue gas, vol %	O_2	
Fuel preheat temperature, °C	T_{fuel}	(5)
Carbon monoxide in dry flue gas, vol %	CO	
Structure radiation and convection loss, %	L_{RC}	(6)
Blowdown temperature, °C	T_{BD}	(7)
Feed water to blowdown, wt %	BD	(8)
Feed water temperature, °C	T_{H_2O}	(9)
Maximum theoretical CO_2 in dry flue gas, vol %	CO_{2MAX}	(10)
Water in fuel, wt %	H_2O_{fuel}	(1) (11)
Hydrogen in fuel, wt %	H_{fuel}	(1) (11)
K1 fuel characteristic constant	K_1	(10)
K2 fuel characteristic constant	K_2	(10)

Notes

(1) These data relate to the quality of the fuel "as fired". Note that in the case of coal fuels, "as fired" quality may be significantly different from proximate or ultimate analyses.

(2) Value should be within the range 0.00 to 1.00

(3) Temperature after any economizers or air preheaters

(4) Temperature at which slag and/or ash (other than fly ash) leave the furnace or boiler.

(5) This temperature should be recorded if the fuel is preheated by external means (but not heat recovery from the furnace/boiler). External preheating will be common only for oil fuels. In the case of no preheating or preheating by heat recovery (e.g. self-recuperative gas burners), the ambient temperature can be used for T_{fuel}.

(6) L_{RC} can be the output of the "Heat Losses from Hot Structures" program. A typical value for a reasonably insulated boiler or furnace operating at full capacity would be around 3% of fuel fired.

(7) Blowdown temperature after any heat recovery.

(8) Percentage of feedwater to blowdown, including any flash steam produced by blowdown.

(9) Feedwater temperature including recycled condensate and makeup, but before preheating in economizer.

(10) These values depend entirely on the characteristics of the fuel used. Select the appropriate value from Exhibit A.1.4 or in the program itself.

(11) These values depend on the free water in the fuel and the fuel analysis itself. Use actual test data or the typical values shown in Exhibit A.1.4.

EXHIBIT A.1.3

PROGRAM CALCULATION BASIS
(In order of program execution)

(1) $$LFA = \frac{A_{fuel} \times F_{FA} \times C_{FA} \times 808{,}300}{(1 - C_{FA}) \times CV_G}$$

(2) $$LSA = \frac{A_{fuel} \times (1 - F_{FA}) \times C_{SA} \times 808{,}300}{(1 - C_{SA}) \times CV_G}$$

(3) $$LFASH = \frac{A_{fuel} \times F_{FA} \times (T_{FG} - T_A) \times 21}{(1 - C_{FA}) \times CV_G}$$

(4) $$LSASH = \frac{A_{fuel} \times (1 - F_{FA}) \times (T_{SA} - T_A) \times 21}{(1 - C_{SA}) \times CV_G}$$

(5) $$CO_2 = \left[1 - \frac{O_2}{21}\right] \times CO_{2MAX}$$

(6) $$LDG = \frac{K1 \times (T_{FG} - T_A) \times (1 - 0.01\ [LFA + LSA])}{CO_2}$$

(7) $$CV_G^0 = CV_G + ([T_{fuel} - T_A] \times 0.47)$$

(8) $$LH2O = \frac{[H_2O_{fuel} + 9H_{fuel}]\ [588 - T_A + 0.50\ T_{FG}]}{CV_G^0}$$

(9) $$LCO = \frac{K2 \times CO\ (1 - 0.01\ [LFA + LSA])}{CO + CO_2}$$

(10) SIGMA L = LFA + LSA + LFASH + LSASH + LDG + LH2O + LCO + LRC

(11) LBD = $$\frac{[T_{BD} - T_{H_2O}] \times BD \times [100 - SIGMA\ L]}{([T_{BD} - T_{H_2O}] \times BD) + ([100 - BD] \times [660 - T_{H_2O}])}$$

(12) E = 100 - [LBD + LFA + LSA + LFASH + LSASH + LDG + LH2O + LCO + LRC]

(13) XSA = $$\left[\left(\frac{CO_{2MAX}}{CO_2}\right) - 1\right] \times 100$$

Derived Variables

LFA	energy loss% as combustibles in fly ash
LSA	energy loss% as combustibles in slag ash
LFASH	energy loss% as sensible heat in fly ash
LSASH	energy loss% as sensible heat in slag ash
LDG	energy loss% in dry flue gas
CV_G^0	fuel gross heating value + sensible heat in fuel
LH2O	energy loss% as moisture in flue gas
LCO	energy loss% as unburnt CO in flue gas
LBD	energy loss% in blowdown
SIGMA L	sum of various losses, as defined
E	overall thermal efficiency, %
XSA	excess air, %

1 INTRODUCTION

This program enables the energy loss from the outside surface of kilns, boilers and furnaces to be estimated, based on measurements of the temperature of the structure surface. Temperatures may be determined using a contact thermocouple or a non-contact infrared pyrometer, the latter being particularly useful for equipment such as rotating cement and lime kilns.

2 HOW THE PROGRAM IS ORGANIZED

The Visicalc worksheet is divided into various elements, as shown in Exhibit A.2.1:

(1) Introduction for the user (A1-D37)
(2) Miscellaneous emissivity values (H1-K35)
(3) Convection constants (M1-N6)
(4) Calculation field (A40-X51)
(5) Summary of results (V54-Y61)

The structure may be divided into a number of sections (up to a total of 15), and for each section the following input data are needed:

(1)	Area of the surface, square meters	(A)
(2)	Surface emissivity	(E)
(3)	Convection constant	(C)
(4)	Surface temperature, °C	(TS)
(5)	Ambient temperature, °C	(TA)

3 CALCULATION BASIS

The heat loss from a structure consists of two main components, radiation and convection. For each subdivision of the total surface, heat loss by radiation and convection is calculated by the following equations:

Radiation heat loss (Kcal/hour):

$$QSR = 4.90\ EA \left[\left(\frac{TS + 273}{100} \right)^4 - \left(\frac{TA\ \ 273}{100} \right)^4 \right]$$

Convection heat loss (Kcal/hour):

$$QSC = CA\ (TS - TA)^{1.25}$$

The actual emissivity of a surface may be determined experimentally or typical values may be used (see blocks H1-K35 of the worksheet). A perfect black body radiator has an emissivity value of 1.0.

It should be noted that this program gives the heat loss for structures in still air conditions and will underestimate the heat loss from structures exposed to windy conditions.

4 WORKED EXAMPLE

Exhibit A.2.2 presents a typical worked example of the heat loss program. The user must ensure that all input data are changed to correspond to each new calculation, otherwise data will be retained from the previous calculation.

EXHIBIT A.2.1: WORKSHEET FOR "HEATLOSS-STRUCTURES"

A1 D1

INTRODUCTION

A37 D37

H1 K1

MISCELLANEOUS EMISSIVITY VALUES

H35 K35

M1 N1

CONVECTION CONSTANTS

M6 N6

A40 X40

CALCULATION AREA

A51 X51

V54 Y54

SUMMARY OF RESULTS

V61 Y61

GAS FLOW RATES BY PITOT TUBE

1 INTRODUCTION

Energy audits frequently require the preparation of heat and material balances across important energy consuming items of equipment. For most boilers, kilns, dryers and HVAC systems, it is often necessary to determine air (or flue gas) flow rates into and out of the equipment in order to prepare an acceptable balance. Permanent instrumentation for the measurement of these flows is usually not installed. In situations where the air pressure is sufficiently low to permit an access hole to be inserted in the pipe or duct, a reasonable measurement of flow rate can be made using a portable pitot tube and manometer set. This computer program provides a quick and simple method for the conversion of plant pitot readings to volume and mass flow rates.

The pitot tube used should be purchased from a reputable manufacturer and should be in accordance with an appropriate national standard (e.g. U.S. or British). A drawing of a typical pitot tube head is shown in Exhibit A.3.1.

The principle of operation of the pitot tube and manometer is illustrated in Exhibit A.3.2. A manometer is used in preference to other pressure measuring devices as it is sensitive to the relatively small pressures involved.

The total pressure of a fluid flowing in a pipe is the sum of two components: the static pressure and the dynamic or velocity pressure. The static pressure is the non-directional potential energy of the fluid, or its "bursting" pressure. The velocity pressure is a measure of the fluid's kinetic energy in a given direction by virtue of its motion. The pitot tube consists of two concentric tubes. The inner tube has a total pressure hole which faces the direction of fluid flow and is subjected to the velocity and static pressures. The outer tube has static pressure holes which are arranged at 90° to the direction of fluid flow. These are subjected only to the static pressure. By connecting the pitot tube to the manometer in such a way that the pressures on the total and static pressure holes are opposed, the manometer will display only the (net) velocity pressure.

The velocity pressure is related to the flow rate of the fluid. In precisely controlled use and by applying various correction factors, fluid flow rates can be determined to an accuracy of ±1% with a pitot tube. In practical energy audits, an accuracy of ±5% is probably realistic when used with care.

The program described here can be applied to the measurement of air and flue gas, but <u>not steam</u>, flowing in <u>circular cross section pipes.</u>

The standard procedure is to determine the velocity profile along any one pipe diameter and to repeat for a second diameter at right angles to the first. Ten measurements should be taken along each diameter, as shown in Exhibit A3.3. The position of each measurement point is selected so that it

represents one of a number of concentric annuli, all having the same cross sectional area. It is assumed that the mean cross sectional velocity is equal to the numerical average of the local velocities measured along the two traverses. The average velocities for the two traverses should be within reasonable agreement.

2 HOW THE PROGRAM IS ORGANIZED

The program "PITOT" is written using the Visicalc system. Following loading of the main Visicalc program, PITOT may be loaded. The worksheet is organized as shown in Exhibit A3.4, and the program calculation basis is summarized in Exhibit A.3.5

3 WORKED EXAMPLE

A worked example of the program is shown as Exhibit A.3.6, with the input data clearly indicated on the left hand side.

EXHIBIT A.3.4

WORKSHEET FOR "PITOT"

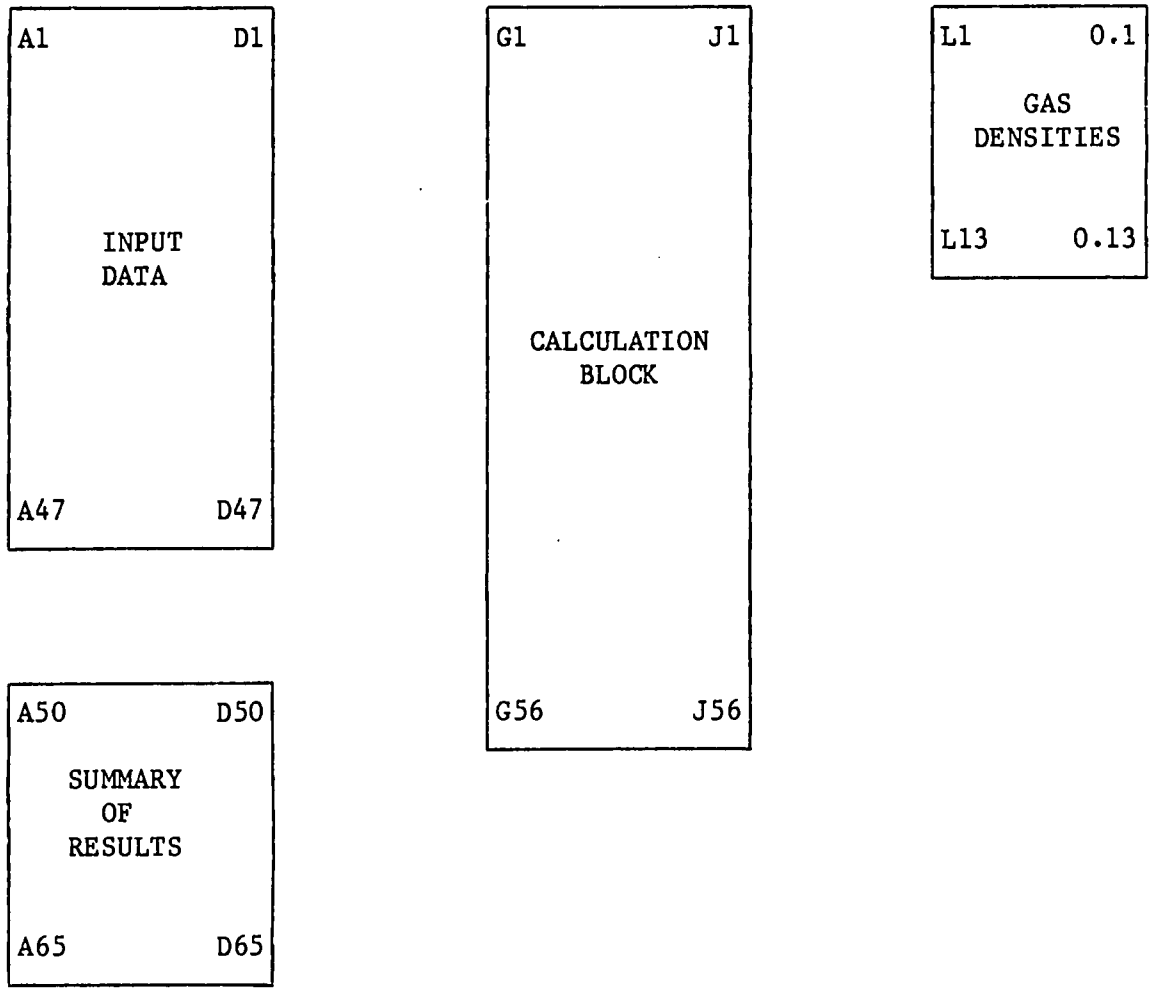


EXHIBIT A.3.5

PROGRAM CALCULATION BASIS

(1) $Y = \dfrac{(10^5 + PS)}{(10^5 \div PS + PV)}$

(2) $X = 0.085Y$

(3) $W = 1.291 \times \sqrt{\dfrac{(T1 + 273) \times 1.20 \times 10^8}{(1 + X) \times 289 \times PA \times (10^5 + PS) \times D}}$

(4) $VHN = W\sqrt{PVHN}$

where PVHN is one of a total of HN horizontal traverse pitot readings

(5) $VVN = W\sqrt{PVVN}$

where PVVN is one of a total of VN vertical traverse pitot readings

(6) $VHA = \dfrac{\sum VHN}{HN}$

(7) $VVA = \dfrac{\sum VVN}{VN}$

(8) $VAV = \dfrac{\sum VHN + \sum VVN}{HN + VN}$

(9) $Q1 = 188.5 \times R^2 \times VAV$

(10) $P1 = 10^5 + PS$

(11) $Q2 = \dfrac{Q1 \times (T2 + 273) \times P1}{(T1 + 273) \times P2}$

(12) $M = \dfrac{Q1 \times 17.34 \times 10^3 \times p^1 \times D}{(T^1 + 273) \times 10^5}$

EXHIBIT A.3.5 (Cont.)

Derived variables

W intermediate calculation constant depending on gas conditions in pipe

VHN velocity, m/sec, at point N of horizontal traverse

VVN velocity, m/sec, at point N of vertical traverse

VHA mean velocity, m/sec, along horizontal traverse

VVA mean velocity, m/sec, along vertical traverse

VAV mean velocity in pipe, m/sec

APPENDIX B
CALCULATING THE RATE OF RETURN ON CAPITAL INVESTMENTS

1 INTRODUCTION

The economic aspects of energy conservation projects requiring capital investment are at least as important as the technical aspects. When sizing energy conservation equipment such as heat exchangers, the selection of the optimum size is usually determined by economic considerations rather than technical criteria.

Various techniques are available for ranking energy conservation projects according to the amount by which their energy savings exceed their cost of capital. These methods of estimating the rate of return on investments have essentially the same objectives:

(1) to provide a basis for the selection or rejection of projects by ranking them in order of profitability

(2) to ensure that investments are not made in projects which earn less than the cost of capital, which is frequently expressed as a minimum or "cut-off" rate of return.

A simple method of ranking projects is to determine the "payback period", the time taken to repay the invested capital by the net savings from the project. However, the value of savings and costs which occur at different times are not adequately reflected in the determination of payback period, and therefore discounting techniques are now used for evaluating most major investments.

2 DISCOUNTED CASH FLOW CALCULATIONS

In project appraisal work, the objective is to compare and evaluate alternative projects which have different future "net cash flows" at different times. The net cash flow in any given year is the arithmetic sum of cash outflows (e.g. capital expenditures, operating costs, etc.) and cash inflows (energy savings). The problem is to determine the present value of the series of future cash flows which will be generated by the project.

The present value P (i.e. today's value) of an amount of money F_t that will be earned t years in the future is given by:

$$P = \frac{F_t}{(1 + r)^t}$$

where r is known as the discount rate, analogous to the rate of interest obtained on money invested with a bank. Application of the above formula provides a consistent method of comparing the present values of different amounts of money that will become available at different times.

A pre-requisite for the use of discounting methods is the determination of the cash flow profile of a project. The profile must show all expenditures and all revenues relating to the project for each year of the project's construction, operation and demolition. The cash inflows and outflows are summed to give the net cash flow for each year of the project.

The net present value of the project is defined as the sum of the individual present values of the cash flows that occur in each year of the project:

$$NPV = \frac{F_t}{(1 + r)^t}$$

Clearly, for any project, the NPV depends on the value of the discount rate (r) that is used in the calculation. Normally the discount rate adopted represents the cost of capital to the enterprise making the investment.

The significance of net present value is that it represents the residual surplus, in today's values, that the project will earn after repaying the initial capital investment. When projects requiring the same amount of capital are compared, the project with the highest NPV would be preferred as it represents the most efficient use of capital.

The Exhibits illustrate a typical NPV calculation:

(1) Exhibit B.1 is a cash flow profile for a hypothetical project

(2) Exhibit B.2 is a typical NPV calculation using the cash flows from the previous exhibit.

It will be seen that the NPV decreases sharply as the discount rate increases. In other words, the real value of energy savings decreases as the cost of investment capital increases.

Exhibit B.3 shows in graphical form the relationship for NPV against the discount rate for the same example. It can be seen that the NPV becomes zero at a discount rate of about 11%. This figure is known as the "Discounted Cash Flow Rate of Return" and is defined as the discount rate at which the NPV is zero. The DCF rate of return is normally calculated by iteration or by graphical means.

The significance of the DCF rate of return is that it represents the maximum cost of capital which a project can afford to pay and still break even (including repayment of capital) at the end of the project life. The DCF return provides a quantitative method of ranking projects in order of their efficiency of capital use. The method is particularly effective for comparing projects of different size and timing and is probably the method most widely used for the economic analysis of major investments.

EXHIBIT B.1 – CASH FLOW PROFILE
HYPOTHETICAL WASTE HEAT RECOVERY PROJECT

$ or £	0	1	2	3	4	5	6	7	8	9	10	11
Initial capital investment	(60,000)	(20,000)										
Residual scrap value												8,000
Value of energy savings		10,000	15,000	15,000	15,000	15,000	20,000	20,000	20,000	20,000	20,000	
Operating costs:												
labor		(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	
utilities		(1,000)	(1,500)	(1,500)	(1,500)	(1,500)	(2,000)	(2,000)	(2,000)	(2,000)	(2,000)	
maintenance		–	(500)	–	(500)	–	(1,000)	–	(1,000)	–	–	
overheads		(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	(500)	
Net Cash Flow	(60,000)	(12,500)	11,500	12,000	11,500	12,000	15,500	16,500	15,500	16,500	16,500	8,000

Brackets ( ) denote cash outflow

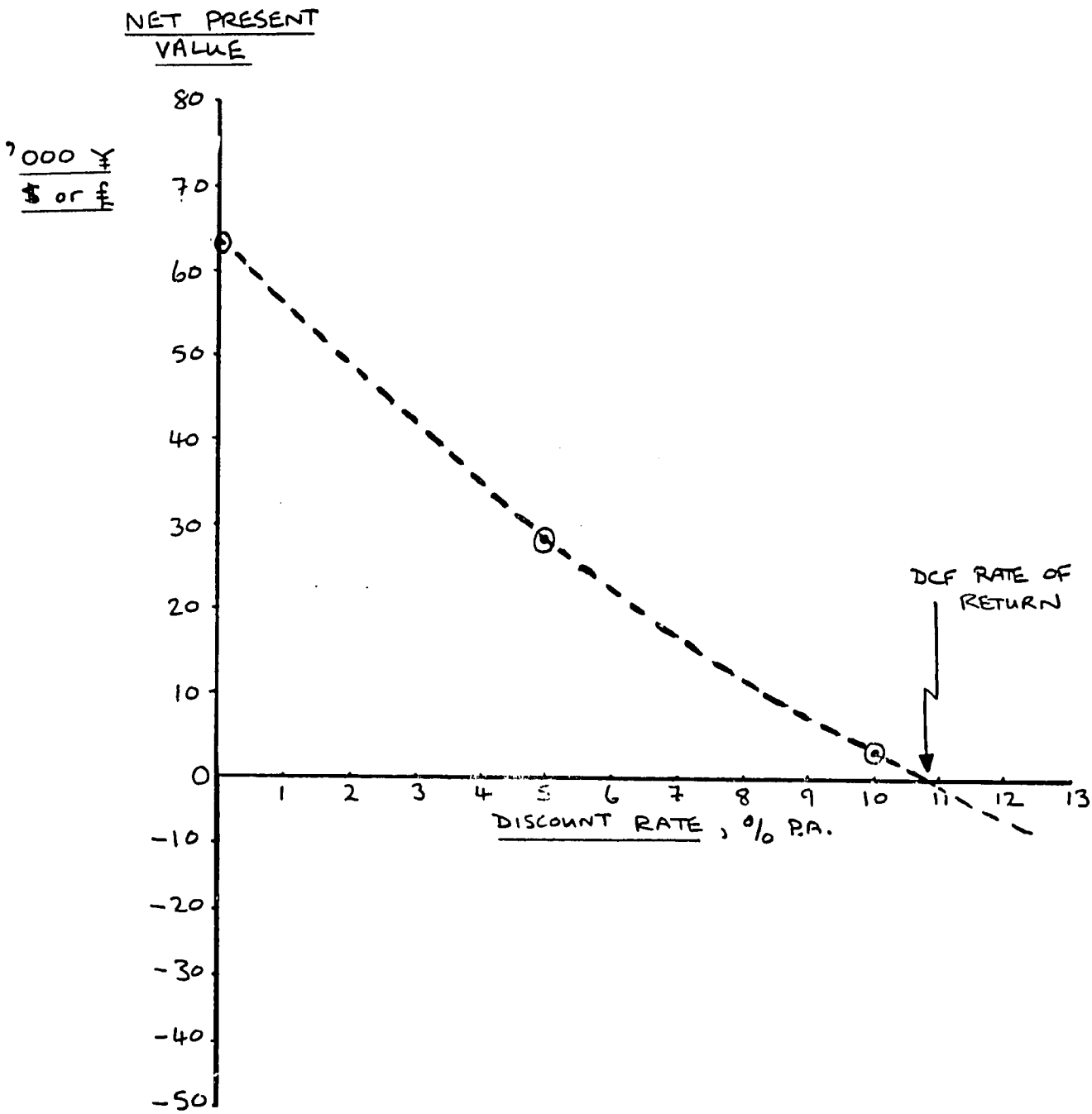
EXHIBIT B.2
ILLUSTRATION OF NET PRESENT VALUE CALCULATION

	0	1	2	3	4	5	6	7	8	9	10	11	Sum of Annual Cash Flows
Net Cash Flow (no discounting)	(60,000)	(12,500)	11,500	12,000	11,500	12,000	15,500	16,500	15,500	16,500	16,500	8.000	63,000
5% Discount Rate													
Discount factor	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711	0.677	0.645	0.614	0.585	
Present value	(60,000)	(11,900)	10,431	10,368	9,465	9,408	11,563	11,732	10,494	10,643	10,131	4,680	27,015
10% Discount Rate													
Discount factor	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386	0.350	
Present value	(60,000)	(11,363)	9,499	9,012	7,855	7,452	8,742	8,465	7,239	6,996	6,369	2,800	3,066

Discount Rate % per year	Net Present Value $ or £
0	63,000
5	27,015
10	3,066

EXHIBIT B.3

RELATIONSHIP BETWEEN NET PRESENT VALUE AND DISCOUNTED CASH FLOW RATE OF RETURN



3 COMPUTER PROGRAM

A computer program "ROI" to calculate the NPV of a series of cash flows has been written in the Visicalc format, the calculation procedure following the method described above. Exhibit B.4 shows the layout of the worksheet.

The user enters the required investment, scrap value, savings and costs data for each year. A total of 11 years are allowed in the program; normally, the first (year 0) will include the major capital investment, the next ten years (years 1 - 10) will represent the useful life of the project, and year 11 is the year in which the equipment is dismantled and some scrap value obtained. The influence of savings and costs after 10 or 11 years is usually quite minor for most projects, and in practice there is little need for data beyond that period.

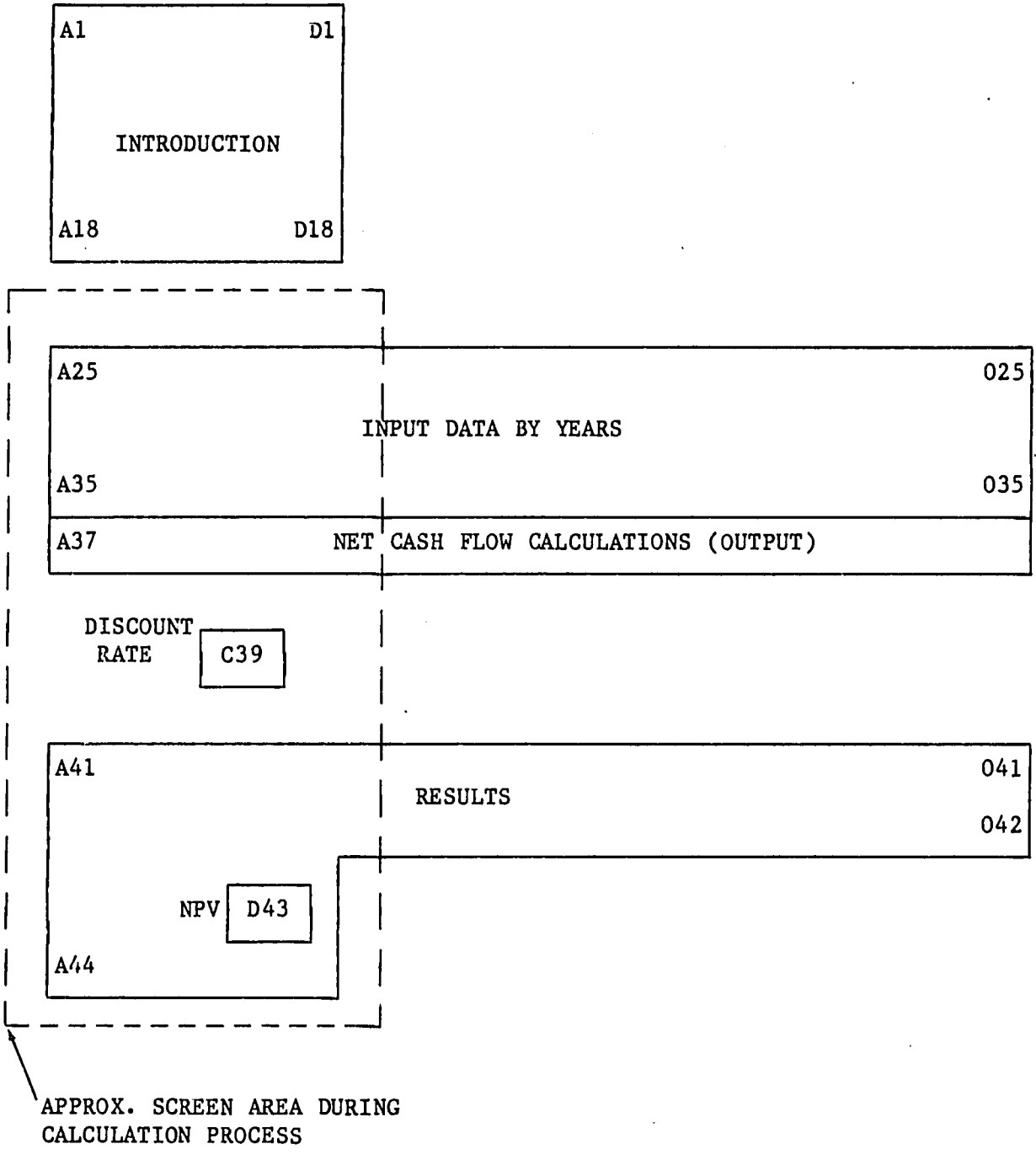
It is recommended that the user enter the data for the project in the appropriate columns and then set the screen into the position indicated in Exhibit B.4, showing the discount rate block C39 and the NPV results simultaneously. Various discount rates can then be entered and the corresponding NPV seen directly. Note that a "forward reference" exists and the user must use the [!] key to obtain the correct NPV after entering each new discount rate value.

4 WORKED EXAMPLE

Exhibits B.5 through 7 present the computer worksheet for the example described previously (Exhibit B.1 etc.). Three worksheets are shown to illustrate the effect of changing the discount rate from 5% to 10% and finally to 10.808%, at which point the NPV is close to zero (i.e. the DCF rate of return for this project is 10.808%). Exhibit B.8 shows the three screen presentations that the user will observe for the various discount rates.

EXHIBIT B.4

WORKSHEET FOR ROI



A1 RATE OF RETURN CALCULATION D1

THIS PROGRAMME MAY BE USED TO CALCU--LATE THE NET PRESENT VALUE OF A SERIES OF CASH FLOWS RESULTING FROM A CAPITAL INVESTMENT. BY CHANGING THE DISCOUNT FACTOR (INTEREST RATE) THE USER MAY DETERMINE THE DISCOUNT RATE AT WHICH THE NET PRESENT VALUE OF THE INVESTMENT IS ZERO--THAT IS, THE "DISCOUNTED CASH FLOW" RATE OF RETURN.

THE WORKSHEET BEGINS ON LINE 25 AND ALLOWS FOR CALCULATIONS OVER A 12 YEAR PERIOD OVERALL--INVESTMENT BEGINS IN YEAR 0 AND THE LIFE OF THE PROJECT IS ASSUMED TO END IN YEAR 12

A18 D18

EXHIBIT B.5

WORKED EXAMPLE: DISCOUNT RATE 5%

A25

YEAR:	0	1	2	3	4	5	6	7	8
CAPITAL INVESTMENT	60	20							
RESIDUAL SCRAP VALUE									
VALUE OF ENERGY SAVINGS	0	10	15	15	15	15	20	20	20

CONTINUED.....

THE WORKSHEET BEGINS ON LINE 25 AND
ALLOWS FOR CALCULATIONS OVER A 12
YEAR PERIOD OVERALL--INVESTMENT
BEGINS IN YEAR 0 AND THE LIFE OF THE
PROJECT IS ASSUMED TO END IN YEAR 12

D 18

EXHIBIT B.5 continued

WORKED EXAMPLE: DISCOUNT RATE 5%

A 25 O 25

YEAR:	.....0....	....1...	....2...	....3...	....4...	....5...	....6...	....7...	....8...	....9...	...10...	...11..
CAPITAL INVESTMENT	60	20										
RESIDUAL SCRAP VALUE												8
VALUE OF ENERGY SAVINGS	0	10	15	15	15	15	20	20	20	20	20	0
OPERATING COSTS												
LABOR	0	1	1	1	1	1	1	1	1	1	1	0
UTILITIES	0	1	1.5	1.5	1.5	1.5	2	2	2	2	2	0
MAINTENANCE	0	0	.5	0	.5	0	1	0	1	0	0	0
OVERHEADS	0	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	0
A35												0.35
A37 NET CASH FLOW	-60	-12.5	11.5	12	11.5	12	15.5	16.5	15.5	16.5	16.5	8

A39 C 39

DISCOUNT RATE----- 5 PERCENT

A41 O.41

DISCOUNT FACTOR	1	.9523810	.9070295	.8638376	.8227025	.7835262	.7462154	.7106813	.6768394	.6446089	.6139133	.5846793
PRESENT VALUE	-60	-11.9048	10.43084	10.36605	9.461078	9.402314	11.56634	11.72624	10.49101	10.63605	10.12957	4.677434
NET PRESENT VALUE	26.98216											
NPV PER UNIT INVESTMT	.3747522											

O.42

A44 D 44

EXHIBIT B.6 WORKED EXAMPLE: DISCOUNT RATE 10%

YEAR:	.....0....	....1...	....2...	....3...	....4...	....5...	....6...	....7...	....8...	....9...	...10...	...11..
CAPITAL INVESTMENT	60	20										
RESIDUAL SCRAP VALUE												8
VALUE OF ENERGY SAVINGS	0	10	15	15	15	15	20	20	20	20	20	0
OPERATING COSTS												
LABOR	0	1	1	1	1	1	1	1	1	1	1	0
UTILITIES	0	1	1.5	1.5	1.5	1.5	2	2	2	2	2	0
MAINTENANCE	0	0	.5	0	.5	0	1	0	1	0	0	0
OVERHEADS	0	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	0
NET CASH FLOW	-60	-12.5	11.5	12	11.5	12	15.5	16.5	15.5	16.5	16.5	8

DISCOUNT RATE----- 10 PERCENT

DISCOUNT FACTOR	1	.9090909	.8264463	.7513148	.6830135	.6209213	.5644739	.5131581	.4665074	.4240976	.3855433	.3504939
PRESENT VALUE	-60	-11.3636	9.504132	9.015778	7.854655	7.451056	8.749346	8.467109	7.230864	6.997611	6.361464	2.803951

NET PRESENT VALUE 3.072329

NPV PER UNIT INVESTMT .0424712

EXHIBIT B.7 WORKED EXAMPLE: DISCOUNT RATE 10.808%

YEAR:	0	1	2	3	4	5	6	7	8	9	10	11
CAPITAL INVESTMENT	60	20										
RESIDUAL SCRAP VALUE												8
VALUE OF ENERGY SAVINGS	0	10	15	15	15	15	20	20	20	20	20	0
OPERATING COSTS												
LABOR	0	1	1	1	1	1	1	1	1	1	1	0
UTILITIES	0	1	1.5	1.5	1.5	1.5	2	2	2	2	2	0
MAINTENANCE	0	0	.5	0	.5	0	1	0	1	0	0	0
OVERHEADS	0	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	0
NET CASH FLOW	-60	-12.5	11.5	12	11.5	12	15.5	16.5	15.5	16.5	16.5	8

DISCOUNT RATE----- 10.808 PERCENT

DISCOUNT FACTOR	1	.9024619	.8144375	.7349988	.6633085	.5986106	.5402233	.4875309	.4399781	.3970635	.3583347	.3233834
PRESENT VALUE	-60	-11.2808	9.366031	8.819986	7.628047	7.183327	8.373461	8.044261	6.819661	6.551548	5.912522	2.587067
NET PRESENT VALUE	.0051373											
NPV PER UNIT INVESTMT	7.135E-5											

EXHIBIT B.3 WORKED EXAMPLE: SCREEN DISPLAYS

YEAR:	.....0...
CAPITAL INVESTMENT	60
RESIDUAL SCRAP VALUE	
VALUE OF ENERGY SAVINGS	0
OPERATING COSTS	
LABOR	0
UTILITIES	0
MAINTENANCE	0
OVERHEADS	0
NET CASH FLOW	-60
DISCOUNT RATE-----	5 PERCENT
DISCOUNT FACTOR	1
PRESENT VALUE	-60
NET PRESENT VALUE	26.98216
NPV PER UNIT INVESTMT	.3747522

YEAR:	.....0...
CAPITAL INVESTMENT	60
RESIDUAL SCRAP VALUE	
VALUE OF ENERGY SAVINGS	0
OPERATING COSTS	
LABOR	0
UTILITIES	0
MAINTENANCE	0
OVERHEADS	0
NET CASH FLOW	-60
DISCOUNT RATE-----	10 PERCENT
DISCOUNT FACTOR	1
PRESENT VALUE	-60
NET PRESENT VALUE	3.072329
NPV PER UNIT INVESTMT	.0426712

YEAR:	.....0...
CAPITAL INVESTMENT	60
RESIDUAL SCRAP VALUE	
VALUE OF ENERGY SAVINGS	0
OPERATING COSTS	
LABOR	0
UTILITIES	0
MAINTENANCE	0
OVERHEADS	0
NET CASH FLOW	-60
DISCOUNT RATE-----	10.808 PERCENT
DISCOUNT FACTOR	1
PRESENT VALUE	-60
NET PRESENT VALUE	.0051373
NPV PER UNIT INVESTMT	7.135E-5

3.2 INDUSTRIAL ENERGY CONSERVATION IN MOROCCO AND SENEGAL

Claude Garrigues

INTRODUCTION

Energy conservation is an important element as such. This is a major conclusion which could be drawn from two surveys made by the World Bank covering Morocco and Senegal.

Morocco. 13% of energy consumed by the Industrial Sector, say 100,000 tep, could be saved by a US $80 million investment. Its overall payback period would be 1.7 years and the yearly savings, US $50 million.

Senegal. The present consumption is 750,000 tons of oil (excluding fuelwood). According to the survey, 10% of the consumption could be saved by an investment with a payback period of less than 3 years. This percentage could be increased up to 40% by considering energy conservation measures connected with extension and modernization investments.

It does not mean privation or income reduction. A 5-speed car gives more miles per gallon, reduces costs, is less noisy and lasts longer; a building heated at 29°C does not mean more comfort, it means more expenses, uneasiness, and respiratory problems.

It means jobs. Carrying out energy audits, implementing energy conservation measures and manufacturing equipment are all job-creating activities.

The only bad effect is on the Gross National Product. Energy conservation reduces the G.N.P. in the same way as car accidents increase it!

But, evaluating the potential for energy conservation is relatively easy; coming down to the implementation is not so simple. The decision-making process is very peculiar. It has nothing to do with the chain of decisions leading to the opening of a cement or textile plant. A large part of the potential can be achieved with very little investment and sometimes with no investment at all. This means that there is no incentive for a salesman to go to the factory, meet the decision maker, provide him with information, and try to convince him. Consequently, the decision maker very often does not realize the potential for conservation. It is the duty of the government to evaluate this potential and do something to activate the decision-maker. We will deal with this point later on.

THE POTENTIAL FOR ENERGY CONSERVATION IN MOROCCAN INDUSTRY

To carry out this evaluation, we visited 9 plants, and obtained energy data on 15 other plants. We calculated the specific consumptions of those 24 plants, compared them with their European counterparts, and evaluated the potential. This potential was then extrapolated to the whole Moroccan

industrial sector. We assumed 100,000 tep, say US $50 million, could be saved by investing US $80 million in retrofitting equipment (programmation, regulation, leak-plugging, insulation, and heat recovering). Further financial savings could also be achieved by shifting from oil products to imported coal or eventually to local natural gas.

THE POTENTIAL FOR ENERGY CONSERVATION IN SENEGALESE INDUSTRY

This assignment was quite similar to Morocco's, with a difference: the Senegalese Industrial Sector is not as developed as Morocco's. This gave us sufficient time to look at other aspects of the Senegalese economy, e.g., utility companies, building, and transport activities.

We visited 10 plants and, when possible, we calculated the specific consumptions, compared them with their European counterparts, and evaluated the potential for energy conservation.

On the basis of data collected by another consultant, we also calculated the specific consumption of three utility companies and similarly evaluated their potential.

We then extrapolated these potentials to the whole industrial and utility sectors. The result of these calculations was that the potential for energy conservation is 36,000 tep -- say 8% of consumption -- if we restrict to retrofitting measures or 154,000 tep -- 30% of consumption -- if we consider longer payback period investment -- say modernization or extension investment.

ANALYZING ENERGY EFFICIENCY IN THE INDUSTRIAL SECTOR 1

METHODS OF CONDUCTING ENERGY AUDITS

a. Evaluation of the overall potential for energy conservation.
b. Thorough examination of the plant or building.
c. Setting up a list of measures leading to energy savings.
d. Selection of measures.
e. Setting up the definitive list of measures.
f. Implementation of recommendations.
g. Setting indicators to monitor plant or building performances.

a. Evaluation of the overall potential

Data is collected on energy consumptions, production, manpower, covered surface, followed by a site visit to understand the process and identify obvious opportunities for saving. This requires usually between one and three hours. Then energy balances are drawn up and specific consumption calculated, and, by comparing these figures with similar plants or buildings, one can estimate the potential for savings.

One or two days are necessary to evaluate the energy conservation potential.

b. Thorough examination of the plant or building

The installation is visited for a second time for a more complete examination. Each part of the installation where energy is transformed is submitted to a systematic search and for each of them as much information as possible is collected.

This job usually requires one full day.

c. Setting up a list of measures leading to energy savings

Each function of each system where energy is transformed is confronted with the following checklist, which recapitulates the techniques for energy conservation:

- Modifying the relationships with the environment
- Pricing (paying the minimum price for energy)
- Planning (providing energy when it is required)
- Regulation (providing just the quantity of energy required)
- Leak-plugging (avoiding the use of energy without making it work)
- Insulation
- Energy recovery
- Shifting to other fuels
- Shifting to another product
- Shifting to another process

When an opportunity for energy savings is discovered, we evaluate it in terms of quantity, price, and investment.

This is the longest part of the audit: between 10 and 20 days are required.

d. Selection of the measures

This usually very long list is submitted to the plant manager for approval. Some of the measures are retained, others are not, if they are not feasible.

A 2-hour meeting is necessary to establish the final list.

e. **Drawing up the definitive list of measures**

The retained measures are classified according to their cost efficiency. Their interactions will be taken into consideration. This leads to a definitive list and a final objective of energy savings.

This phase requires two or three days.

f. **Implementation of recommendations**

The industrialist or the building owner is assisted in his negotiations with the contractors or utility companies.

Usually a 2-hour meeting is sufficient.

g. **Setting up indicators to monitor plant or building performances**

We usually recommend to the industrialist or building owner that he calculate every month or every year a handful of ratios or specific consumptions to evaluate the overall performances of his plant or building.

ECONOMIC ANALYSIS OF ENERGY EFFICIENCY MEASURES 2

GOVERNMENT INCENTIVES

As said before, government cannot count on private initiatives to promote energy conservation. The list of incentives they can propose is as follows:

- Set up a price for energy in accordance with its future expected cost.
- Promote the idea of energy conservation (press, ratio, T.V.).
- Start a promotion campaign from the country's top authorities down to the bottom.
- Set up an organization in charge of energy conservation.
- Collect energy data in all sectors.
- Launch a 5-year Energy Conservation Plan.
- Setup a system of financial incentives.

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ANALYZING ENERGY EFFICIENCY IN THE INDUSTRIAL SECTOR 2

CASE STUDIES OF INDUSTRIAL ENERGY CONSERVATION IN WEST AFRICAN COUNTRIES

A. PHOSPHATE AIR DRYER

To obtain a preliminary estimate of dryer efficiency, we will compare the quantity of fuel oil burned with the quantity of water removed from the phosphate rocks.

Q = tons of fuel oil

Pci = Calorific value of fuel oil (thermies/ton of fuel oil)

We = Water content of wet rocks (tons of water/ton of dry rocks)

Ws = Water content of dry rocks (tons of water/ton of dry rocks)

M = tonnage of rocks

$$R = \frac{\text{Quantity of heat required to turn water into steam}}{\text{fuel oil heat content}}$$

$$R = \frac{(We - Ws) \times M \times 600}{Pci \times Q}$$

if $R > 0.9$ data are wrong
if $0.9 > R > 0.8$ another part of the plant deserves more attention
if $R < 0.8$ there is an opportunity for energy savings.

If $R < 0.8$, it is worth trying to find out where the opportunities for energy savings are. We shall establish the energy balance sheet as indicated on the attached table, and on the basis of these figures, determine energy conservation techniques which can be applied to the dryer.

B. CEMENT PLANT

Energy conservation in a cement plant is a very specialized job. Our purpose will be more to identify where problems are than to try to solve them.

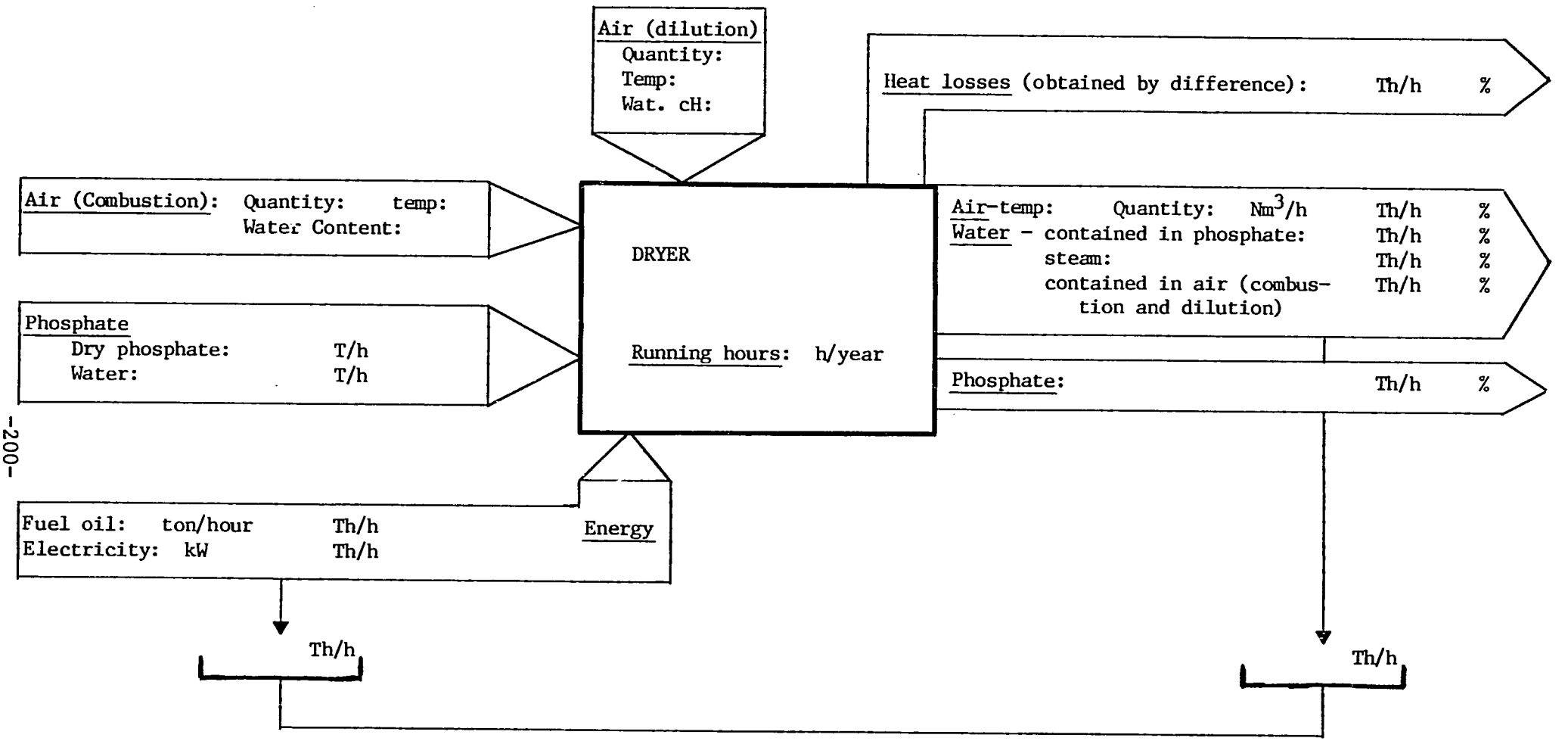

Figure 1. Material flows and heat balances.

ANALYZING ENERGY EFFICIENCY IN THE INDUSTRIAL SECTOR 2

CASE STUDIES OF INDUSTRIAL ENERGY CONSERVATION IN WEST AFRICAN COUNTRIES

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B. CEMENT PLANT

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Our first task will be to understand the overall performance of the whole plant by calculating the ratios:

- quantity of thermies/tons of klinker
- quantity of electricity/ton of cement

and ton of cement/ton of klinker (taking into consideration that some tonnage of klinker are shipped before being ground into cement). These ratios will

be compared with the corresponding ratios of comparable cement plants. This comparison will establish the order of magnitude of the problem.

The next step will be to compare the specific consumption of each sector of the plant in terms of Kwh/ton or liter of gas-oil/ton of production. We will examine the following sections:

- Quarry
- Primary crushing
- Formulation
- Drying
- Secondary crushing
- Homogenization
- Storage 1
- Kiln(s)
- Storage 2
- Grinding

Ratios will be compared with those obtained in similar plants. Differences will be noted and on explanation will be obtained from management.

The last step will be a visit to the plant to identify other possibilities for saving (warming up of the heavy fuel oil, electric generators, lighting, etc.).

SECTION 4

THE ELECTRIC POWER SECTOR

4.1 PREVENTIVE MAINTENANCE IN THE ELECTRIC POWER SECTOR

Paul H. Shoun

1. INTRODUCTION

For the past five years I have been a member of a five-man team critiquing electric power disturbances in the U.S. and Canada. I am presently chairman of the Disturbance Analysis Subcommittee (formerly known as Reliability Issues Task Force), which serves under the Operating Committee of the North American Electric Reliability Council (NERC). In September 1981, we published our second report analyzing major power outages which occurred during the period January 1, 1979 through December 31, 1980. Since then we have been updating the disturbance analysis data for the continental grid on an annual basis.

In those 1979 disturbances, lack of adequate maintenance or poor maintenance practices was the second most prominent cause of system outages in those cases studied. We suspect that poor maintenance practices represent an increasing exposure to additional system malfunctions and outages. Fortunately, for the North American power grid, maintenance performance has improved considerably since 1979 when this subject was emphasized. However, in future years as utilities find themselves hard-pressed for operating funds, the temptation is to cut maintenance. When a utility's cash flow is short, the first place many budget people turn to is the maintenance account. This happens because preventive maintenance is something that can be temporarily delayed. Also it happens because few people in administrative management really understand the value of maintenance. Further, there is always a considerable time lag before the consequences begin to show.

It was the San Francisco longshoreman, Philosopher Eric Hoffer, who a few years ago best emphasized the value of maintenance. In an interview with Eric Severeid of CBS, Mr. Hoffer was asked how he had so accurately predicted the recovery of Germany and Japan following World War II. Mr. Hoffer replied, "That was easy, I was familiar with their capacity for maintenance. I had studied their maintenance records. Show me a country or a company that has a good maintenance capability and I will show you a country or a company that will succeed."

A good preventive maintenance program is the key to a safe and reliable operating utility. A good maintenance program will also contribute significantly to energy efficiency and conservation. Such a program must fit into the whole concept of building and operating a power system. In order to be successful, a preventive maintenance program should have at least five major ingredients: good planning and design, good construction and installation, good inspection and test, good operational checks and scheduled maintenance, and good documentation and recordkeeping. In TVA we have our best engineers, technicians, and craftsmen assigned to the operating and maintenance (O&M) forces. It could be said that a power system plan designed without emphasis on O&M is no design at all. Certainly O&M needs should be paramount in plan-

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ning and designing any power system component. Assuming that a good system plan is developed and that good detailed engineering follows, it is then essential that the facility be constructed accordingly. If the quality of workmanship or installation is not adequate, it is imperative that a system of inspection and test be devised to detect those flaws and discrepancies. A good field inspection and test organization can make up for a lot of mistakes and, if necessary, can redesign and reinstall to make the various components work together in a system configuration as it was conceived to work.

Once installed, properly tested, and certified for service, it is essential that a schedule of routine tests, inspections, and operational checks be implemented. Proper maintenance must be performed to keep the equipment in good operating condition. Experience is the best teacher when trying to determine the optimum interval for operational test and routine maintenance to assure system component reliability.

Last and equally important is the necessity for good documentation and record keeping. The larger the organization, the more essential and more valuable data record keeping really is. Component failure and system outage data should be communicated so that system planners and designers can have constant feedback on equipment performance, component failure, etc., so that systems can be planned better and designed better.

There is no substitute for a good preventive maintenance program. This subject deserves the highest order of priority on the part of every electric utility. It is the least expensive and most cost-effective effort a utility can have.

2. BASIC PRINCIPLES

An effective preventive maintenance program is a form of operational quality assurance (QA) program and, as such, is one of the key elements of safe and reliable utility operations of any kind. A comprehensive program is rooted in good design and construction practices which recognize that all types of equipment require some types of maintenance. After equipment has been installed, tested, and certified for service, the program includes a schedule of routine inspections, tests, and operational checks to detect incipient failure conditions which would prevent proper operation. The program includes good documentation of the inspection and test procedures to be followed by maintenance personnel, results of the work performed, and the dates when work was performed and is next scheduled. Lastly, the program includes feedback of information on actual equipment performance to system planners and designers so that future facilities can be made more safe, reliable, and economical. Good documentation and recordkeeping of equipment performance, inspection, and maintenance performed are essential.

One of the few phases of any utility's operations that is not directly impacted by legislative or judicial actions, intervention by environmental and "public interest" groups, or even by its own customers, is that of its preventive maintenance programs. For all practical purposes, it is master of its own destiny in this phase of its operation. It can maintain that degree of maintenance which it believes necessary for safe and reliable operation of

its system. That degree may, however, be influenced significantly by the utility's short-term financial postion.

If you are considering development of a preventive maintenance program for the first time, here are some of the fundamentals you might like to consider:

Preventive Maintenance (PM). PM in the literature is variously wirtten about as a simple procedure and a complex, sophisticated maintenance program. The reason is quite simple--PM can be either. The intensity of the program should be dictated by reliability, availability, and life-cycle cost considerations. To help you address PM within your requirements, let us cover the fundamentals of PM briefly. Whether you are involved with a power system, an individual plant, or any other institution or enterprise, the same basic principles apply.

What is PM? PM is the planned, systematic repair or replacement of selected components to achieve the established goals and objectives of the program.

Is PM necessary or justifiable in your activity? To answer this question, one must do a thorough review of several facets of the maintenance and operations requirements of the equipment or system in question.

1. What exactly is the ultimate objective of the plan, system, or component in question?

It is obvious that the dependability of an emergency generator for a hospital is more critical than the same equipment that is on a construction site. The former can be life supporting, the latter is a matter of economic concern. Not all distinctions are as clear. Therefore, the analysis should strive to identify the precise end function for the plan, system, or equipment under study. Remember, 99% reliabilty can cost 5 to 10 times as much as 80% reliability.

2. What exactly is the expected consequence of an untimely failure?

The answer to this question is perhaps the key to determining the intensity of PM. If every critical component has an in-line spare, PM is not as important as on a single critical component. The economic consequences of failure may far outweigh the costs of preventing failure.

3. When failure occurs, what is the "allowable" turnaround time to resume operation?

The "allowable" turnaround time dictates the requirements of redundant design, spare inventory, and PM cycle.

If need is established, how is the program developed?

I. Once the need for a program is established, the research of specific data for each major component can begin. The ultimate list of data for each component will be the product of numerous revisions, but it should include the following.

A. Nomenclature. Describe the equipment by its critical "pedigree," e.g., motor, G.E., T.E.F.C., 350 hp, 3-phase, 480 V, model number, serial number, etc.

B. Service and envionmental data, e.g., pulverizer motor, fine dust and ambient temperature of 150°F, 2-shift, 5-day operation, etc.

C. Location. Physical and system, e.g., pulverizer A-4, elevation 481, NW corner, etc.

D. Critical operating and maintenance data. These data can be a few lines of information for the mechanic or a copy of a several-page technical procedure.

To begin a PM program, few things can beat an index card system. Many well-defined systems have failed because of automation before maturity.

II. Once the equipment is adequately identified, the next step is the accumulation of failure and repair history for each component to be included in the program. These records will be valuable in determining initial inspection/repair cycles and to help the craftsman in diagnosis of equipment malfunctions.

The next piece of data needed is the manufacturer's recommended service cycle. If this information is not available on site, contact the vendor. These recommended cycles serve as an excellent starting point, but later equipment performance and operating experience are the best teachers.

III. Determine the inspection/repair/replacement cycle. The resultant plan must address the following constraints:

A. Maximum operation between inpsections
B. Warranty considerations (if any)
C. Mean time to failure from analysis of equipment history and vendor material.

IV. Levelize the requirements into a workable schedule.

It is amazing the number of quarterly, monthly, semi-annual, and weekly inspections that are scheduled for the first week of July!

One approach to leveling a schedule is to add the total annual hours of craftmen's time required for each job. Add all the total jobs together

and divide by 12. Then manually distribute index cards into 12 "piles" until the schedule is about equal. Then a special crew can be assigned PM work after the schedule is leveled on an annual basis.

Installing the Program. While the mechanics of designing the PM program are straightforward, selling the program to management and labor may not be. Management may require an engineering analysis to show how a return on the initial expenditure can be returned. There will be questions of why maintenance costs go up initially. Answering these and other valid management concerns will require you to do a thorough job of analyzing past performance, estimating costs (both direct and consequential), and making predictions as to future performance.

Selling the maintenance department will require finesse, perseverance, and human relations skills. After all, "they" have been doing things for a long time without a PM program, so why start one now?

Nurturing the Program. Good PM systems are not self-perpetuating! They will die and wither from inattention. The successful PM program is dynamic, constantly improving from feedback. If it does not receive sufficient attention, it will not survive more than a few months.

TVA, like most good electric power operations, places a lot of emphasis on preventive maintenance in its diversified programs. Since there are so many different maintenance programs, it would be impossible to discuss any one of them in any depth in a short seminar presentation. Therefore, for follow-up study, I would recommend the document "Tennessee Valley Authority's Maintenance Program - Our Successes, Failures, and Future Plans" as an example of what one of our major maintenance programs in power operations is all about.*

Certainly, in these days of high fuel cost and harsh economic times, we need to get more utiliziation out of existing facilities. Therefore, preventive maintenance offers one of the best tools to achieve this objective.

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*Available from W. B. Martin, Jr.; TVA; 100 IBM Building; Chattanooga, TN 37401, U.S.A.

4.2 COST-BASED RATES AND OTHER CONSERVATION OPTIONS FOR ELECTRIC UTILITIES

Richard W. Leigh

INTRODUCTION

Rapidly rising demand and severe financial constraints on construction are placing many electric utilities in developing countries in severe binds. In this series of lectures we will examine several conservation alternatives and see, first, that under certain ideal circumstances, the growth of electrical demand can be curtailed for less than the cost of additional electricity. Since conservation choices are normally made by consumers, however, while new generating capacity is supplied by the utility, the options are often not explored in a logical way. We explore several such impediments to rational selection of the best mix of conservation and utility expansion options and develop two approaches which will help to overcome them.

To quantify the discussion, we first develop several aspects of the costs of operating an electric utility. We then turn to the loads served by the utility, first characterizing them by sector and structure, and delineating the impediments to conservation in each case. We will incorporate in this discussion a point which will be established in succeeding lectures, that load growth can easily be curtailed at a cost of $0.08/kWh (28 CFA/kWh) or less, or moved off-peak at a cost of $0.04/kWh (14 CFA/kWh) or less. In the last two sections of this lecture, we will discuss the options available to the utility for promoting these cost-effective conservation measures, better rate design and direct intervention to promote conservation.

THE COSTS OF OPERATING AN ELECTRIC UTILITY

The primary job of an electric utility is to provide electric power to meet a load, the sum of hundreds of thousands of individual loads, which varies in response to people's habits, the earth's turning, weather and a variety of other regular and stochastic processes. The load is typically lowest late at night, rising throughout the morning to reach a peak at midday or in the afternoon and declining again through the evening, although a broad shoulder due to lighting requirements will often hold it steady as the day fades. On weekends many industrial and commercial enterprises are shut and the peak demand will be substantially lower than during the week. If the load is dominated by air conditioning, it will be characterized by strong peaks and be highly weather dependent; if by a continuous industrial process, the entire load will be stable and uniform.

The load can be partially characterized by three parameters: the total annual electric energy consumed, TE, the annual maximum peak load, PM, and the dimensionless ratio of those, the load factor LF, where:

$$LF = TE/(PM \times H)$$

with H = 8760 hours per year. Thus, a uniform load has a load factor of 1.00, and the "peakier" the load, the smaller LF is.

The electric power is supplied by a variety of types of generating equipment, which we will group into two loose categories: "baseload" equipment, which has higher capital costs but which burns less expensive fuelmore efficiently, and "peaking" equipment, which is relatively inexpensive, but which tends to burn expensive fuels less efficiently. Nuclear power plants or coal fired steam turbines are examples of baseload capacity, while combustion turbines burning oil or gas would be typical peaking facilities. For simplicity, we will consider only one representative of each type, a coal plant and a combustion turbine; in actuality, the number of systems and choices is quite large. Various parameters characterizing these two types of plants are shown in Table 1.

Table 1
Characteristics of Generating Equipment

		Typical Values		
	Symbol	Baseload	Peaking	Units
Peak Power Output	P	>100,000	<100,000	kW
Annual Energy	E	>7x108	<1.8x108	kWh/yr
Load Factor	LF	0.80	0.20	
Conversion Efficiency	Y	0.33	0.25	
Unit Capital Cost	K	1200	200	$/kW
		420,000	70,000	CFA/kW
Unit Fuel Cost	CF	2.60	4.60	$/GJ
(Coal and Oil, respectively)		910	1610	CFA/GJ
Unit Maintenance Cost	M	0.005	0.005	$/kWh
		1.75	1.75	CFA/kWh
Levelizing Factor (Capital Recovery)	R	0.28	0.28	1/yr
Energy Conversion Factor	GK	0.0036	0.0036	GJ/kWh

The conversion efficiency, Y, is the ratio of electricity produced per year (E) to the total chemical energy content of the fuel consumed. The unit fuel costs are given in dollars or CFA per GJ (billion joules, "gigajoules"), and the conversion factor GK is used below to convert $/GJ to $kWh. For a plant or group of plants, as for the entire utility load, E = PxHxLF. When we need to differentiate, BL will indicate baseload equipment and PK will indicate peaking equipment. Thus, E(BL) is the total electrical energy produced by baseload equipment and P(PK) is the peak power available from peaking equipment.

The capital recovery (levelizing) factor converts a one time capital charge into a stream of annual payments over a period of perhaps thirty

years, assuming that the utility took out a loan to cover the capital outlay and is paying it back over the life of the equipment. The value of 0.28 is typical of U.S. utilities currently and includes interest, repayment of capital, insurance and the repayment of loans taken out during construction. It will be discussed further in a later lecture; for now it is sufficient simply to remember that if an item costs K $/kW in capital, it will cost RxK $/kW-yr to own and energy will have a unit cost of RxK/(HxLF) $/kWh.

With this established, we can write down the total annual cost of operation of a unit, including capital, fuel and maintenance, as:

$$CT(E) = RxKxP + (CFxGK/Y + M)xE,$$

where we have explicitly included the dependence of total cost on annual energy E. Then the average unit cost of electricity from this unit is

$$CA = CT(E)/E = RxKxP/E + CFxGK/Y + M$$

$$= RxK/(HxLF) + CFxGK/Y + M.$$

Clearly, as the load factor on a device goes down, the unit cost of electricity from that device goes up. Substituting values from Table 1 we find

$$CA(BL) = \$(0.048 + 0.028 + 0.005)/kWh = \$0.081/kWh,$$

$$= (16.8 + 9.8 + 1.8)\ CFA/kWh = 28.4\ CFA/kWh,$$

$$CA(PK) = \$(0.032 + 0.066 + 0.005)/kWh = \$0.103/kWh,$$

$$= (11.2 + 23.1 + 1.8)\ CFA/kWh = 363.1\ CFA/kWh,$$

so the average cost of baseload power is some 20% less than that of peaking power.

So far we have answered the question "What is the average cost of electric power from a given unit?", but that is not the only question it is important to ask. Suppose the unit is installed and operating at less than full power. We may then ask what it will cost to produce an added amount of energy E1, and this will indicate the cost to the utility of having a load added under these circumstances or the savings accruing if the load E1 is turned off. The quantity we seek here is the "unit marginal operating cost", and in terms of the annual cost defined above it is

$$MOC(E1) = (C(E+E1) - C(E))/E1$$

$$= CFxGK/Y + M$$

$$= \$0.033/kWh = 11.6\ CFA/kWh\ (baseload)$$

and

$$= \$0.071/kWh = 24.9\ CFA/kWh\ (on\ peak).$$

Note that no capital costs were incurred. For a system with excess or adequate capacity, additional power produced on peak costs over twice as much as power produced by baseload equipment.

It is also reasonable to inquire as to the cost of meeting a load for which capacity does not currently exist. This quantity is called the total marginal cost of the load in question. Because capacity must be installed in some relation to the peak power demand of the new load, while other expenses will be incurred in proportion to the total energy involved, this quantity is more complex and cannot be adequately defined in the time available for this discussion. Its determination rests on interpreting the total difference in capital and operating costs between two least-cost ("optimized") utility systems, one serving the currently anticipated load and one serving that plus the additional load for which the cost is sought (see the paper by R. Bright and myself in the Bibliography). These results are obtained by using large computer programs which simulate the operation and growth of the utility over a substantial period of time, perhaps thirty years ("WASP" or "PROMOD"). Even without such efforts, however, there are several factors indicating that the total marginal cost of new load will be as high or higher than the average cost of baseload energy, CA(BL).

First, the cost will involve a large capital component, and with interest rates high and likely to stay high, the levelizing factor for capital recovery on new equipment will not fall significantly in the near future. Second, most utilities have built too many oil plants (considered peaking plants these days) due to the low price of oil when the planning was being carried out. Anything they build today must almost certainly be a baseload plant, and the capital requirements for baseload plants have been rising inexorably and in excess of inflation. The cost of nuclear plants is at this point prohibitive, and at least in the developed countries, pollution control requirements are driving up the price of coal plants as well. Finally, even coal prices have been tracking rising oil prices, although these seem at last to be levelling off and even falling a bit for the time being.

Thus, the cost of electrical energy from new generation facilities seems to be at least $0.08/kWh (28 CFA/kWh), the cost of new capacity is several hundred dollars per kilowatt and on-peak loads cost at least $0.04/kWh (14 CFA/kWh) more than off peak loads. We, therefore, turn to the loads served by the utility to see what can be done to lower consumption and to slow its growth.

UTILITY LOADS

The loads served by the utility can be broken into two useful sectors, the industrial sector on one hand and the residential and commercial sectors on the other. Industrial loads tend to be uniform (have high load factors), especially in industries which work three shifts, and to be large, with a single customer often having a peak demand in the megawatt range. Residential and commercial loads tend to be dominated by air conditioning and lighting, and thus to have strong peaks and low load factors, with very small average demands late at night.

The differing character of these loads offer different possibilities for conservation. There are several major reasons for inefficient use of electricity by the consumer (who may be the resident of a home, the manager of a small business or the plant manager of a large building or factory):

(1) The potential total annual savings are not worth the additional investment needed to bring about efficient use of electricity;

(2) The rates the consumer is paying are conveying misleading information about the cost of electricity;

(3) The potential total annual savings are well worth the investment required to bring them about, but are not worth the time required on the part of the consumer to analyze the situation and realize this;

(4) The total annual cost of the electricity is too small to merit the attention of the consumer;

(5) The consumer does not understand the situation even if (3) is not the case and, therefore, takes no action to lower or to shift consumption.

Many other reasons could doubtless be enumerated, but these will give us sufficient material for discussion here. With respect to problem (1), we will see in the succeeding lectures that there are in fact a great many ways in which electricity use can be curtailed or shifted to off-peak at costs substantially below those derived in the last section for energy from new capacity. Thus, we will see that problem (1) is not a problem in so many cases that we should turn our attention to issues (2) through (5).

Problem (2) arises when the tariffs are structured so that, for example, a customer with a very peaked load, responsible for the purchase of a substantial amount of largely unused capacity, pays only an energy-related charge, or when the rates do not differentiate between on-peak and off-peak demand for a customer who is in a position to shift the load in time cost-effectively. Since the cost of more sophisticated metering is often viewed as an obstacle to adequate rate structures, the problem is somewhat more likely to arise with small users. The next section, rate structures, will discuss problem (2) in detail.

Problems (3) and (5) represent cases where direct action by the utility may be advantageous, since the limited resources of individual residential consumers make inefficiencies based on inadequate analysis more likely. We will see in the last section of this lecture that the benefits are sometimes sufficiently large to permit these actions to be taken without coercion and to structure them so as to be to the benefit of all concerned parties. Problems (3) and (4) can occur in industrial settings, where managers do not take all cost-effective measures, but rather pay attention to a few projects with the largest cash flows or the largest political implications. Here the virtues of direct utility action are less clear, since the management of an industrial plant ought to be able to pay sufficient attention to energy issues, given the large size of typical industrial loads. In industrial settings, a combination of rate design, education and argument should probably be tried before the utility itself gets involved in end use conservation technology.

UTILITY RATE STRUCTURE

The primary function of utility tariffs is, of course, to recover the annual operating expenses of the utility so that it can pay the fuel bills and payroll and finance new construction. The tariffs have a second function, however, which is almost as important, and that is to convey to the consumers information about the cost of supplying electricity to meet precisely the type of load they are imposing on the utility.

If the utility and its customers were all one economic entity, it would be straightforward to compare the costs of high efficiency lighting or of some form of storage for peak shaving to those of expanding the generating capacity of the utility and to make a rational decision about which way to proceed. The fact that consumers and utility are different, however, complicates this process. The utility decides what to build on the basis of past and projected loads (and other factors, such as availability of funds or environmental constraints) while the consumers decide whether to conserve or not on the basis of the costs they perceive in the utility's rate structure. To the extent the rate structure distort the costs actually incurred by the utility (and all rate structures do, to some extent) the ability of the customers to make decisions that are optimal from the perspective of the utility and the customers taken as a whole will be impaired.

The process of constructing rates which do transmit the true costs adequately to the ultimate consumers is a complex one which cannot be treated here in detail (see the books of Kahn, Bonbright and Caywood in the bibliography). We will simply review the principles of the process, delineate several common rate structures and discuss their advantages and disadvantages in a general way.

The first step is the definition of a variety of "classes" of customers, usually on the basis of size. Such a breakdown might group customers into residential, commercial, small industrial and large industrial users respectively, for example. For each such class one or more of the rate structures to be described below is offered, but before proceeding to that discussion, I would like to emphasize the importance of allocating costs between classes in proportion to the costs of providing services to that class. If, for example, the industrial sector is overcharged for electricity while the residential sector is undercharged (perhaps as a result of political pressure), residential consumers will have insufficient incentive to conserve, thus, forcing the utility to operate in an uneconomic manner, and they will pay for this electricity anyway when they purchase the output of the industry. Conversely, if the residential sector is overcharged to subsidize the industrial sector (perhaps as a result of political pressure), industries will have insufficient incentive to economize and the resulting diseconomy in the operation of the utility will ultimately cost all parties more. The mechanics of equitable allocation of costs between classes is a complex and not entirely closed question which is dealt with in the above-mentioned texts; the importance of doing it as well as possible if cost-effective levels of conservation are to be achieved cannot be over-emphasized.

An an aside, this does not mean that subsidies must be ruled out, only that they must be made explicit. It may be that the only way to promote rural electrification, which many view as an important part of the development process, is to offer rural villages a modest amount of electricity for free or for a small and symbolic rate. The advisability of such subsidies must be determined on a case specific basis; my point is only that if they are deemed advisable, the subsidy should be a visible item in the budget of some appropriate agency, not a hidden tax on other consumers, no matter how attractive the option may appear politically.

Within each class, various rate structures may be offered. The simplest, no longer in use in developed countries except for the particularly well defined case of street lighting, is simply to establish a monthly charge based on the number of lightbulbs or outlets a customer has. This eliminates the cost of metering, but constitutes such a strong incentive for theft of power (by installing but not reporting other appliances) that it has fallen into almost total disuse. Note that this is a perfect example of a system which fails to give the consumer any information concerning the cost of the power being consumed.

A similar system has proven very uneconomic in large apartment buildings in the U.S. Here the consumption of the entire building is metered and paid for at wholesale rates, but the individual apartments are not metered; rather the monthly bill for the entire building is simply divided among apartments, so that users of small amounts of power held to pay for the consumption of large users. This situation actually constitutes an incentive to consume more power, and in the recent conversion of a New York City building to individual apartment "submetering", electricity consumption dropped 15-20% as individuals became directly responsible for their own consumption.

It is not surprising, then, that it has become common for individual residential consumers to pay rates based on the use of a simple integrating energy consumption meter. The tariff incorporates a fixed monthly "customer charge" which pays for the capacity required to meet that customer's demand, the accounting costs associated with that customer and (sometimes) the first few units of energy consumed. To this is added an energy charge proportional to the customer's energy consumption that month. At one point in the U.S., "declining block" rates were popular, wherein lower and lower energy charges were assessed as the customer's monthly consumption increased; today it is widely accepted that if anything, larger amounts of electricity correspond to increased costs and these schemes are being phased out in favor of rates based on a constant energy charge.

Time of day rates which reflect to the customer the different costs of on-peak and off-peak energy are available to residential consumers in the U.S. and Europe, but their primary application is in electric space heating, an area of little interest in West Africa. Only if substantial residential demand for electrically produced hot water or central air conditioning (see the discussion of cool storage below) develops will time-of-day metering and rates become worthwhile for the residential sector. In the southwest U.S., electric loads dominated by air conditioning were lowered by seven to sixteen per cent after the introduction of time of day rates (1); this was due solely

to changed habits, rather than the introduction of storage technologies or other technical improvements.

In the commercial and industrial sectors, however, the availability of time of day metering and cost based rates for on peak and off peak power could lead to the widespread implementation of various end-use technologies which would slow the growth of peak loads in the short run and produce a more uniform load, which could be more economically served, in the long run. One example of such a technology, cool storage for off-peak air conditioning, will be discussed in detail in a later lecture; other possibilities include late night pumping of irrigation water (also attractive because of significant reductions in evaporation losses) and the re-scheduling of electrically intensive processes in industry or food processing.

The preceeding discussion was implicitly confined to consideration of time-of-day metering of energy consumption alone; at modest increase in the complexity of the metering equipment, the maximum power demanded during the billing period (or during some subset of the billing period such as on-peak or off-peak hours) can be measured and a "demand charge" assessed in addition to the energy charge. Such rate structures, to date usually without a time-of-day component, are common in the industrial sectors of developed countries, and are already in use in some developing countries. Of course, compared to rates based only on measurement of energy, either the customer charge or the energy charge or both is reduced, so that for some "typical customer" there is no change in the monthly bill. But now the manager of a large building can examine the bill and determine that, in fact, a large part of the cost of electricity is arising from the fact that, for example, the air conditioners, refrigeration and water pumping unit all go on at once and create a very large demand for power. In fact the installation of a switch preventing the air conditioning from going on when the pumps are running would cost a minuscule amount compared to the potential savings, and with a tariff incorporating demand charges (and an explanation of how they work) the building manager has a strong incentive to take action. The utility will benefit immediately both because they can run inefficient peaking units less often and because the lowered peak load will increase system reliability. (This was a particularly simple example; microcomputer based "load management systems" which keep track of many different systems at once and establish priorities for operation are available for factories or large buildings.)

An important factor to consider in defining rate structures is the cost of metering. Meters range in price from $50-100 (CFA 17500-35000) for a device measuring only energy to ten times that for a sophisticated digital meter capable of measuring reactive as well as resistive power and energy in each of several time-of-day categories. The only sure thing is that the advance of digital electronics will bring the cost of sophisticated metering down, probably very quickly over the next few years. Currently, however, separate demand metering is probably not a worthwhile effort in the residential sector, due to the combination of its added cost, the added cost of collecting the data, the small size of residential bills and the likelihood that homeowners would not have the expertise or inclination to perform the type of load management described above. As a rule of thumb, however, both demand metering and time-of-day metering will prove worthwhile in a broad spectrum of commercial and industrial applications.

DIRECT UTILITY INTERVENTION FOR END USE CONSERVATION

In an earlier section of this lecture, five potential reasons for insufficient implementation of end use conservation of electric energy were presented. The preceeding discussion of rate structures was structured around the second reason and focused on ways of getting sufficient information to the consumer to permit him or her to make decisions that would be reasonable from the perspective of both the utility and its other customers. The last three reasons for insufficient end-use conservation assumed that the consumer has sufficient information about the consequences of decisions but for other reasons - the small relative or absolute size of the potential savings and lack of information or education - still will not take action. Several approaches are possible. In the case of problem five (inadequate education), for example, obvious approaches such as poster campaigns or the inclusion of conservation awareness and education material in the utility bill can produce significant benefits if done thoughtfully, with both the interests and background of the customer kept carefully in mind.

Problems (3) and (4), however, represent an issue of substance, since life is short and one cannot reasonably ask consumers to spend unjustifiable amounts of time on what is to them a small problem; the only reason the utility can justify the time to analyze many conservation issues is because it can do so for many consumers at once. There are, however, many examples of small conservation initiatives which are (to the utility) well worth pursuing; we will examine in detail the value of reflecting plastic films which reduce air conditioning peak and energy loads significantly when installed on east and west facing windows. For cases like this there is an approach which has met with substantial success in parts of the U.S., which is essentially for the utility to undertake and/or subsidize (in whole or in part) certain electricity conservation measures in the customer's premises even though these measures will lower the customer's electric bill sufficiently to have caused the customer to undertake the measures spontaneously in a more perfect world. The key point is that the rate structure and potential savings to the utility must be such that the savings to the utility exceed the decrease in the customer's bill by an amount sufficient to pay for the subsidy and leave a margin of advantage for the utility to share with its other customers.

How is this possible? The most well known case occurred in the Northwest U.S., where several conditions which are neither common nor unique obtained: 1) the average cost for electricity produced by the utility, which was also the price paid by residential consumers, was quite low due to the presence in the generation system of a great deal of inexpensive hydropower; 2) the total marginal cost of electricity from new generation capacity was quite high, perhaps twice the average cost, since no more hydropower was available and new nuclear or coal fired plants had to be built; 3) the load, which was largely space heating in poorly insulated houses, could be curtailed (by adding insulation) at a price per kilowatt hour saved that was substantially less than the total marginal cost of new energy but roughly equal to the lower average price per kilowatt hour seen by the customers.

Thus, there was little incentive for individual customers to insulate the buildings themselves - the savings would be small and slow in coming and

they had other things on their minds. But when the utility installed the insulation, it (and all the customers, not just those getting the insulation) saved the cost of building expensive new capacity that would have been required to meet normal load growth at the (smaller) cost of providing free insulation to the least insulated homes in the utility's service area.

I will not provide the detailed economics of this particular example since they cannot possibly apply to West African situations. Consider, however, the case of reducing air conditioning loads by the application of reflecting films to west facing windows. In a later lecture, we will see that this can, under certain circumstances, reduce the peak power demand on the utility at a cost of 40-110 $/kW, substantially below the capital cost of new peaking capacity. (For the peak load reduction to actually occur, the peak must be largely due to air conditioning, and must actually be reduced by the conservation effort, not simply postponed an hour or so with a slight reduction in magnitude.) Since most developing country utilities are in demand-limited situations, anything that cuts peak loads and allows the postponement of capacity additions can lessen the financial pressure on the utility considerably.

If a careful case study shows that peak reduction will occur, the utility should give serious thought to distributing such reflective films to customers for free, including instructions and projections of the savings that will accrue to the customer if the installation is carried out (getting the customer to provide the labor will ensure that the cost is at the low end of the range, near 40$/kW). Even in situations where the customers probably lack the necessary technical expertise, the utility may find it worthwhile to carry out the whole job themselves; in other cases, it may be possible for the utility and the customers to share both the costs and the benefits of the conservation retrofit.

Other technical innovations offering small individual savings and large utility impacts may be analyzed in a comparable manner. The point I hope to have made clearly is that careful analysis of conservation options includes analysis from the perspective of all the players in the arena: individual customers, the utility and its management, and the group of all customers taken together, who ultimately pay the bills for the utility which supplies them with power.

NOTES

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4.3 ENERGY EFFICIENCY IN ELECTRICAL POWER GENERATION AND INDUSTRIAL SECTORS

H. N. Sharan

INTRODUCTION

One of the major goals of national economic policy. both for developing as well as industrialized countries, has clearly to be the rational utilization of primary energy resources. Globally dwindling fossil fuel reserves, especially oil and gas, increasing energy prices, and widespread lack of national fossil fuel resources demand solutions which enable maximum efficiencies to be obtained at economically viable costs and minimal ecological impact. For industrialized countries, higher efficiencies of utilization and conservation are imperative in order to offset the adverse effects of rising energy costs on their standards of living. For developing countries, which in addition to the rising energy bills are being crippled by adverse balance of payments problems, shortage of capital and growing population, it is even more critical to find ways to maximize the effectiveness of energy utilization in such a way that conservation does not lead to a curtailment of their development activities. Ways have to be found not only to make energy go further in industrial plants, agricultural as well as in domestic and service areas, but emphasis has to also be put on maximizing the returns on the huge investments made in the energy and power sectors. After all, capital investments in these areas as well as energy import bills account for the lion's share of development budgets of most of the developing countries.

This workshop and its theme address themselves to one particular area of energy technology, namely, conservation of energy. However, conservation of energy has to be done in many ways and at diverse levels of technology, investments, and policies. This paper, therefore, has attempted to highlight the broader perspectives of efficient energy utilization, covering power station technology including co-generation of power and process energy and giving examples of fuel savings in combustion systems.

To start with, Figures 1 - 5 put the problems of energy in the context of the actual situation in developing countries, contrasting them with industrialized countries and numerically highlighting energy wastage which is the inheritance of a cheap oil era. In Figures 3, 4a, and 4b concepts of integrated energy planning are also discussed.

The second section, Figures 6 - 8, deals with thermal power stations and trends of development of advanced technologies in the USA, Japan, and West Germany. The effect of capital costs, fuel prices, and operation and maintenance costs on generation costs of electricity have to be examined simultaneously with the power station reliability, availability, and plant load factors in order to examine the suitability for a country of highly efficient, but extremely complex technologies.

The third section, Figures 9 - 14, deals with examples of power and process co-generation which provide excellent possibilities of reaching high

efficiencies without increasing the technological complexities of a plant to any significant degree. The "value of one percent" is discussed in this context.

For co-generation, basically the following cycles are of significance:

- Rankine cycle with various combinations,
- Brayton cycles for gas turbines with WH rcovery for process energy,
- Combined cycle (ST/GT) with WH recovery,
- Otto and diesel cycles (internal combustion engines) with WH recovery, and
- Combination of IC engines with Rankine cycles.

The possibilities of combination are rather large and evaluation of suitable alternatives has to be done on the basis of available fuel sources and costs, requirements of process energy, as well as the local situation regarding grid-interconnections. Solutions for expansion and/or renovation of existing plants are likely to be substantially different from new plants where the energy system can be optimized on its own with given process parameters or an integrated optimization of the entire energy-process can be attempted including modifications of process parameters.

Furthermore, in an integra approach to energy-efficient industrialization, not only is it necessary to do energy process optimization, but it is important to examine the present and future role of renewable energy resources. In many cases, for example, the economics of a solar system integrated as an energy-saver in a process or a co-generation plant can become substantially more attractive than a stand-alone solar installation with the additional costs of its storage and piping systems. In a co-generation plant, therefore, there are possibilities of vertical as well as horizontal integration with topping and bottoming cycles, supplementary energy systems, cascading, and grid interconnections being used as required to give an optimum solution under local boundary conditions.

Gas turbine plants have the well known advantage of simplicity and low cost as well as the capability of quick start ups and load changes. Their disadvantages are the requirements of clean fuel and low efficiencies when operating in open cycles.

The combination of steam and gas turbine cycles, however, enables high efficiencies to be attained, since the average temperatures at which the heat is supplied to the cycle can be raised compared to the steam cycle and the average temperature at which the heat is rejected from the cycle can be lowered compared to an open gas turbine cycle.

Various possibilities exist with regard to the combinations of electricity and process heat generation, with fired and unfired waste heat recovery systems and condensation as well as extraction/back pressure turbines. As

far as fuel limitations are concerned, heavy fuel oils can be used to a certain extent after pretreatment, but the application of coal has to wait until fluidized bed combustion and/or coal gasification processes become commercially available for GT applications.

Diesel engine power plants offer both advantages and disadvantages compared to gas turbine plants. Advantages of diesel engines are the ability to burn low grades of heavy fuel oil with lower fuel pretreatment costs, lower maintenance costs for base load operation, higher efficiencies both at full and part loads, and high reliability. Advantages of gas turbine plants are bigger unit ratings, smaller space requirements, lower specific capital costs, and the inherent capability of being integrated in coal-gasification as well as pressurized fluidized bed systems. Overall, for smaller unit ratings, diesel co-generation plants for power and process heat are capable of competing on techno-economic grounds with gas turbine plants. Waste heat in exhaust gases as well as from engine cooling systems can be economically used for generating process heat and, up to a certain extent, additional 8-10% electricity at full load. The energy balance of a large two-stroke diesel co-generation plant supplying electricity and medium pressure process steam from a fired WH-boiler is shown together with an example of another diesel co-generation plant which generates electricity from the diesel generator as well as from a bottoming steam turbine cycle and supplies auxiliary steam from the unfired waste heat boiler.

The generation of "cold" on a power process energy co-generation plant can be achieved in three ways:

1. using co-generated electricity in a compression-absorption cycle with integrated waste heat recovery systems. The profile of electricity generation has to be matched with the requirements of "cold" process energy as well as process steam, if present.

2. using waste heat to run an organic vapor turbine in an ORC plant to drive the compressor of a refrigeration/cold storage plant.

3. using waste heat to operate a vapor absorption cycle.

The possibility of generating shaft-power for driving a compressor in a refrigeration plant is shown for various waste heat temperatures. The refrigeration capacity which can be generated from such a system is also shown; and an example gives the flow diagram and the systems data for a vapor absorption cycle plant operated with waste heat.

Examples given in the paper clearly show that co-generation and power process coupling provide overwhelming techno-economic advantages for supplying electricity and process energy in desired forms to industrial plants. It has the added advantage of familiarity, since most of the co-generation plants consist mostly of well tried-out systems and equipment which need to be combined and optimized with a new set of boundary conditions. New technologies such as ORC plants or perhaps new designs of vapor absorption systems will help to expand the scope of application of co-generation plants and

improve their economics for certain types of applications, but the proven techno-economics of co-generation plants demand their large scale application in countries where industrialization still has a long way to go. In these countries there is still time to give a more cost-effective direction to the energy planning and industrialization programs. It will pay us to find ways to avoid some of the pitfalls which lie in the path of a linear extrapolation or duplication of the experience of industrialized countries gained during a cheap energy era.

Experience elsewhere shows, however, that planning and implementation of a systematic and coherent policy for introduction and promotion of co-generation on a large scale is considerably more difficult than normal power planning. There are fewer interactions in deciding about central power stations than there are for co-generation plants. The larger amount of possibilities in the design and layout of the station and in cascading the energy levels to match the process needs, which may also have to be modified for optimum results, require a much greater amount of calculations, optimization studies, and analysis than for central power stations. The linkages to the grid also need careful study to take into account the fluctuation of power generation in co-generation plants so as to match the flow of energy to and from the grid with the loading and stability of the grid itself.

The last section gives examples of energy conservation. Figures 15 and 16 show some areas of energy savings and give a few examples of the very attractive financial results which can be obtained from good management and housekeeping as well as retrofitting of energy saving systems.

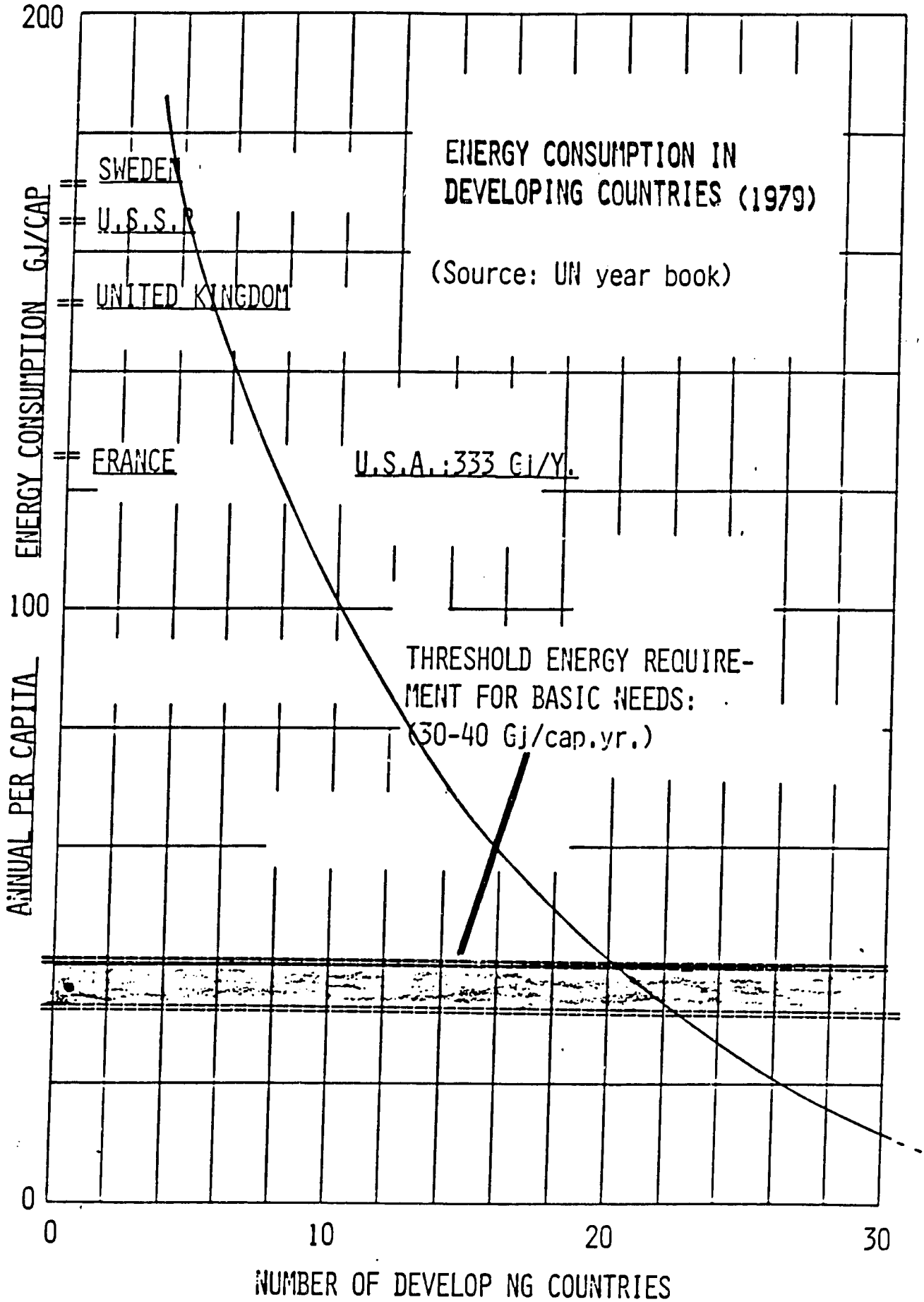

200
100
0
ANNUAL PER CAPITA ENERGY CONSUMPTION GJ/CAP
SWEDEN
U.S.S.R
UNITED KINGDOM
FRANCE
ENERGY CONSUMPTION IN DEVELOPING COUNTRIES (1979)
(Source: UN year book)
U.S.A.:333 Gj/Y.
THRESHOLD ENERGY REQUIREMENT FOR BASIC NEEDS: (30-40 Gj/cap.yr.)
0
10
20
30
NUMBER OF DEVELOP NG COUNTRIES

Figure 1

CONTRASTS

AVERAGE NUMBERS TELL ONLY HALF THE STORY

	WORLD	DEVELOPING COUNTRIES	INDUSTRIALIZED COUNTRIES
POPULATION DENSITY (Cap./km^2)			
Total	7,000	10,000	5,000
Urban	12,000	20,000	7,000
Rural	6,000	8,000	3,000
ENERGY CONSUMPTION (GJ/cap.yr)			
Total	68	18	144
Urban	144	108	180
Rural	29	14	72
		(Incl. non-comm.)	
POWER DENSITY (w/M^2)			
Total	15	5	25
Urban	50	70	40
Rural	5	4	7
		(Incl. non-comm.)	

Figure 2

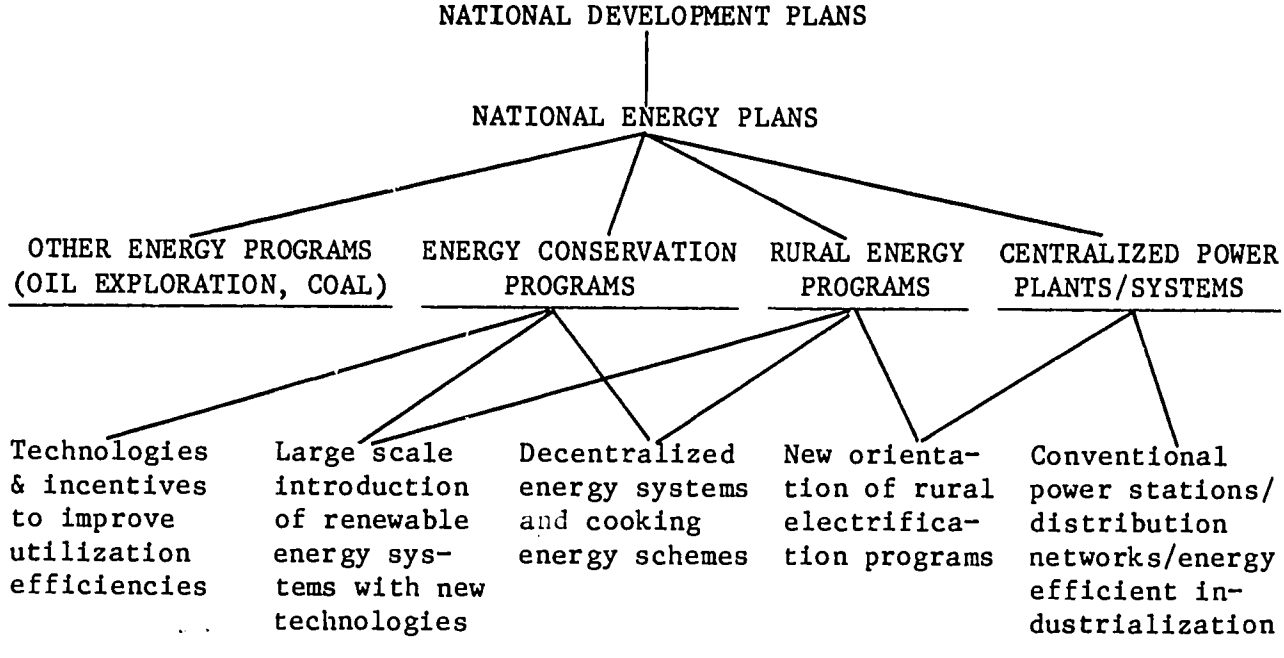


Figure 3

A. POWER PLANNING NOT ENOUGH: ENERGY PLANNING NEEDED

UNORGANIZED SECTORS NEED SPECIAL ATTENTION

- SHORT TERM CRASH PROGRAMS
  - Conserve/substitute firewood
  - National cooking energy scheme
  - Subsidized kerosene???
  - Stoves/ovens/charcoal from agricultural wastes

- MEDIUM TERM POLICIES
  - Energy/fuel plantations: fast growing trees
  - Bio-mass technologies
  - Mini/micro hydro plants
  - Solar systems
  - Biogas plants
  - Decentralized rural energy schemes (based on locally available resources)
  - Energy conservation

- LONG-TERM POLICIES
  - Optimum mix of centralized and decentralized systems
  - Local, regional, and national matching of conventional and renewable energy resources (demand and supply)
  - Allocation of funds and priorities to develop renewable energy technologies
  - Energy efficient industrialization planning (power-heat/cold-coupling) (new processes)

B. ENERGY PLANNING MUST ENSURE:

- Compatibility of short-, medium-, and long-term policies and programs

- That long term national and local goals are not sacrificed for short term expediency

Figure 4

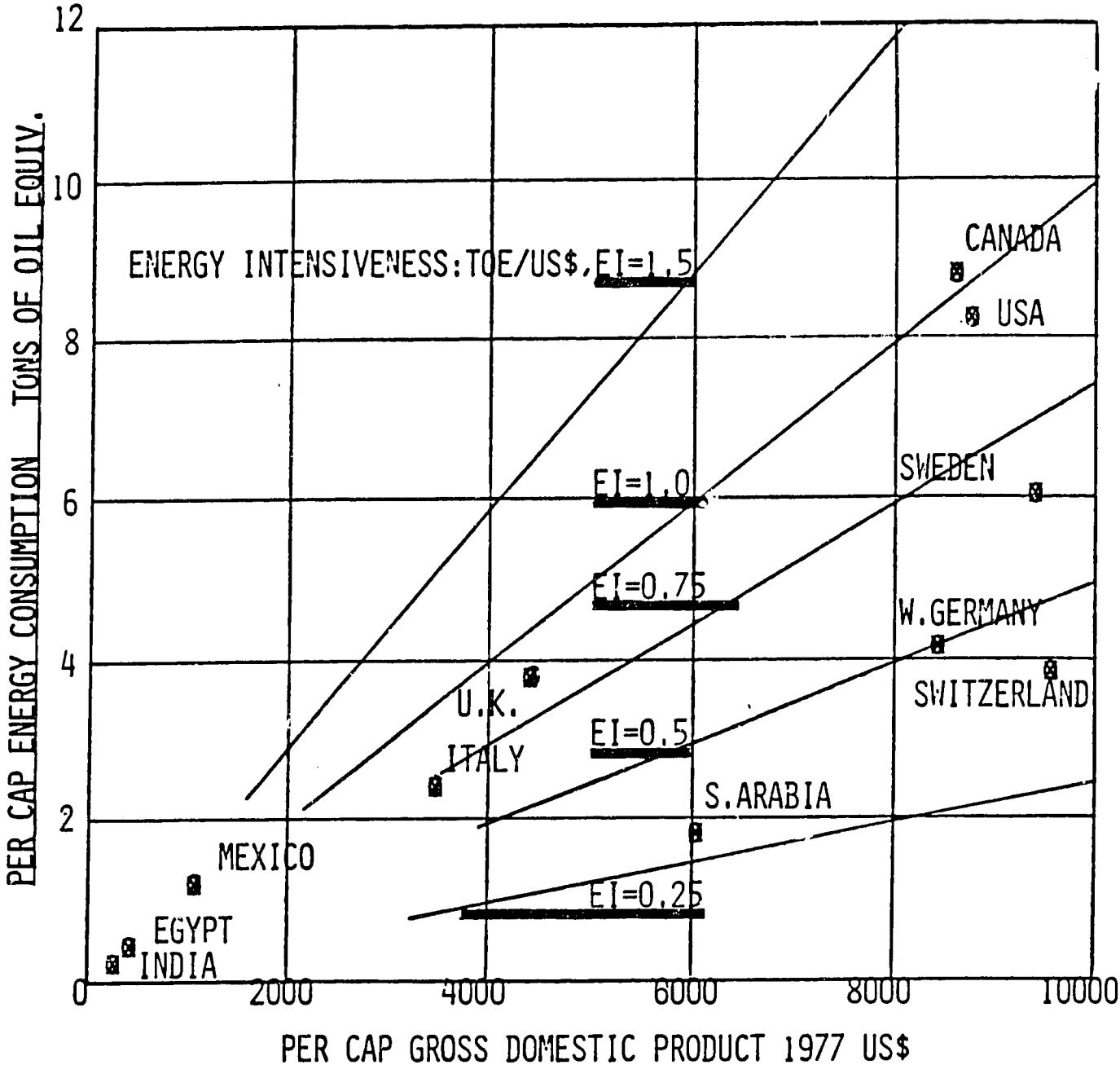
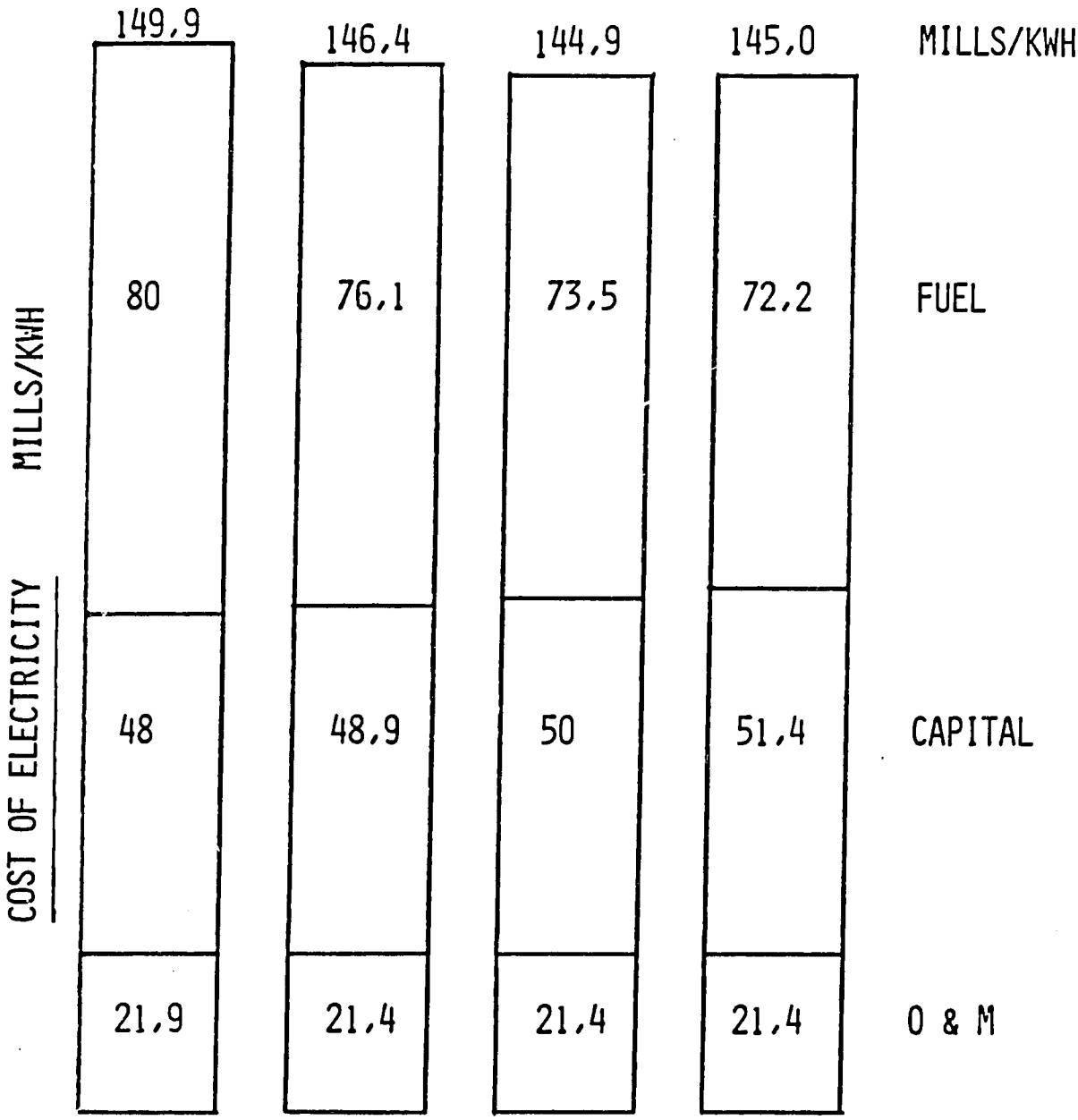


Figure 5. Energy Consumption and Energy Intensiveness
(Source: IEA Workshop, 1979)



U I	U II	U III	U IV
165 B	241 B	310 B	310 B
538 C	538 C	538 C	566 C
538 C	552 C	552 C	579 C
	566 C	566 C	593 C

LEVELISED BUSBAR ELECTRICITY COST (70 % PLF, 30 YRS., 1.9 $/KJ)

PL. NOTE

A 3 % LOWER PLF (67 % INSTEAD OF 70 %) FOR PLANT U II WILL EQUALIZE THE ELECTRICITY COSTS FOR STATIONS U I AND U II.

Figure 6. Electricity Costs for U.S. Stations

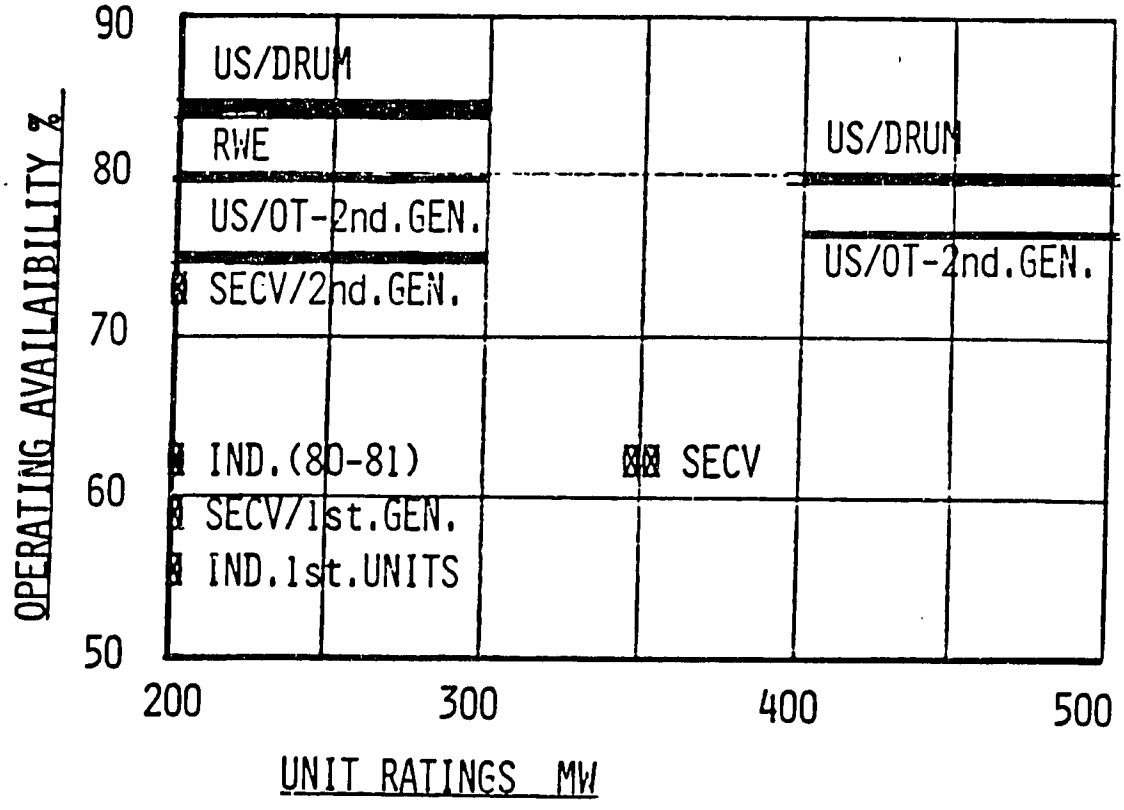

90
80
70
60
50
OPERATING AVAILAIBILITY %
US/DRUM
RWE
US/OT-2nd.GEN.
SECV/2nd.GEN.
IND.(80-81)
SECV/1st.GEN.
IND.1st.UNITS
SECV
US/DRUM
US/OT-2nd.GEN.
200
300
400
500
UNIT RATINGS MW

Figure 7

A SHIFTING TARGET: Who?
Where?
When?

CONTRASTING SITUATIONS: e.g., Japan vs a Developing Country

JAPAN: Fuel savings paramount

PRIORITIES

High Technology
New Processes, Advanced Cycles
New Equipment, New Materials
Energy Conservation: Bottoming Cycles

A DEVELOPING COUNTRY:

ACUTE SHORTAGE OF

- Capital
- Energy and power
- Adequately trained and experienced technical manpower
- Infrastructure base

RESULTING PRIORITIES

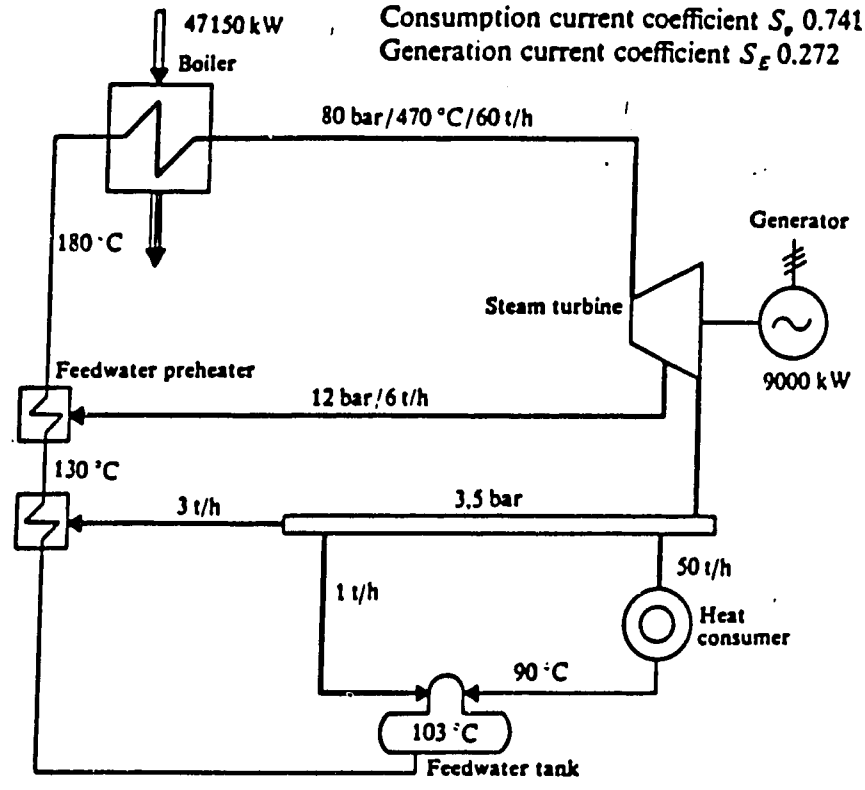
- Max. power generation per unit new investment (kWh not kW)
- Maximizing generation from existing units
- Energy/fuel savings with technologies which do not lead to loss of generation

Figure 8. Value of one percent

Economics of scale + higher efficiency to be balanced against

Availability
Plant load factor
Load pattern
Distribution losses
Efficiency gain via process-electricity coupling

Figure 9



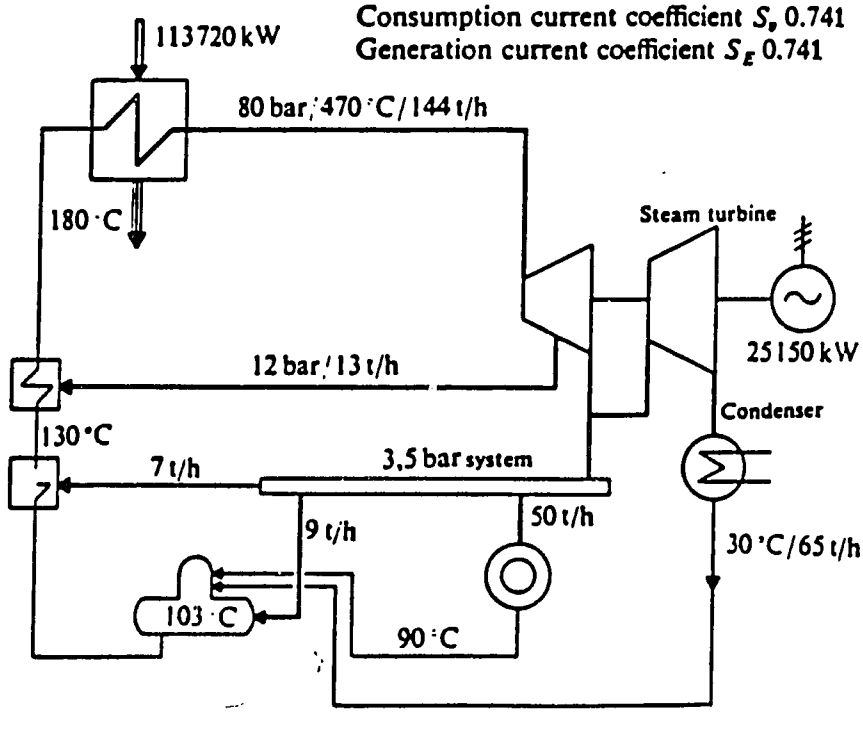
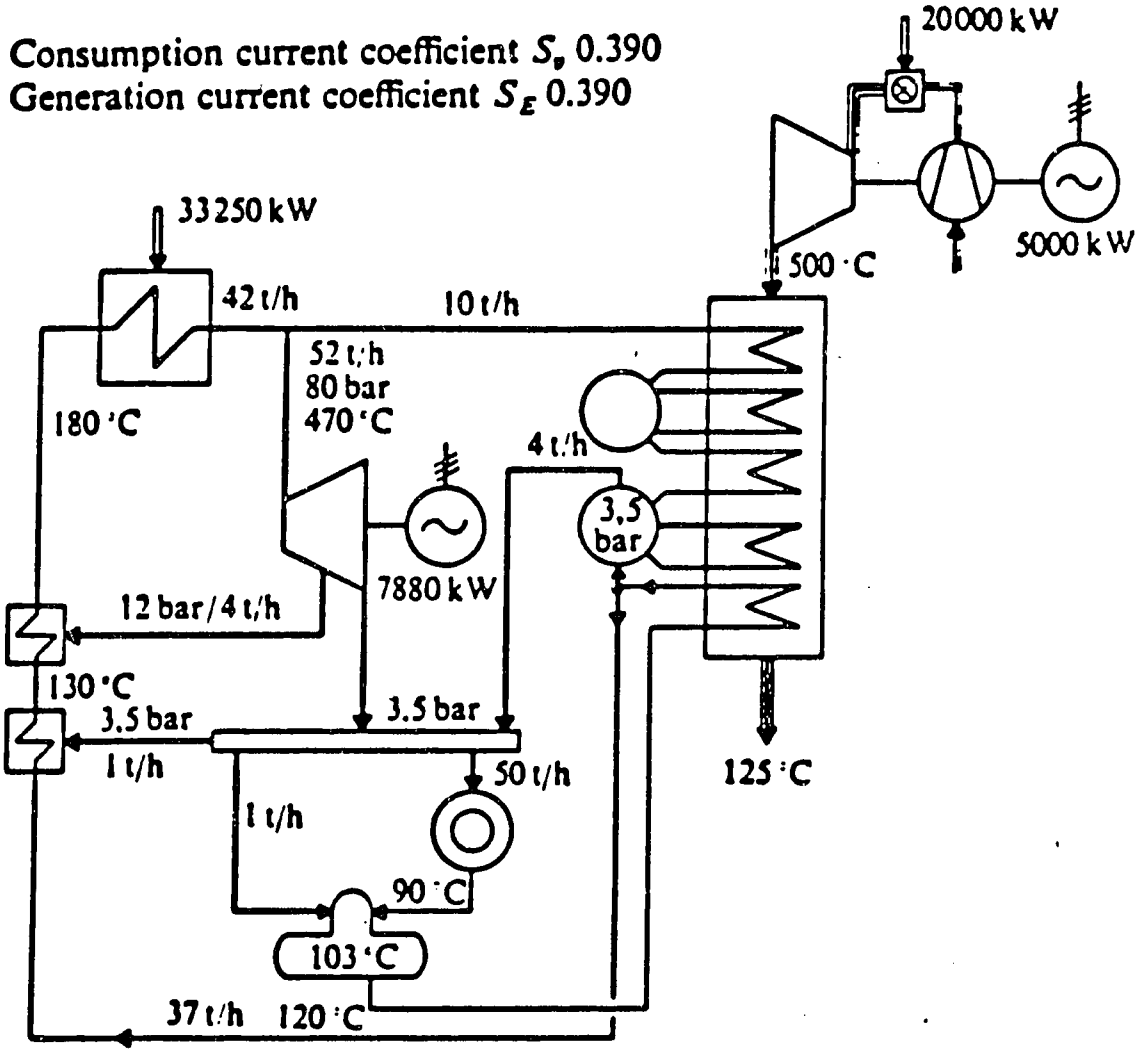


Figure 10. Examples of Process Heat Power Coupling with Steam Turbines



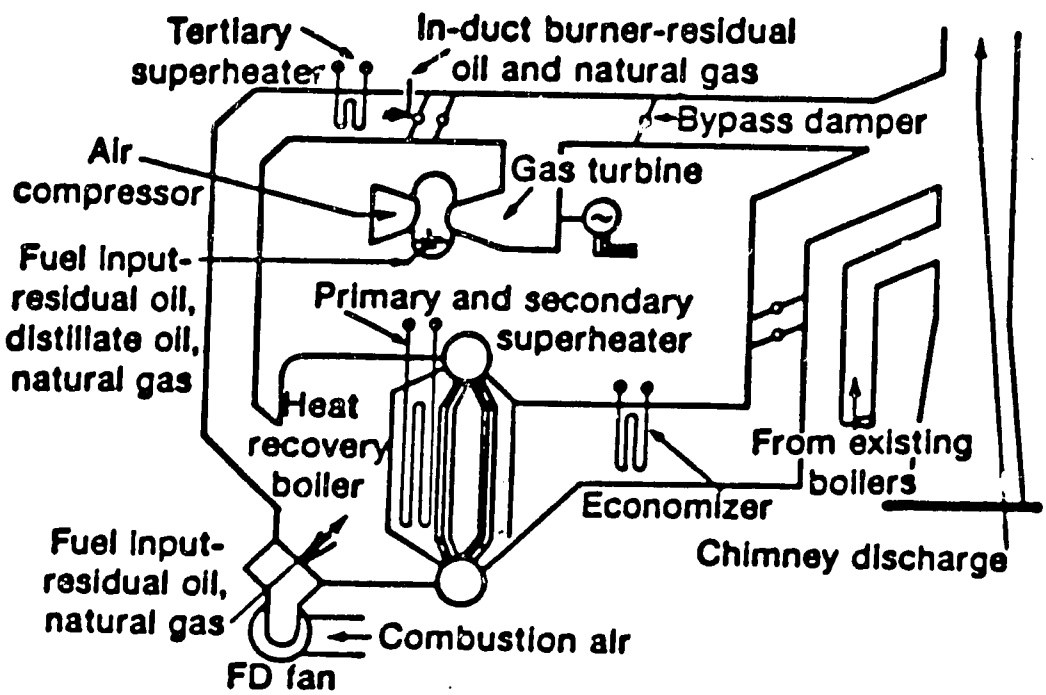
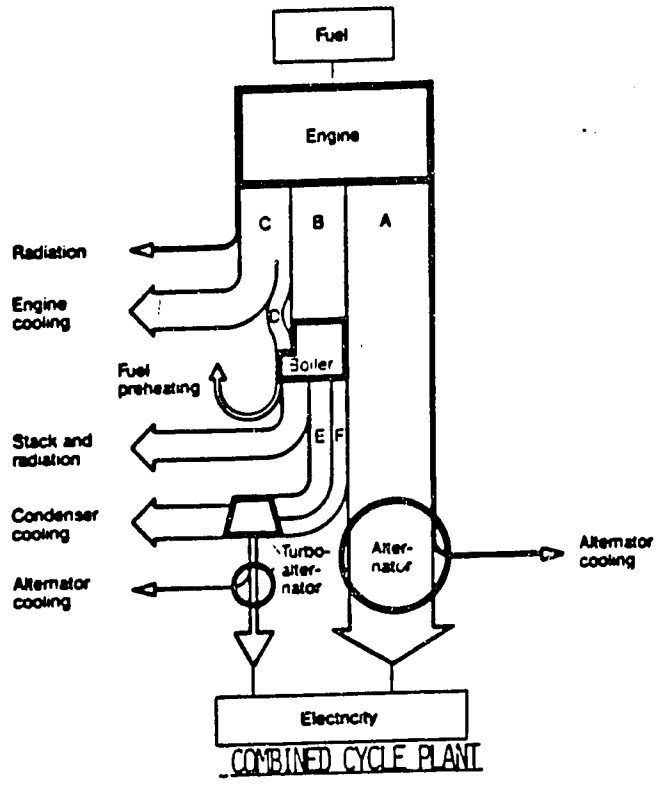


Figure 11. Examples of Un-fired and Fired GT/ST Combined Cycle Plants (with process heat generation)



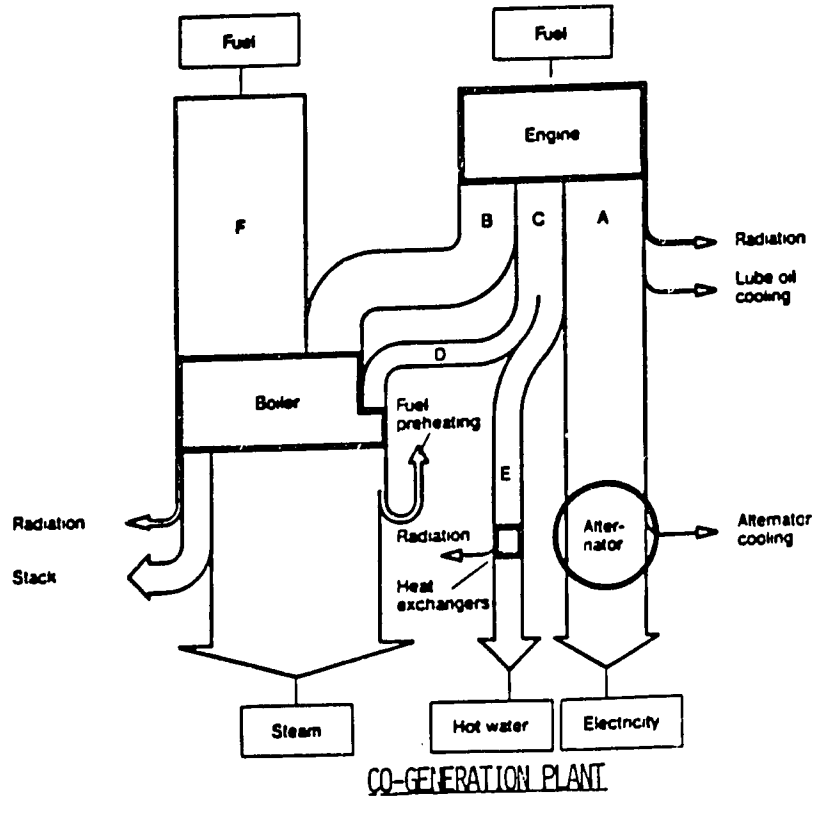


Figure 12. Waste Heat Utilization Systems for Diesel Generators

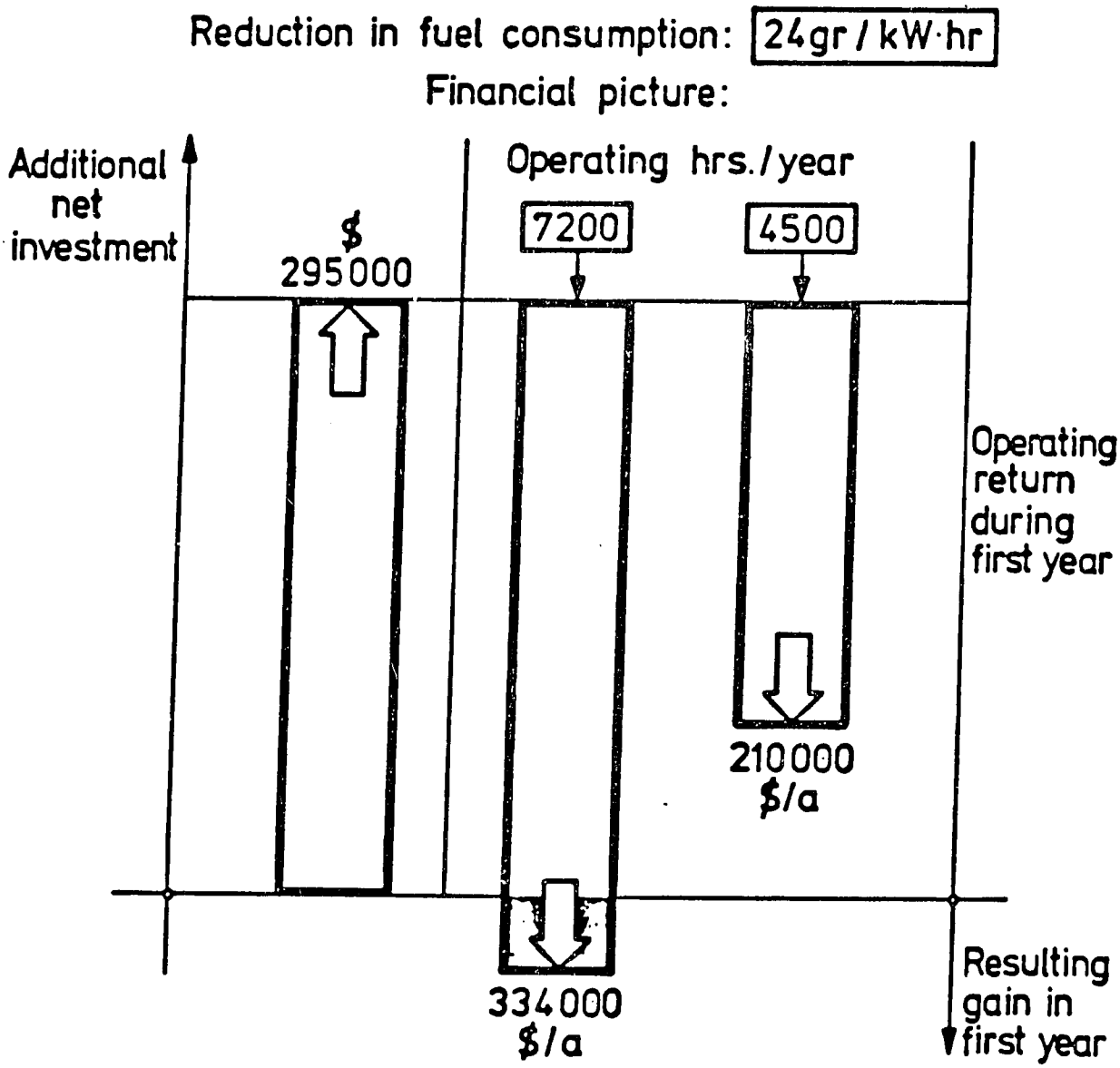


Figure 13. Economics of a Diesel Engine Plant with a WH-Steam Cycle (15,000 kW diesel/1500 kW steam turbine) (Source: Wolf/Steiger)

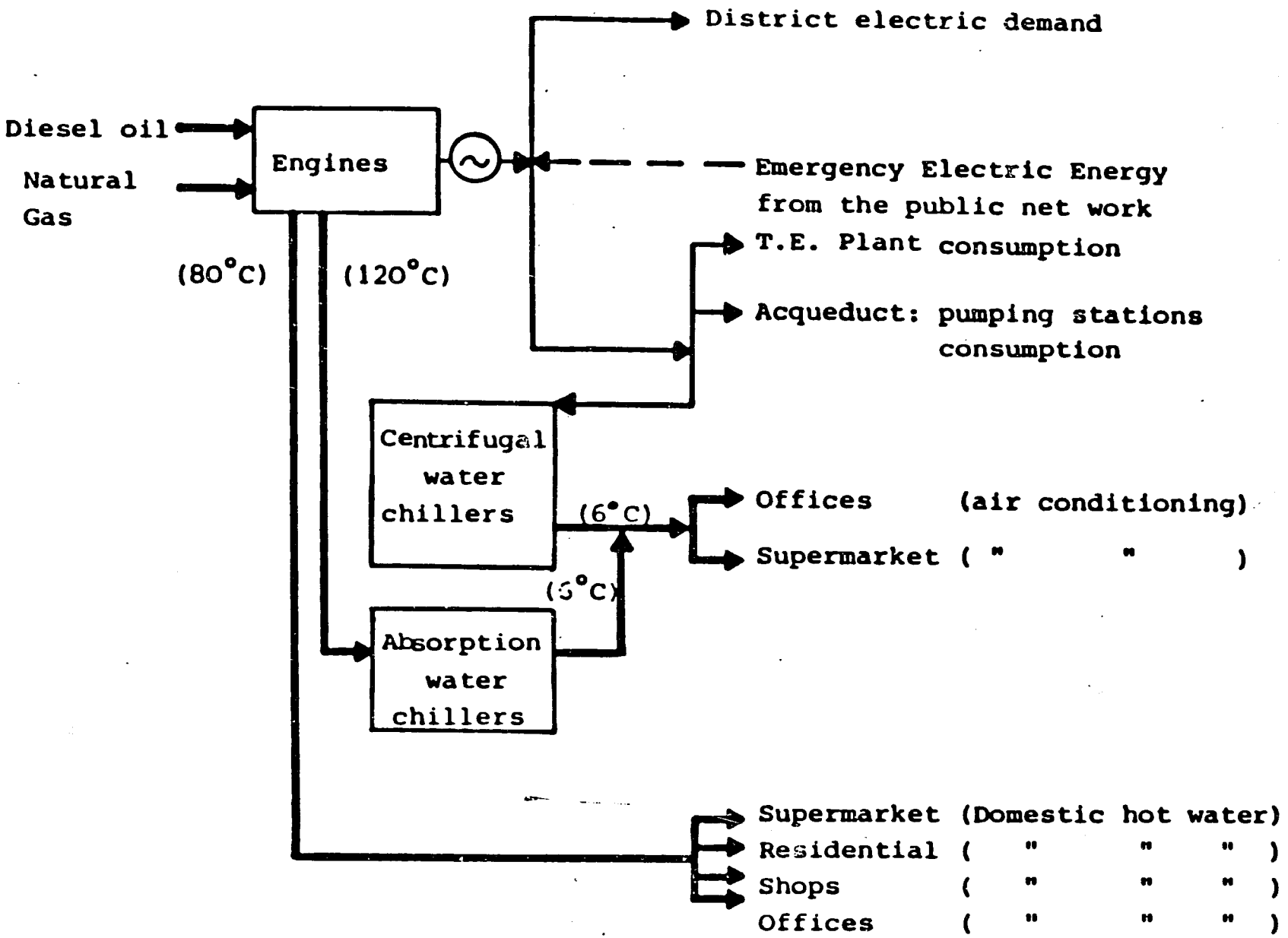
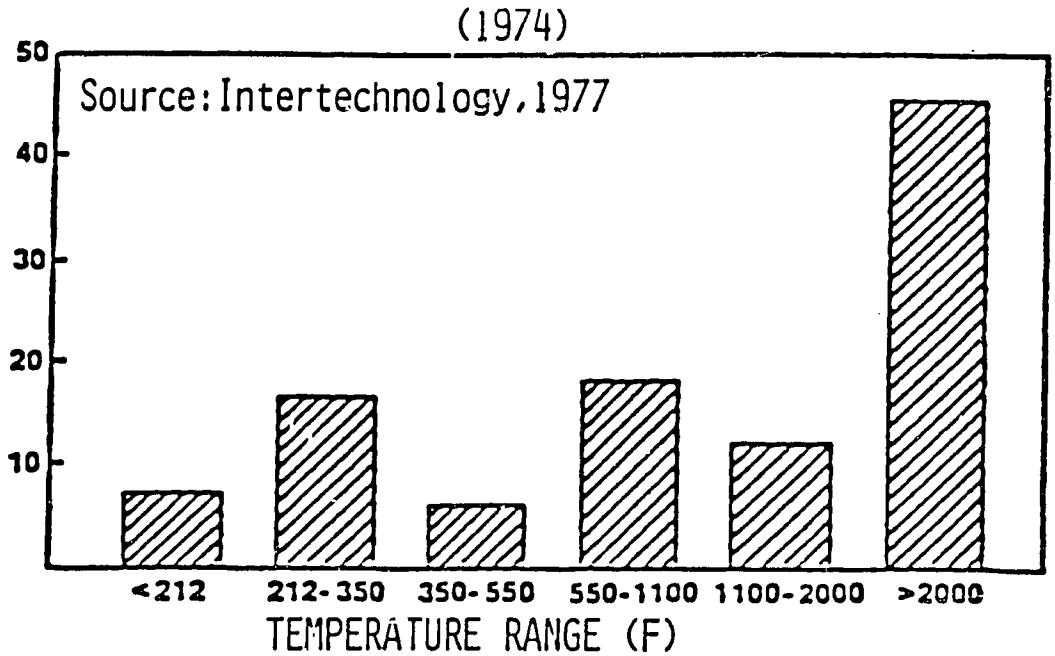


Figure 14. An Example of Process-Cold and Power Generation from Diesel Engine Plants

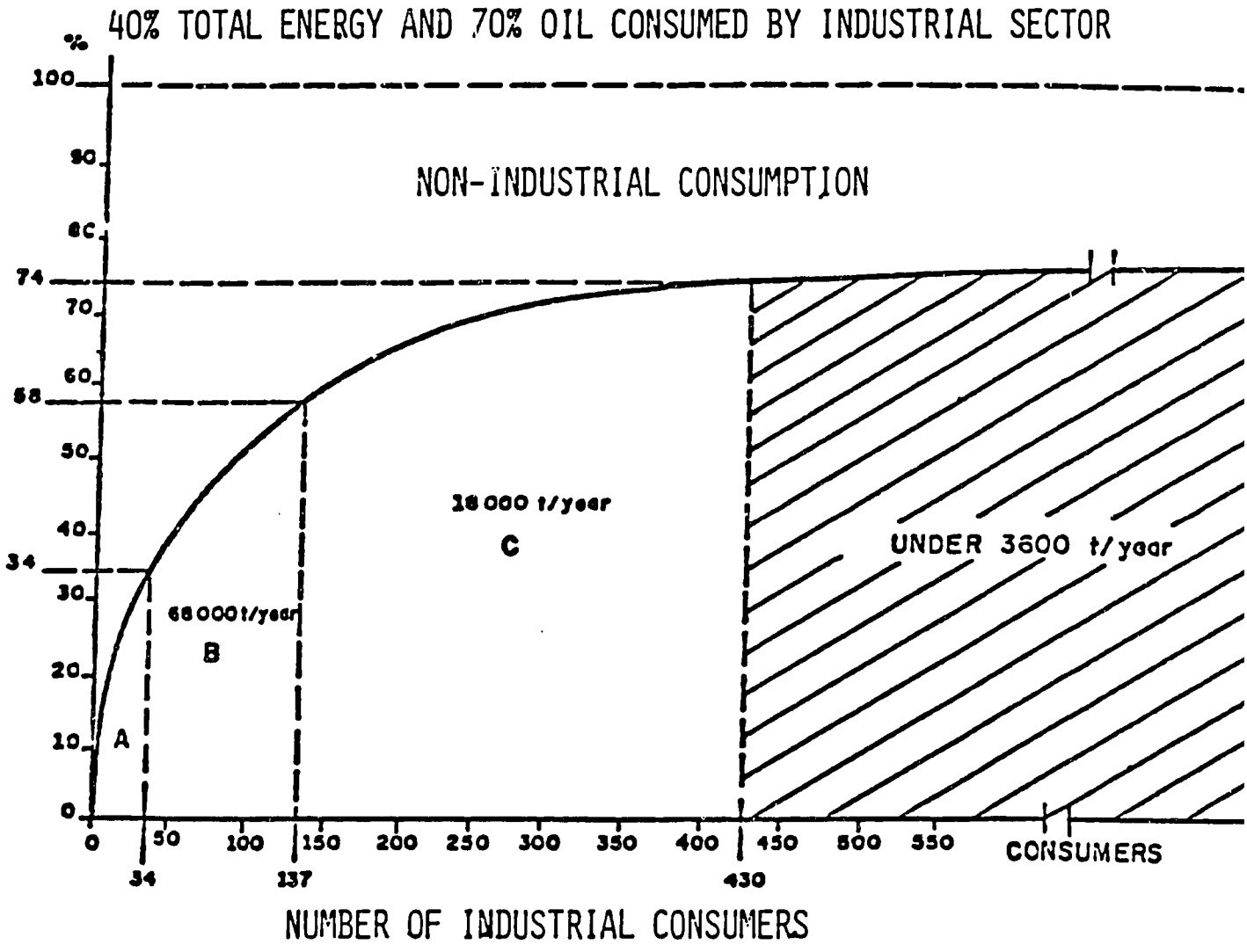


SOME TYPICAL DEVELOPING COUNTRY DATA ON INDUSTRIAL ENERGY CONSUMPTION

	CEMENT	STEEL	ALUMINUM
ENERGY CONS.	1.4 10^6 (wet) 0.9x10^6 (dry) (excl.grinding) Kcal/ton.	6-8 10^6(crude) 9-11 10^6(fin.) Kcal/ton	Reduction Alumina to Aluminum. 15-19 Mwh
ENERGY COST (% Total)	33	20-35	20-35

	AMMONIA	PULP/PAPER	PETROLIUM REFINING
ENERGY CONS.	8-11 10^6 Kcal/ton	5-11 10^6 Kcal/ton	Dist. 0.068 10^6 Cracking: 0.137 10^6 Kcal/ton
ENERGY COST (% TOTAL)	30-50	10-30	6-8

Figure 15. Industrial Process Heat Demand at Various Temperatures (Source: World Bank)



ENERGY SAVINGS SCHEME : 90% OF INVESTMENT AS LOAN AT 5% INTEREST RATE PAYABLE IN 5 YEARS WITH 1 YEAR GRACE PERIOD

RESULTS:

TILL DEC.1981,24% SAVINGS IN IRON & STEEL IND.
14% SAVINGS IN PULP & PAPER IND.
39% OIL REPLACEMENT IN CEMENT IND.

Figure 16. Industrial Energy Conservation Program, Brazil
(Source: Monaco, 1982)

SECTION 5

THE BUILDINGS SECTOR

5.1 TECHNOLOGICAL AND ECONOMIC ISSUES IN BUILDING ENERGY USE

Richard B. Curtis and Jerome M. Weingart

PART ONE: ENERGY EFFICIENCY AND BUILDINGS IN WEST AFRICA

1. INTRODUCTION

Demographic projections indicate a rapid growth in the cities of West Africa over the coming several decades. The buildings constructed during this period will be operated well into the next century and the amount of energy they use will be an important dimension of the economics of the region. There is an opportunity for the nations of the region to insure that buildings be designed and operated in an efficient manner, freeing valuable capital and electricity supply and distribution infrastructure for other uses.

Commercial buildings are one of the largest single users of electricity in West Africa. According to the recent Proceedings of the 1981 ECOWAS Energy Symposium (National Academy of Sciences, 1982):

> Some 40% of the electrical energy produced in the ECOWAS countries is reportedly used for air conditioning, lighting, and water heating. Appropriate architectural design and new building materials could reduce electricity consumption.

A single office building of 25,000 square meters would typically require electricity at an average rate of several MWe. In some ECOWAS states, several such buildings could alone consume five to ten percent of the total installed capacity. In a region where the total installed generating capacity is on the order of 4000 MWe, rapid growth in buildings will require an associated growth in electricity generation, transmission and distribution. Since much of the power generation is from thermal plants using imported oil, the costs of buildings which are highly consumptive of energy and also inefficient are substantial. The electricity which is consumed inefficiently in buildings is not available for productive uses. In addition, higher fuel consumption places a higher burden on the balance of payments. Energy conservation can therefore be thought of as a source of fuel whose marginal cost is a fraction of that of conventional fuels or electricity, and whose price does not rise with time.

There is now considerable experience to suggest that energy efficient building design and operation can have a financial payback in a very short time, sometines within a few years. Moreover, buildings which have been designed and operated for a high degree of energy efficiency routinely achieve comfort levels at least as high as in non-efficient buildings. Energy efficiency means doing more with less, not doing without.

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2. ENERGY EFFICIENT BUILDINGS - TRADITIONS AND CURRENT CONCERNS

Throughout the world, indigenous traditions of architectural design have evolved over hundreds and even thousands of years. These designs, usually the result of long periods of trial and error, have resulted in building designs which use local materials and technology to provide shelter and comfort to inhabitants. Such techniques have included the use of massive building materials in hot, dry regions to moderate the often extreme temperature swings between night and day. In hot, humid tropical regions, the use of designs to capture breezes and shade the building from direct sunlight is well known.

For the most part, these indigenous techniques have evolved for residential structures and some public buildings. The large contemporary office building is a distinctly twentieth century product which has its roots in Europe and the United States. Much of the development of such buldings has been in cold or temperate climates. Beginning in the 1950's, large numbers of similar buildings have been constructed in regions of the world very different in climate and culture from the environments in which they initially evolved. The result has too often been the construction of buildings ill-suited to either tropical or hot arid regions, where the inadequcies of the design have been "overcome" through massive amounts of air conditioning.

During the last decade, there has been an increased movement among architects throughout the world towards environmentally-conscious building design, towards rediscovery and application in contemporary form and technique many of the ancient principles which evolved for indigenous building forms of the past. The approach has not been the literal adoption of such practices in new buildings, but rather the incorporation in a rational way of energy-efficient climatically-sensitive design techniques. The result has often been buildings which are not only efficient in energy use and comfortable for their occupants, but visually exciting and interesting to work in.

3. ESTABLISHING NATIONAL ENERGY EFFICIENT BUILDING POLICIES

There is no simple all-encompassing policy which a country or region can adopt to insure that buildings will be designed, built and operated in an energy-efficient manner. One of the authors (JMW) was involved in the design of legislation in California in 1972 whose purpose was to establish energy performance guidelines and standards for new commercial (non-residential) buildings in the state. It took several years of hard work by various committees made up of architects, engineers, building contractors, equipment suppliers, building code officials, and other professionals, to develop an approach which was more or less workable. It is fair to say that the policy process was a turbulent one. There is no reason to think that it would necessarily be simpler anywhere else.

At the same time, the economic imperatives for improving the energy performance of existing buildings and designing more efficient new buildings have had an effect in California, and elsewhere in the United States and Europe, as well as increasingly in other parts of the world. There have been

several key elements to achieving increased energy efficiency, both in new and existing buildings. These include:

- Economic incentives for building owners and operators to increase energy efficiency;

- Availability of usable design tools and calculational procedures for use by architects and engineers.

- Availability of straightforward means for building code officials to verify compliance with energy efficient design and operation procedures. (Unless the rules have workable means for implementation, they will not be implemented. This is common sense and also common experience throughout the world.)

4. OBSTACLES TO IMPLEMENTING ENERGY-EFFICIENCY FOR BUILDINGS

There is a variety of obstacles to widespread practice of energy efficient design and operation of buildings. These will have to be addressed in development of any effective energy efficiency programs. Some of the important institutional issues include:

- Building owners rarely experience the buildings they create. Consequently, the owners tend to be less concerned than they might about operating costs, especially when these can be recovered through rents.

- First costs tend to be more important than life-cycle building costs, even for many buildings which are owned by the original builder (including the government).

- Adequate experience and design tools are not widely available in some regions, and design professionals can rarely afford the costs of training themselves in energy-efficient design practices.

- There are inadequate policy guidelines for establishing energy-efficiency criteria, and

- There are insufficient economic incentives for builders and designers to develop energy-efficient buildings, even when there is a clear imperative at the national level.

A central issue is the development of national policy which translates the need for energy efficiency at the national level into economic imperatives at the level of the individual building designers, builders, owners, and operators. Some of the means for accomplishing this include the following:

- In Singapore, building owners are required to occupy a major fraction of the building for several years before they can become an absentee landlord. This has the effect that the owners pay the operating costs and therefore experience the degree of efficiency (and comfort) of the building.

- Investment policies, such as interest rates on building loans and energy efficiency tax credits can be related to life-cycle costs as opposed to first costs. Until the investor also feels the need for energy efficiency, it will not become a widespread reality.

- In the past, architects have generally not been concerned with energy conservation and efficiency. There is a need for the training of architects, engineers and bulding operators in how to save energy. As part of the training, there needs to be design handbooks and manuals appropriate to the specific locale where the building will be located, which can be used in a familiar way by design professionals and operators.

5. DEVELOPMENT OF A WEST AFRICAN BUILDING ENERGY DESIGN MANUAL

While the use of simple "rules of thumb" in building design can contribute to energy efficiency, considerably greater gains can be obtained through the use of computer-assisted design. However, there are important practical problems involved in the implementation of computer tools for building design. Most architects and engineers, in all countries, remain unfamiliar with the use of computers as design tools. By contrast, the use of guides and manuals containing calculational procedures (including easy to use nomographs or graphical methods) for sizing air conditioning equipment, optimizing window area and building orientation, determining effective use of insulation and so forth could quickly become a familiar and widely used procedure.

An important contribution to the goal of the diffusion of energy-efficient building practices in West Africa would be the development of a set of design manuals for the major climatic zones of the region, for use by architects, engineers, and building managers. These manuals would be designed for straightforward use by these professionals, but their development would require the use of a computer program such as DOE-2, incorporating the necessary hour by hour information on temperature, humidity, insulation, etc. for the various regions of interest.

Such a manual could be developed within an appropriate institution in West Africa, with participation by professionals from the various ECOWAS member states. Through collaborative arrangements with design professionals who have developed and used these computer-based tools, it would be possible to

implement the programs, train people in their use, and develop the series of manuals which would be periodically updated and refined through actual use of these in the local design process.

An important associated activity would be the establishment of a suitable data base of climatic information, both from available records and, as needed, through new measurements. Buildings designed and operated using the manuals could be monitored to compare predicted and actual energy performance. Through such monitoring, the effectiveness of the manuals could be determined and the manuals improved as necessary.

6. COMPUTER SIMULATION OF BUILDING ENERGY USE

The thermodynamics of commercial buildings is a complex subject. Even the best and most comprehensive of available computer models which attempt to simulate the energy performance of such buildings are only approximations and their use is as much an art as it is a science. They really must be considered as imperfect tools to be used in the craft of energy efficient building design. Yet the complexity of these buildings really requires computer analysis in order to quantify the energy use and cost implications of various design possibilities. Because of the large number of interacting variables for a building, the modification of one (such as lighting level or window area on a specific exposure) affects the response of the building to changes in others.

Our intention is not to go into the details of energy efficient design techniques for large buildings. These are covered in an extensive literature and in the User Manuals for the various computer programs currently available. In Part II, we provide a discussion of one specific computer-based tool which is now in wide use internationally for evaluation of energy use in complex buildings. This program (DOE-2) could be used as discussed above to help develop a practical energy efficiency design guide for commercial and public buildings in West Africa.

PART TWO: THE DOE-2 BUILDING ENERGY USE ANALYSIS PROGRAM

1. MOTIVATION FOR DEVELOPMENT

DOE-2 is a public domain computer program which can be used to explore the energy behavior of proposed and existing buildings and their associated heating, ventilation and air conditioning (HVAC) systems. Incorporating mathematical models (called algorithms) and utilizing hourly weather data, DOE-2 calculates the hour by hour performance and response of a building whose description has been provided by the user. In addition, DOE-2 can produce an economic analysis of the energy use and the costs and benefits of making algorithms in design.

DOE-2 is intended to be used by architects, engineers, and others who are concerned with the energy analysis of buildings and with the consequent economic implications. Although energy analysis was initially the concern of the mechanical engineer alone, it is now recognized that the architect also has tremendous influence on the energy usage of buildings. Before the rise of modern HVAC equipment, the architect was the primary determiner of the energy consumption of a building and architectural building design including consideration of how the occupants were to be sheltered and kept comfortable. Use of passive solar heating and ventilating was a primary concern. With the rise of cheap and apparently abundant energy and with the development of technologically clever delivery systems, it became less incumbent on the architect to be as energy conscious when designing a building. The secondary HVAC systems could be relied upon to make up for the lack of natural heating and ventilating and to provide a comfortable interior climate. The realization that energy is no longer plentiful and inexpensive has reawakened the architect to the need to consider energy analysis in building design.

The same need has arisen for the mechanical engineer. Since the aim is no longer simply to provide a system which will meet the heating and cooling loads of the building, but also to do that efficiently so that the loads are met with the least expenditure of energy, the mechanical engineer can no longer deliberately oversize the equipment to ensure meeting the loads. Oversizing usually means the equipment operates extensivey in a less efficient mode. Avoiding this energy waste requires knowing what minimum capacity is required.

Master carpenters are fond of impressing their young apprentices by measuring a desired length of lumber by running their thumbs along the board and making a thumbnail impression at the point where they intend to saw. When the apprentice measures the mark with a rule, it is inevitably accurate. Although an architect or an engineer applies more sophisticated techniques in design, there is in these professions an appreciation - indeed, a certain amount of reverence - for the ability to sift through the complex considerations that go into the design of a bulding or a HVAC system and to specify the dimensions and the components without recourse to detailed computations. At most, the calculations should be limited to "the back of an envelope". To require more is often perceived as a detriment to good design and the sign of a failure to be well trained. After all, the person is a designer and not a calculater.

The energy and economic considerations mentioned above, however, have made many old "rules of thumb" out of date. The design of energy (and money) conserving buildings and systems depends upon attending to the subtle interactions of a large number of design features. When one is designing without the safety of over-sizing, the energy consumption becomes sensitive to the many variables which describe the design. To keep track of this large number of variables, a computer becomes essential.

Even if a hand calculation were possible, to consider a number of alternatives would require a number of hand-done analyses. The tedium of such a task is what a computer is designed to alleviate and what a computer allows. The outgrowth of making parametric runs, as the recalculation of many alternatives is called, is the development of a more informed "rule of thumb," and this is also a contribution that the computer can make. Among many other options, with the computer fine-tuning of sizing can be made, the efficacy of hot gas bypassing can be assessed, and various alternative energy storage strategies can be explored.

It was to create such a computer tool that in 1976 the Energy Research and Development Administration (ERDA), which later became part of the US Department of Energy (USDOE), began the development of what has become the DOE-2 program. Although several national laboratories have been involved in the program over the last seven years, the work is now concentrated at Lawrence Berkeley Laboratory. The purpose of this project has been to create, test, document, and maintain a user-oriented, public domain, computer program that will enable architects and engineers to perform design studies of whole-building energy use under actual weather conditions. The development of this program, which in its successive public generation has been known as Cal-ERDA, DOE-1.4, DOE-2.0, and, finally, DOE-2.1, has been guided by several objectives:

1) that the description of the building by the user be in quasi-English so that the input can be read and understood easily by non-computer scientists;

2) that, when available, the calculations be based upon well-established algorithms, i.e., the calculational procedures used should be acceptable to the engineering community;

3) that it permit simulation of commonly available heating, ventilation, and air-conditioning (HVAC) equipment;

4) that the computer costs of the program be minimal; and

5) that the predicted energy use of a building be acceptably close to measured values.

All of these objectives have been met and the DOE-2.1B version of the program is now available from the National Technical information Service for less than $2,500. Considering that the development costs for this program have exceeded $10 million, this has to be a great bargin.

2. GENERAL DESCRIPTION OF DOE-2

Energy use analysis of buildings involves four principal steps:

First is the calculation of heat loss and gain to the building spaces and the heating and cooling loads imposed upon the bulding HVAC systems. This calculation is carried out for a space temperature fixed in time and is commonly called the Loads calculation. It answers the question: How much heat addition or extraction is required to mainain the space at a constant temperature as the cutside weather conditions and internal activity vary in time and the building mass absorbs and releases heat.

Second is the calculation of the energy addition and extraction actually to be supplied by the HVAC system in order to meet the possibly varying temperature set-points and humidity criteria subject to the schedules of fans, builers and chillers, and to outside air requirements. This calculation results in the demand for energy that is made on the primary energy sources of the building. This step, called the Systems calculation, answers the question: How are the accumulative heat extraction and addition rates modified, when the characteristics of the HVAC system, the time-varying temperature set-points, and the heating, cooling and fan schedules are taken into account?

Third is the determination of the fuel requirements of primary equipment such as boilers and chillers, and the energy production of solar collectors, etc., in the attempt to supply the energy demand of the HVAC systems. This Plant calculation answers the question: How much fuel and electrical input is required to feed the secondary HVAC system given the efficiency and operating characteristics of the plant equipment and components.

The fourth step evaluates the costs of equipment, fuel electricity, labor, and retrofit components against the alternative of investing the money in other ways. It answers the question: Is the expenditure of funds for energy conserving materials and systems cost effective, when compared with alternative systems and investment possibilities?

The first three steps are illustrated in Figure 1, showing the flow of energy. The different methods of and accuracy in performing these steps differ essentially in the degree to which the mathematical models chosen to simulate these steps match the actual world. The continually varying outside weather conditions, the movement of people, and heat from lighting and equipment inside the building lead to a cooling and/or heating requirement that is always changing - not only in total amount - but in its distribution in the building. Even if there were valid mathematical models for all the simultaneous processes, an exact calculation of the dynamic response of the structure would not be possible. Every energy analysis program must then make approximations and assumptions.

In particular the continuous time dependence of phenomena is approximated by making the calculation in small discrete time intervals. The objective of more refined calculational procedures is to simulate the heating and cooling loads and system responses by making the time interval as small as is practicable. DOE-2 is programmed to compute the building behavior in hourly intervals which permits a more realistic approximation than energy analysis programs which use an averge day per month.

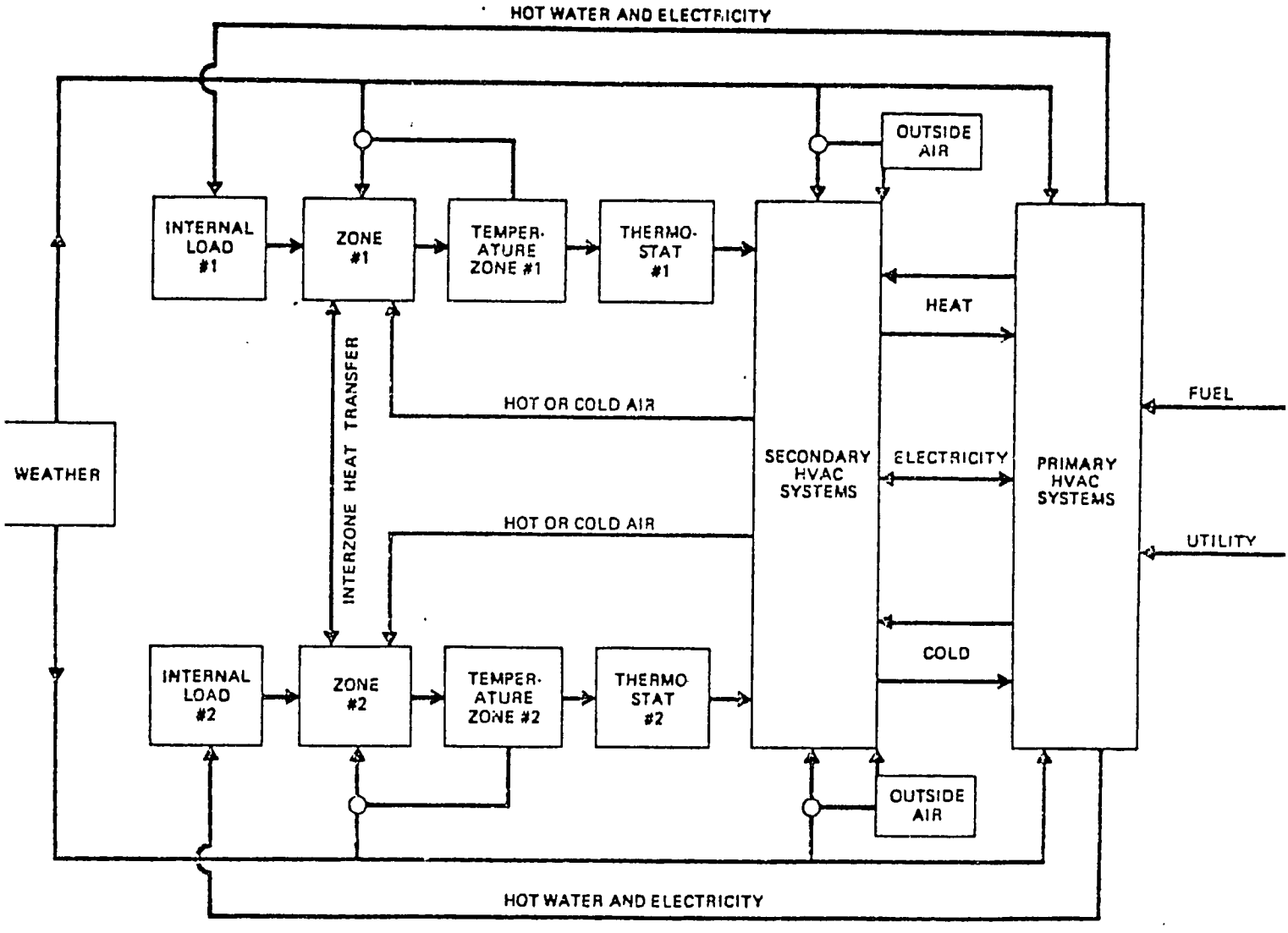


Figure 1. Schematic of Energy Flows in Building

Source: R. Curtis (1981), "The Theoretical Basis of the DOE-2 Building Energy-Use Analysis Program," International Energy Agency Conference, Berlin, Federal Republic of Germany. Report LBL-12300, Energy and Environment Program, Lawrence Berkeley Laboratory.

Such a small interval - implying 8760 steps in a calendar year - would be impossible without the use of advanced computer methods, especially when it is realized that careful design may require the calculation to be made several times to test alternatives. The long history of development of such calculational procedures has been justified on the basis that more accurate calculations will give improved analysis of life cycle costs of building, more precise sizing of equipment and more carefully controlled operation of the primary and secondary HVAC systems.

3. USES FOR THE PROGRAM

Because of the flexibility of its input, the DOE-2 program can be of assistance in many applications, especially the consideration of energy conserving alternatives and in building and systems design:

3.1 ENERGY CONSERVATION STUDIES

a) Effect of the thickness, order, and type of materials and orientation of exterior walls and roofs;

b) Effect of thermal storage in walls and floors and in water tanks coupled to HVAC systems;

c) Effect of occupant, lighting, and equipment schedules;

d) Effect of intentionally undersized secondary HVAC systems and central plant equipment;

e) Effect of intermittent operation, such as the shutdown of HVAC systems during the night and/or on weekends and holidays or for any hour during the day;

f) Effect of reduction in minimum outside air requirements; scheduled use of outside air for cooling;

g) Effect of internal and external shading, tinted, and reflective glass;

h) Effect of off-peak heating or cooling of buildings on peak heating or cooling electric demand;

i) Effect of load management, load deferral, and load limiting on space enviroment and on energy use.

j) Active solar collector/storage systems for heating and cooling; and

k) Heat recovery strategies to eliminate wastage of rejected heat.

3.2 BUILDING DESIGN STUDIES

a) Initial design selection of the basic elements of the building, primary and secondary HVAC systems, and energy source;

b) Evaluation, during the design stage, of specific design concepts and modifications, including optimal system zoning, optimal control strategies, and optimal systems selection;

c) Evaluation, during construction, of contractor proposals for deviations from the construction plans and specifications;

d) Monitoring the operation and maintenance of the finished building to provide the greatest return on energy investment;

e) Analysis of existing buildings for cost-effective retrofits;

f) Analysis of electric load management schemes as applied to single buildings or multi-building complexes; and

g) Comparison of loads and equipment selections using design day features versus those that result from weather tapes.

4. EXAMPLES OF APPLICATIONS OF DOE-2

DOE-2 is now being used in at least 12* countries around the world by architects, engineers, and government agencies. Unfortunately, most of the applications have been made for private firms and the proprietary results are generally not available. The studies made by researchers have been published and include such topics as the optimal combinations of glazing properties as a function of climate and the use of diesel engine driven emergency power generating system for peak shaving in buildings. Other studies have been undertaken specifically to test how well the predictions of DOE-2 compare with field measurements.

Some results of these studies are presented in Figures 2-6. Figure 2, for example, compares the measured hourly temperature in a test cell with the DOE-2 predictions using two different algorithms. With what are called custom weighting factors, it is difficult to discern any differences between the measurement and the prediction, while the other algorithm makes predictions

* These include (in addition to the United States), Austria, Canada, Chile, France, Italy, Japan, Kuwait, New Zealand, Peoples Republic of China, Singapore, and Sweden.

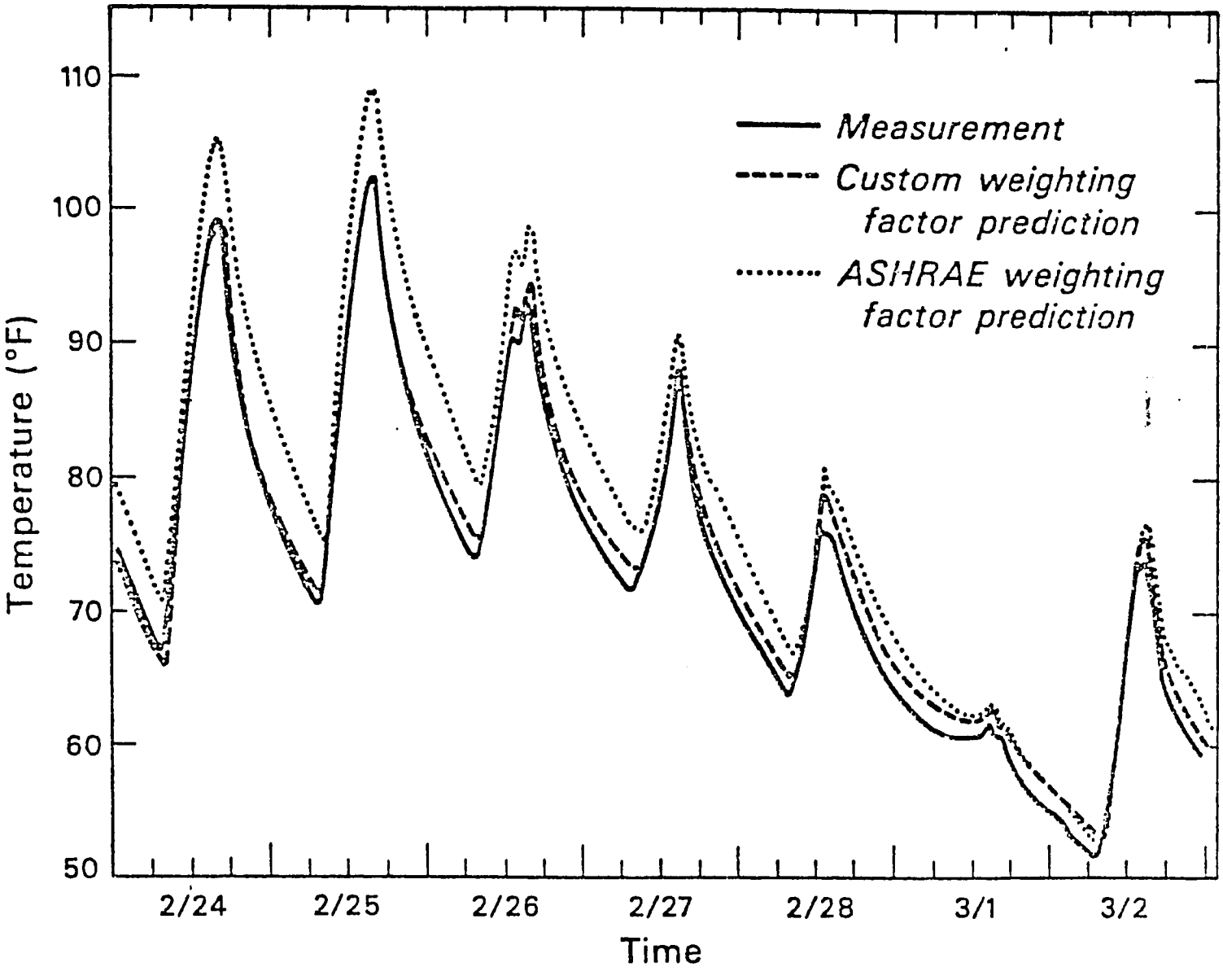


Figure 2. Los Alamos National Laboratory Test Cell Measurement Comparison with DOE-2.1 Predictions

Source: R. Curtis (1981) (see Fig. 1 citation).

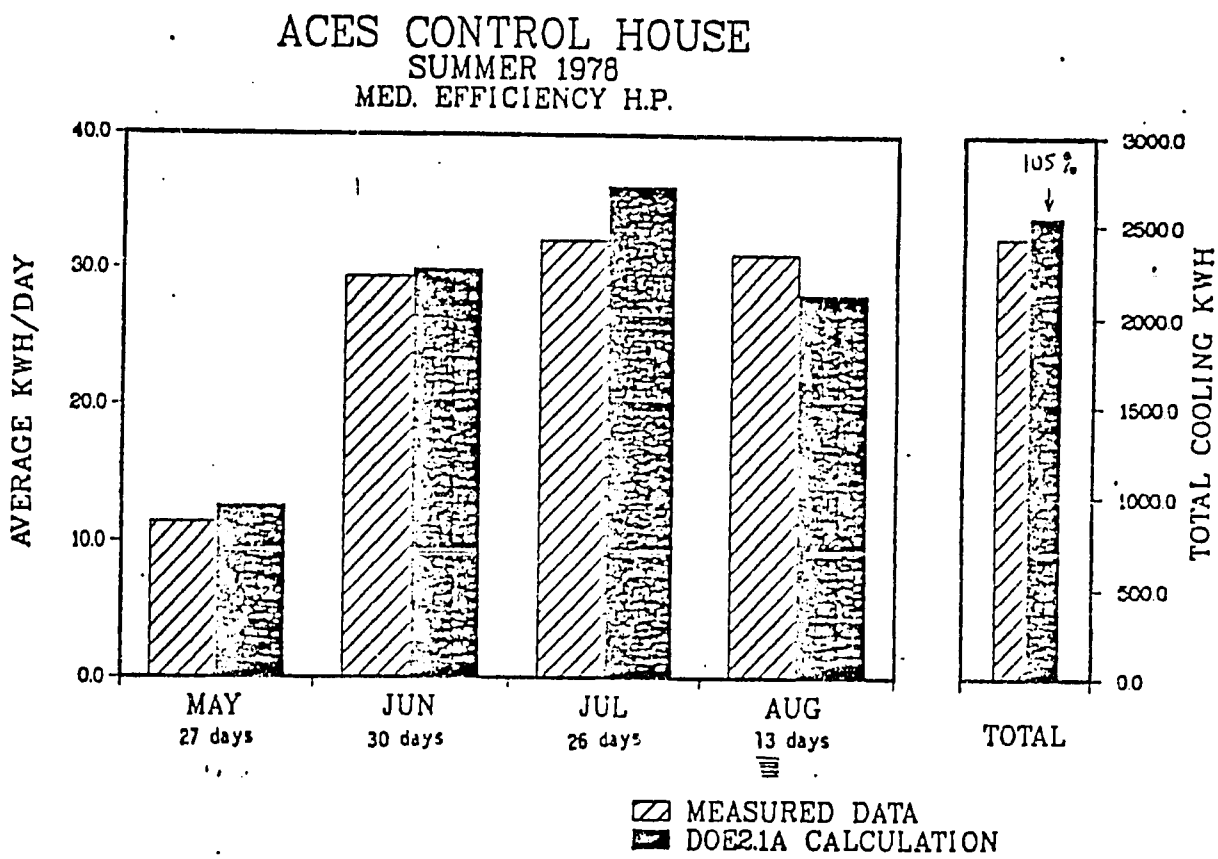
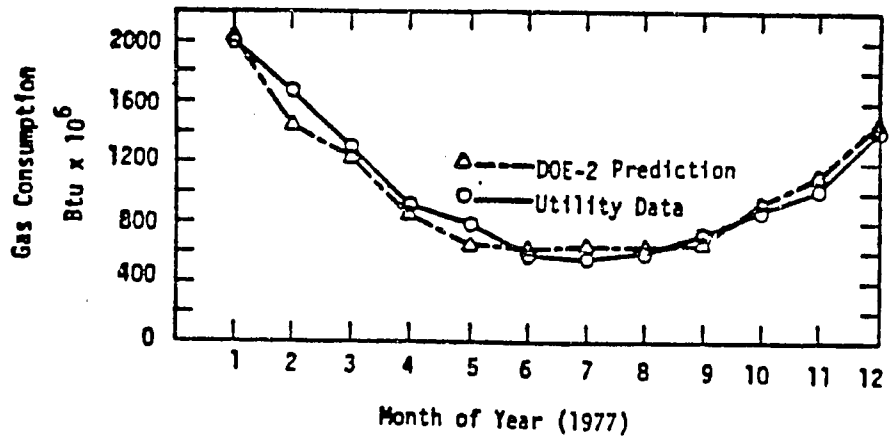
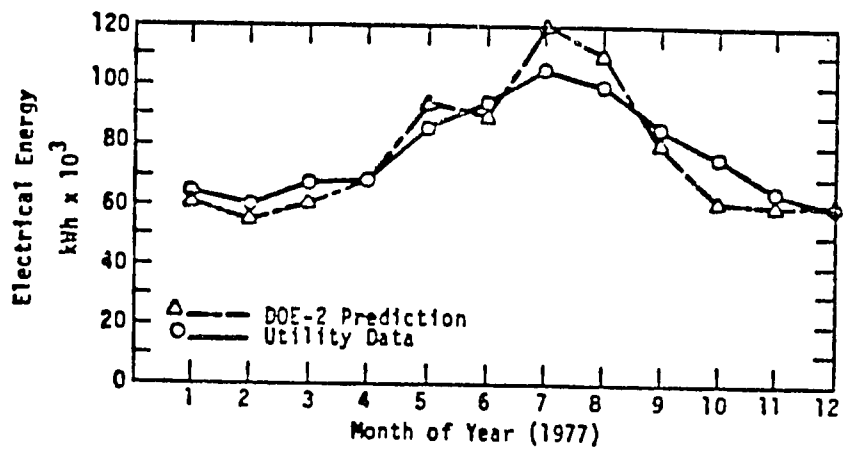


Figure 3. DOE-2 Predictions of Energy Use Compared With Measured Data for a Residual Building

Source: J. W. Michel (22 Nov. 1982) (Informal Memorandum), Oak Ridge National Laboratory.



Reference run - DOE-2 prediction versus gas utility data for restaurant.
Figure 4-a



Reference run - DOE-2 prediction versus electric utility data for restaurant.
Figure 4-b

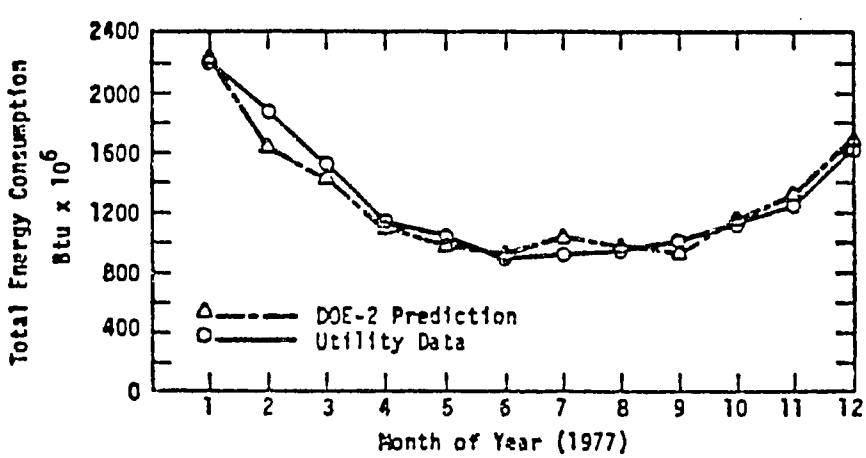


Figure 4-c

Reference run - DOE-2 prediction versus total energy utility data for restaurant.

Figure 4. DOE-2 Energy Use Predictions Compared With Actual Utility Data

Source: "DOE-2 Verification Project - Phase 1 Interim Report," Los Alamos National Laboratory Report LA-8295-MS (April 1981).

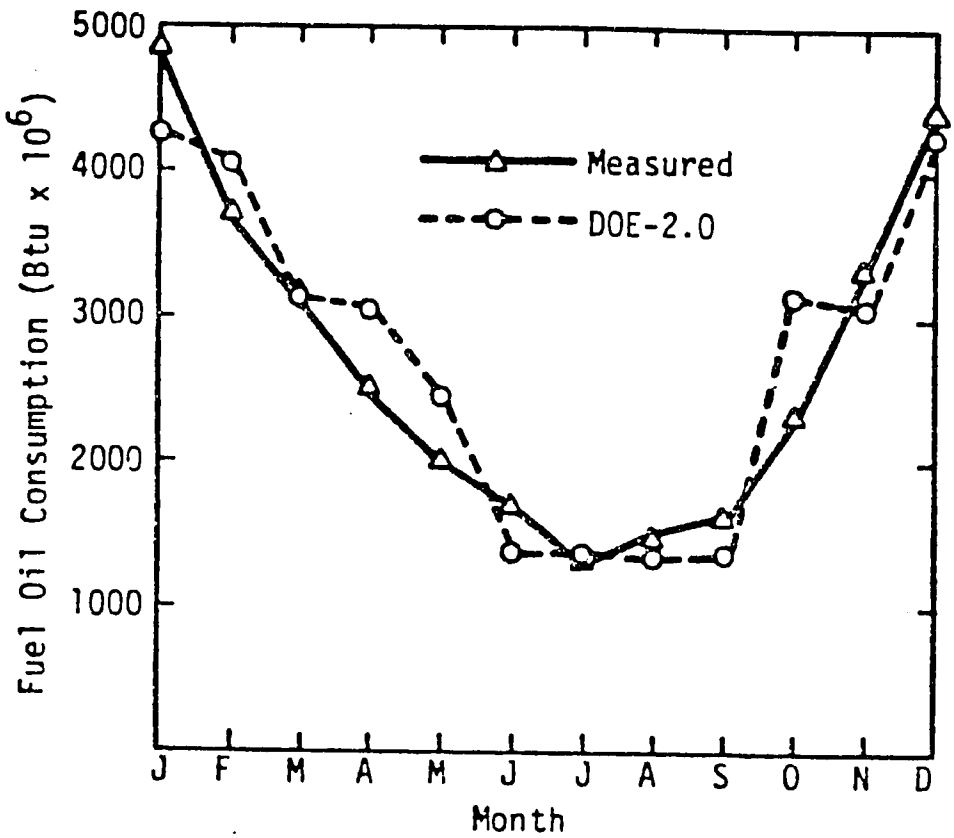


Figure 5. DOE-2 Predicted Fuel Oil Consumption - the Mariott Hotel, Boston, MA

Source: Citation for Figure 4.

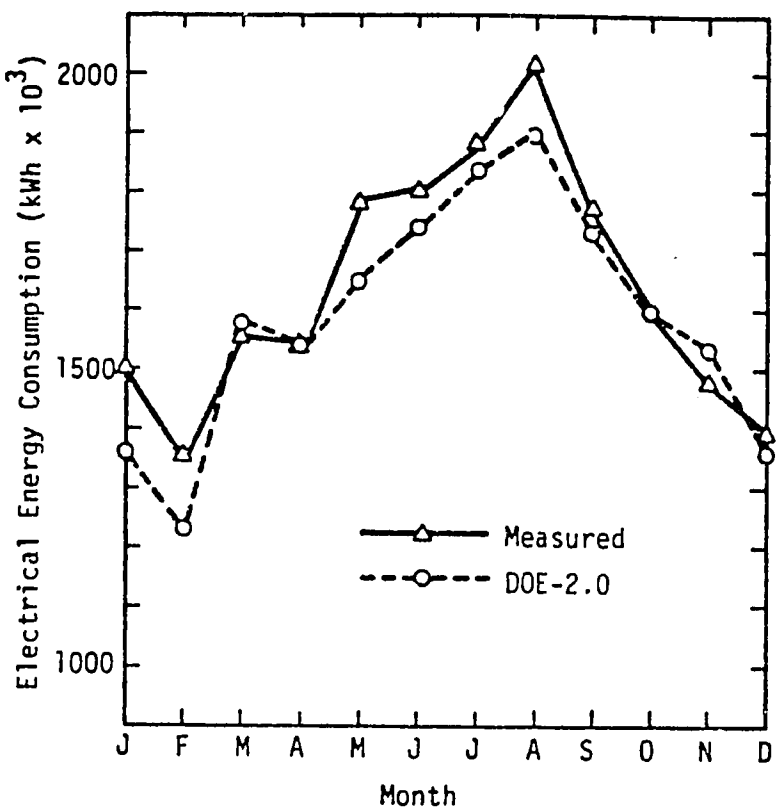


Figure 6. DOE-2 Predicted Electricity Consumption - the Mariott Hotel, Boston, MA

Source: Citation for Figure 4.

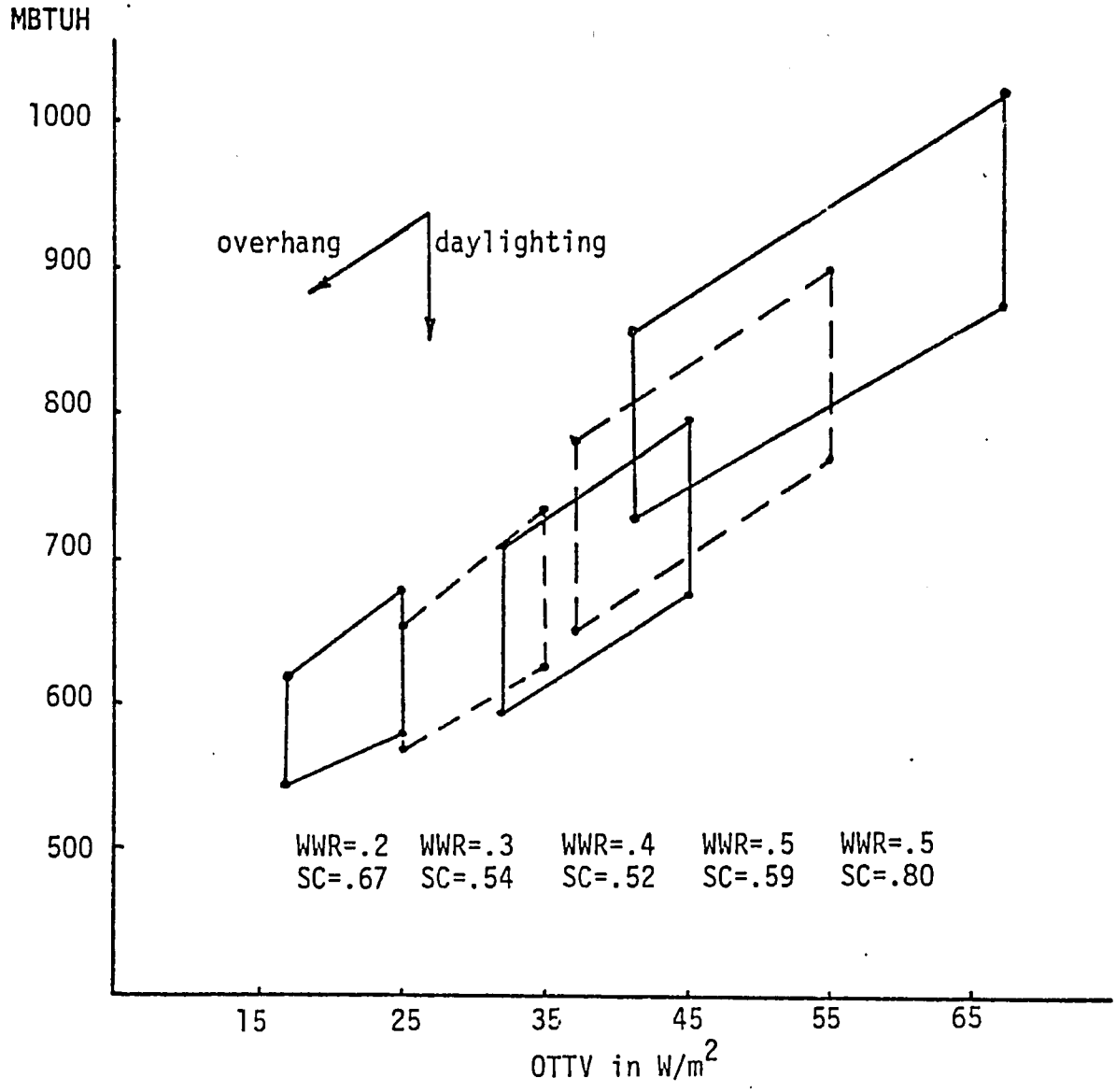
off by as much as 7°F (4°C). In comparisons with actual occupied commercial buildings DOE-2's predictions were within 15% -- quite an achievement given the poor data that exist on operating and occupant schedules. Work done by Oak Ridge National Laboratory on residential properties showed that in unoccupied homes, DOE-2 came within 1% of depicting the monthly utility bills.

What might be of especial interest here is a study in which one of us (RBC) is currently engaged in Singapore. This is an ASEAN (Association of SouthEast Asian Nations) project sponsored by USAID. The purpose of the project is to assist the Government of Singapore in the development of energy standards for buildings. As a part of that project we have been making parametric DOE-2 runs on a proto-typical office building, trying out various strategies and looking for the sensitivity of the building's net energy use to these changes.

One of the consequences of this study is the discovery by the American researchers that the climate and latitude of Singapore gives rise to building energy use considerations for which our experience in a more temperature climate and larger latitude did not prepare us. This has alerted us to the fact that energy conservation strategies are not immediately transferable from Europe and America to equatorial Africa. For example, it never occurred to us that one had to be conscious of solar heat gain through northern windows. Also, the lack of a need for heating removes a stragety for using the heat generated by air-conditioning equipment. Most unsettling was the realization that when the outside temperature does not fall below 75°F (24°C), one cannot use outside air for cooling. We have had, therefore, to look in much more detail at how energy is used in buildings on the equator and to see what was important.

What was discovered was that reducing lighting levels, both by using more efficient ballasts and lamps and by dimming lights in areas where they were not needed, made it possible to reduce building energy use by about 20%. Reducing the ventilation air quantity from 10 cfm per person (4.7 l/sec-person) to half that amount could save another 10%. Shading of windows could produce 10 to 15% savings and moving to variable volume fan systems contributed another 10%. These figures are preliminary, dependent on the building taken as the base, and represent savings taken one at a time. It is often the case that the result of two energy conservation measures is less than the sum of the effects of each one individually. The reason for this is perhaps best illustrated by an extreme example. As mentioned, reducing lighting levels will save energy. So also will reducing the size of the windows. If, however, one removes all the windows, one will not be able to see if all the lights are also turned off. A less extreme example is illustrated in Figure 7 where the energy consumption in peripheral zones is depicted with and without overhangs over the windows and with and without daylighting. If the effects were simply additive, the figures would be parallelograms.

It should be stressed again that these results may or may not be transferrable to the African environment. It is necessary to use building prototypes from this region, to take into account the change in latitude and, especially, the details of the climate. The operation of DOE-2 requires hour



(WWR = Wall-to-window ratio; SC = Shading Coefficient)

Figure 7. Energy Savings in Singapore with Overhangs and Daylighting

by hour weather data for the site being analyzed. One might guess that there are similarities between Singapore and Lome, but even here we would like to study the situation more closely.

5. POSSIBILITIES FOR AFRICA

We have earlier suggested that an ECOWAS supported research center could use the DOE-2 program to develop commercial building design manuals for West Africa. Let us now describe in a little more detail our motivation for approaching the conservation of building energy use in West Africa through such a device. As sophisticated as DOE-2 is, it has an inherent limitation. Before a building can be modeled on the computer, its configuration and detailed construction parameters must be defined. On the other hand, by that time in the design process the energy consumption of the building is already quite well determined. If buildings are to be designed to be energy efficient, the architect must be influenced before he has drawn the first line. What is required is a number of energy-conscious "rules of thumb" that the architect can use as he contemplates satisfying his clients needs.

These "rules of thumb" are necessarily climate and region dependent; what saves energy on the coast may not do so well in the highlands. Areas with dry, cool nights have possibilities that do not exist when the humidity is high. These design manuals, therefore, will be tailored to each climatic region.

What kind of things do we imagine to be in the manuals?

- Curves showing the effect on energy use of the orientation of a building.
- Diagrams showing the dependence of energy consumption on building configuration.
- Trade-offs between wall-to-window ratio and lighting requirements.
- Costs and benefits of roof insulation for various roofing types.
- Impact of building color and surface roughness on building energy use.

These are just the beginning of a long list of design issues that can affect how much energy the building will use.

By centralizing such work, a number of economies of scale could be achieved. It would not be necessary to devote scarce resources to acquiring many computers and training many duplicate staffs. Once proto-typical buildings were defined, they could be used over and over again for different climates and regions by changing the weather tapes. Perhaps at some later stage, it would be possible to use the facilities in the design stages to refine predictions of energy use for large building projects. Finally and

perhaps the most exciting facet of this suggestion, by undertaking such a project, ECOWAS could show the world how valuable such manuals could be. As far as we know, comparable projects are not yet happening anywhere else.

5.2 THE POTENTIAL OF BUILDING ELECTRICITY SYSTEMS FOR LOAD REDUCTION AND LOAD LEVELLING

Richard W. Leigh

INTRODUCTION

In a previous discussion I analyzed the cost of production of electricity as seen by the utility as a function of time of day or time of year. I stressed that there were many activities which could be undertaken at the building level to reduce the load, shave the peak load preferentially or even transfer load from on peak to off peak, and that these steps could reduce the utility load, or the rate of growth of that load, at a cost substantially below the cost to the utility of electricity from new generation capacity. I then went on to discuss two broad classes of utility actions which could realize these potential benefits: effective rate structures, such as peak load and time of day metering, on the one hand, and actions which could be taken unilaterally by the utility, such as a utility sponsored conservation effort in the customer's building, on the other. Here I return to examine a sample list of energy conservation options and to demonstrate both that there are many economically advantageous steps that can be taken to reduce electricity costs (if an adequate rate structure is in effect) and that, in many cases, the analysis can be done in an extremely simple manner.

This last point is important. Although computers and advanced mathematical techniques are valuable in energy planning on a national or utility level, most of the calculations needed to analyze energy conservation devices and techniques can be done by hand on a single sheet of paper (with the help of a calculator). I will demonstrate some of the more useful techniques below. Understanding these techniques is more important than remembering the particular examples, since any conservation idea must be analyzed for the particular application in question, using local weather data, the correct building characteristics and electric rates for the utility in question.

In the analysis of conservation options the perennial problem of financial analysis arises regularly: how is one to compare a one-time capital outlay for a conservation device with the ongoing savings which will accrue from its installation? One way is to use a detailed financial model. In the course of this workshop, some which are quite sophisticated will be discussed. These are quite appropriate to large projects where hundreds of thousands of dollars are at stake or where two projects may be tight competitors for the same scarce capital. For small projects, especially for initial screening, and for cases where the benefits are clearly overwhelming, a much simpler technique will suffice. We assume that we have taken out a five year loan to cover the total capital outlay at an interest rate that is five percent above the inflation rate. This results (1) in annual payments (including interest and repayment of principal) that amount to 23% of the capital outlay when measured in constant (non-inflating) currency of the year of purchase. We add another two percent to cover insurance and the minimal operations and maintenance expenses associated with most of the devices to be discussed, and conclude that for these analyses, the annual cost of a capital

item amounts to 25% of the capital outlay. Thus, to derive annual costs we will multiply the capital outlay by a "capital recovery factor" of 0.25; if we know how much energy a device is saving each year, then the cost of saved energy is given by:

Cost of saved energy = (0.25)x(capital outlay)/(annual energy saved). Note that this gives the cost of saved energy during the first five years of the life of the device; thereafter the savings are virtually free until the end of the technical life of the device. The cost of saved energy may be compared with the cost of purchasing the energy if the device were not installed. Note also that if you do not like the interest rate or the time period of the loan it is easy to apply the same method using your own numbers (1).

We will now apply these techniques to two of the principal consumers of electricity in the ECOWAS countries, air conditioning and lighting, and to one potential alternative source of electricity, cogeneration.

AIR CONDITIONING

In the urban areas of ECOWAS countries, air conditioning is one of the largest consumers of electricity. It is also one of the most troublesome, since the power required depends on weather conditions and so will rise and fall with the sun for an entire city at the same time, putting a severe strain on the electric utility. Thus, there are two ways in which conservation techniques can lower the cooling load and hence the electrical load: overall reduction of the annual energy consumed, which is good, and targeted reduction of the peak load, which is better. We will discuss techniques which produce each of these results.

Before we tackle specific techniques, however, a general discussion of air conditioning loads will prove useful. The heat being removed from the interior of a building to maintain a given comfort level arises from four distinct sources. First, there is solar energy which penetrates directly into the building through windows, skylights or open doors. Second, there is heat which is conducted through the walls because the sun and warm air hold the outside of the wall at a higher temperature than the inside, which is in contact with the conditioned air. Third, air which leaks into the building ("infiltrates") through cracks, open doors and windows and intentional ventilation is warmer than the inside air and must be cooled. Fourth, this same air in humid climates is laden with water which must be partially removed to assure comfort, and the condensation of this water vapor requires energy in addition to that being used to cool the air down.

Each of these mechanisms produces significant cooling loads, but they do so at different times. The solar energy will of course depend on clouds, but has an underlying regularity: on clear days it will peak up in the morning for light coming in through east facing windows, in the afternoon for west facing windows and around noon for apertures in a roof. In equatorial regions, relatively little solar energy will come directly in through south or north facing windows, especially if the roof has any overhang. The sun's maximum intensity is about one kilowatt per square meter (kW/m2) on a surface which is perpendicular to the sun's rays; Thus somewhat less than one kilo-

watt will enter a building through a one square meter west facing window late in the afternoon. If the ground around the building has a light colored surface, such as sand, reflected light can have up to 20% of the intensity of sunlight and can contribute significant amounts of energy to the cooling load; we will ignore this refinement here.

The impact of heat being conducted in through the walls will depend on both the outdoor temperature and the solar heating of the exterior walls and must be calculated on a case by case basis. Heavy masonry or adobe buildings are an important special case; for them the peak load will be considerably delayed and attenuated by their thermal mass. The load due to cooling infiltrating air once it is in the building will peak with the outdoor temperature. The electric load due to dehumidification, however, will be much more constant, since the amount of water in the air does not change greatly during the course of a day. It should be clear that lowering these different cooling loads will have decidedly different effects on the electrical load and the utility. We will consider several possibilities in turn.

Leak Stoppage

At the risk of being obvious, it is a terrible waste to air condition a space which has large amounts of outside air blowing through it. Especially for small window mounted units, a few minutes of care stopping up the leaks around the window sash, particularly those resulting from the window being locked in a half-open position, will pay for themselves in a few weeks in energy savings. A good government policy direction would be to require the inclusion of strips of foam rubber or a similar leak-stopping material in every air conditioner package. We will not attempt to quantify the possible savings here, since the effort involved can range from one minute to one hour and different people value their time very differently. The load reduction will occur both on the temperature peak for the day and more uniformly in humid climates as the dehumidification load drops. Similar savings can be realized in large central installations by ensuring that self-closing doors actually shut, that windows are not left open and that the mixing system is adjusted to admit the minimum amount of fresh air needed for adequate ventilation.

A similar situation occurs with insulation. Many older buildings having little or no insulation in the ceiling are now air conditioned, and the resultant waste of electricity is large. Foamed plastics can be applied directly to the roof from the outside, and 15 centimeters will provide excellent insulation and weatherproofing at minimal cost. In planning central air conditioning systems for new buildings, careful analysis will show that insulation levels substantially in excess of standard practice will pay for themselves in capital costs alone since the lower peak thermal load will allow a lower capacity air conditioning system to be installed at a commensurate monetary saving; subsequent savings will also result from lower energy consumption. Again, due to the wide range of needs and costs, we will not attempt to quantify these options here.

Reflective Surfaces for Windows

Thin films of plastic are available which can be mounted on the exterior surfaces of glass windows and which will reflect 50 to 90% (depending on the

type purchased) of the incident solar energy back away from the building. This will result in a substantial saving in the electricity used for air conditioning, but films with a transmittance so low that people will be led to turn on lights should not be used, since the low efficiency of the lights will lead to a larger air conditioning load than was present initially. The plastic comes with an adhesive attached and need only be cut to the size of the panes of glass and (carefully) applied. The installed cost is $10-20 per square meter (CFA 3500-7000 per square meter). The peak solar input through west (or East) facing windows will be 0.6-0.8 kW/m2 after accounting for haze, the sun's angle and dispersion resulting from the long path of the light through the atmosphere. Thus, a plastic film which transmits 25% of the incident radiation will reflect 0.45-0.6 kW/m2 and thus lower the peak thermal load by that amount.

Since a given building has an air conditioner installed in it of a given capacity, this will not affect the power demand of one building directly, but if such films are installed on a large number of buildings throughout a utility service area, the total power requirements will be lowered since each unit will come on less often, leading fewer units to be on at one time. If the average coefficient of performance (COP) of the air conditioners is 2.5, the power demand on the utility will be lowered by the above thermal loads divided by 2.5, or 0.18-0.24 kW/m2. If the utility load peaks in the late afternoon, it will find its peak load reduced by up to that amount, depending on the shape of the residual peak load and the degree of coincidence of the avoided power demand and the residual peak load. If the utility's peak is lowered significantly, it will actually need less generation capacity, or will be in a position to build additional capacity more slowly. The cost of deferring generation capacity in this way is the cost of the film per square meter divided by the avoided power demand per meter, or 40-110 $/kW (2) (15,000-39,000 CFA/kW), which compares quite favorably with the cost of new peaking capacity. Therefore, if the utility load peaks in the late afternoon, it is less expensive to the utility (and to all its customers) to install such plastic films on the west windows of air conditioned buildings at the utility's expense than it is to build the additional capacity that would otherwise be required. Since the operators of the building would enjoy substantially lower electric bills, a scheme to split the savings between the building and the utility might be most advantageous to both in the long run.

Even if the utility peak occurs early in the afternoon, so that no peak load reduction results from installation of such films, the daily energy load in kilowatt hours (kWh) will be substantially reduced, and here the same results will apply to east windows and the reflection of morning sun. A west (or east) facing window will admit 900-1300 kilowatt hours per square meter per year (kWh/m2-yr) of thermal energy; our reflective film cuts this by 75%, and dividing by our COP of 2.5 we find a saving of 270-390 kWh/m2-yr of electricity. Annualizing the capital cost of the film ($10-20/m2, above) with our 0.25 capital recovery factor (above), we find that it costs 2.5-5 $/m2-yr to have the film in place, and dividing this by the energy savings per meter, we find a cost of saved energy of 0.006-0.018 $/kWh (2.2-6.5 CFA/kWh), well below the cost of generation. If rate structures and education cannot interest customers in this kind of saving (and this may occur simply because the amount of money per customer is small) it is in the interest of all of the customers to have the utility install such reflective films for free, or for

some nominal price which will split the savings between the utility and the customers receiving the installation.

Cool Storage

Except in the most humid and cloudy of climates, cooling loads are substantially greater during the day than they are at night. Partly as a result of this, electric utilities are hardest pressed to meet loads during the day; at night, especially late at night, they can turn off all but their most efficient equipment and consequently, can charge less for electrical energy. Cool storage provides a way for a building to provide a cooled environment during the day while consuming only less expensive nighttime ("off-peak") electrical energy. If the building has a cooling system based on chilled water (the only case we will consider here) the method is extremely simple: A large, insulated tank for water is added, and (if needed) the capacity of the chillers is increased. The chillers are then run all night, cooling the tank of water down to perhaps 4-5°C. Nighttime cooling loads must be met at the same time, of course. During the day, the chillers are turned off and the building cooled by circulation of the stored cool water. The system will function much more efficiently if the tank is designed to function in a stratified mode with heavier chilled water entering and exiting at the bottom and lighter, warm water entering and exiting at the top; mixing will be suppressed by the difference in density between warm and cool water. Enhanced reliability could be an added benefit of this system in an area troubled by unreliable power if the building management also invested in sufficient back-up generation capacity to keep the circulation pumps and fans operating, but we will not pursue this option further here.

These systems are somewhat large: if the average daytime load is 10-100 kW thermal (4-40 kW electric) and we assume a 10°C temperature change in the water and that we must store water sufficient to cool the building for ten hours, we need 8,600-860,000 liters of water, which would occupy a space with linear dimensions of 2-10 meters. Such systems are, however, quite cost effective. Tankage costs 0.60-0.30 $/liter (200-100 CFA/liter) in this size range, with unit cost decreasing with increasing size. Annualized, the cost is thus 0.15-0.075 $/liter-yr (50-25 CFA/liter-yr). With a ten degree temperature drop, we can store 10000 calories per liter per day, or (for daily cycling and a COP of 2.5) 4.23 kWh/liter-yr. Dividing, we get the unit cost of storing electricity as coolness to be 0.035-.018 $/kWh (12-6 CFA-kWh) electric, much less than the normal difference between the costs of on peak and off peak power.

A new cool storage system currently under development at Brookhaven National Laboratory promises to offer more attractive economics in a smaller space by making use of the high specific heat of fusion of ice, eight times the heat storage capacity of the sensible heat stored in a ten degree temperature change. Inside an insulated, lightweight tank, small plastic bags containing pure water are immersed in a mixture of water and anti-freeze which will act as a heat exchange medium. Thus, large amounts of thermal energy can be pumped in and out of the tank by the anti-freeze solution while being stored in the heat of fusion of the pure water.

No matter what storage system is used, if additional cooling capacity is needed to cool it in the few hours available late at night, additional costs

will of course be incurred. It is unlikely that additional capacity will be needed, however, since cooling systems are normally sized to meet a generous peak load, so that they normally operate at a low load factor. Addition of the storage capability will enable the chillers to operate at higher load factors as needed to cool the storage medium.

Although cool storage does offer sufficient returns to the utility to justify installation by the utility, there is little reason to follow that route, as long as appropriate time of day electric rates can be set up. Since the system requires a certain amount of attention to operations (to make sure it has not slipped into charging itself during the day, for example), it is appropriate that those best suited to operate it (the building management) have a financial stake in efficient operation. This is assured if they are the purchasers. Conversely, none of the reasons for utility ownership outlined in the previous talk obtain; the project is big enough to merit careful assessment by the prospective purchaser, the savings will be large and clearly delineated and the technology will not intimidate the purchaser. Consequently, cool storage will stand as an example of an electricity conservation investment most appropriately evaluated and purchased by the traditional decision maker, the building management.

HIGH EFFICIENCY LIGHTING

Although the prevalence of fluorescent bulbs in many parts of West Africa indicate strong awareness of the importance of high efficiency lighting, the value of efforts in this area to utilities is worth emphasizing. A 100 Watt incandescent light bulb produces about 1700 lumens of light (an ill-defined efficiency of about 3%). A standard fluorescent light will have an output of some 60 lumens/Watt, and so will need only 30 W to produce the same output. In addition, the fluorescent will typically have a lifetime of 10000 hours, compared to the 1000 hour life of the incandescent bulb. Thus, the initial cost of the fluorescent light, $20-30, may be reduced by the cost of ten incandescent bulbs, say $10, to leave an increased capital cost for fluorescent lighting of $10-20 for 1700 lumens. But over the 10,000 hour life of the bulb it will save (100-30)x10000 W-hrs or 700 kWh, at a cost of 0.015-0.030 $/kWh (5-10 CFA/kWh). Since this is far below the cost of generating a kilowatt hour, it is advantageous to install such bulbs everywhere, and in fact this is happening. In new installations where the load is dominated by lighting requirements, for example in rural electrification projects, the installation of one 44 W fluorescent bulb in place of one 100 W incandescent represents a saving of 66 W of power capacity that the utility need not install at a cost of $10-20. This corresponds to a cost of avoided capacity of 150-300 $/kW, comparable to the cost of peaking capacity but substantially less than the cost of new baseload power. In short, fluorescent lighting will be paid for completely by the capacity savings it allows the utility, with all energy savings constituting a bonus. In new rural electrification projects, if there is any danger that the new customers would choose incandescent lighting on the basis of low first cost, the utility will find it advantageous to simply give them fluorescent lights gratis to avoid the expense of expanding capacity to supply inefficient lighting systems. Comparable considerations apply to metal arc lighting (sodium or mercury lamps) for lighting outdoor or large indoor areas where the large minimum size inherent in these devices at present is not a problem.

COGENERATION

The standard methods of producing electricity from sources of thermal energy involve the currently unavoidable loss of 60-70% of the energy content of the fuel as waste heat. Furthermore, industrial processes based on thermal inputs often use only a small fraction of the energy available due to temperature requirements; again the bulk of the energy content of the fuel may be rejected as waste. Cogeneration is a technology which attempts to overcome this waste by generating electricity at the site at which the thermal energy is being produced and consumed, thus assuring that a much larger fraction of the energy content of the fuel is put to good use.

The subject is far too broad to cover in the time available at this workshop. I will only attempt to categorize cogeneration systems, delineate some requirements for economic feasibility and give an example of a rough economic analysis suitable for establishing the desirability of further study. For projects of this magnitude, there is no alternative to detailed engineering and economic analyses for each individual project.

Cogeneration systems normally are used in applications where oil or gas is currently being burned, and they continue to burn the same fuel, albeit at higher efficiency. Systems powered by solar energy, garbage burning or coal have been demonstrated in the U.S., but only garbage burning systems have been found economic, and West Africa is probably not yet blessed with enough garbage to make them practical. It should also be noted that the range of possible system sizes is enormous, ranging from a few kilowatts to a few hundred megawatts, and may incorporate a wide variety of prime movers.

Cogeneration systems may be divided into two sorts: "topping cycles" and "bottoming cycles". Topping cycles work like ordinary electric power plants; the fuel is burned and the highest temperature energy is used to produce electricity, either by expansion of the exhaust gases in a combustion turbine or diesel engine or by producing very high pressure steam for use in a steam turbine. The exhaust gases and waste steam from this process, at temperatures ranging from 100-450°C, are then directed to the thermal demands. These could include absorption air conditioners, cleaning, food, lumber or paper processing or even refinery needs in the 350-350°C regime. A bottoming cycle is appropriate where very high temperature heat is needed (brick, cement or primary metals for example) so that the energy exhausted by that process is still at a temperature that is high enough to drive a steam turbine and produce useful quantities of electricity.

For bottoming cycle systems, the efficiency both before and after the introduction of cogeneration is extremely process-dependent. For topping cycles, if the process to which the reject heat is directed can use the thermal energy at temperatures of 150°C or below, it is generally possible to extract 30% of the energy of the fuel as electricity and 30% as thermal energy. If the process demands energy at a higher temperature, the efficiency of electricity generation will be compromised by thermodynamic limitations, but thermal efficiency may be higher. To account for the greater value of electricity, it is customery in the U.S. to measure the efficiency of a cogeneration system as

$$\text{Efficiency} = (E + TP/C)/FC$$

where E is the electricity produced, TP is the thermal energy produced and usefully consumed and FC is the energy content of the fuel consumed.

Due to the expense of moving thermal energy (in insulated hot water pipes, for example), the cogeneration system is almost always installed at or near the point of consumption of thermal energy. Also, the ratio of electricity production to thermal energy production is rigidly fixed for some technologies (diesels and backpressure turbines) and only moderately variable for others (extraction turbines). Since our goal is effective utilization of both electricity and thermal energy, careful sizing of the system is necessary. If the thermal loads are large relative to the electrical loads, supplying all the thermal energy through cogeneration is only feasible if the electricity not consumed locally can be sold to the utility. If the thermal loads are irregular, thermal storage may be needed. If the electrical loads are large, it may be prudent to size the cogeneration system to the smaller thermal loads and purchase the residual electric power requirements from the utility. It should be clear that a good working relationship with the utility is important.

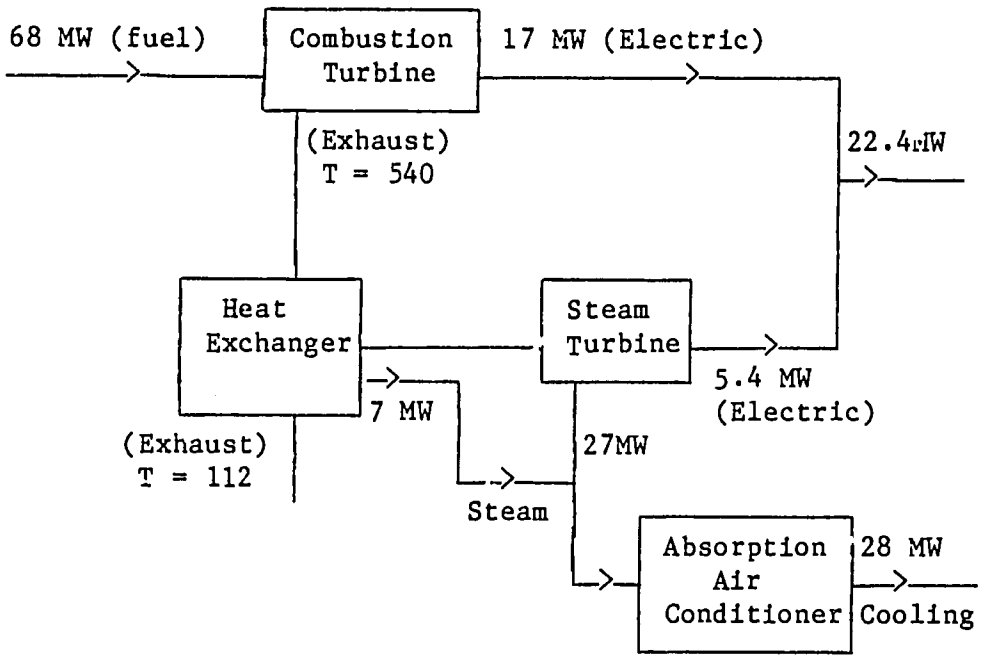
As an example of a fairly large cogeneration system, consider the configuration shown in Fig. 1a, designed around a combustion turbine, a steam turbine operating off of reject heat from the combustion turbine, and an absorption air conditioning system functioning on the heat rejected by both turbines. The fluids, fluid temperatures and steady state power ratings are shown at various points in the system. The alternative, a centrifugal chiller-based system using electric power purchased from the utility, is shown in Fig. 1b for comparison.

The efficiency of electric generation is 33%, and the cogeneration efficiency, as defined above, is

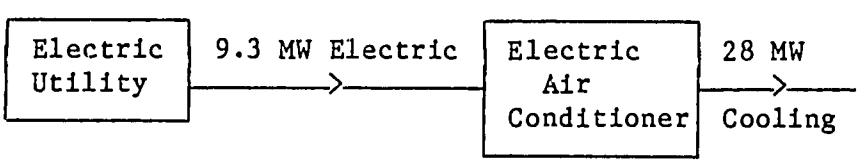
$$\text{Efficiency} = (17 + 5.4 + 34/2)68 = 0.58 = 58\%.$$

To evaluate the economics of operation in the first year, we first define the necessary economic parameters and give some exemplary values:

KxP = Total Capital (=$22.4 million @ $1000/kW)
R = Levelizing Factor (=0.20 here, to account for longer life, separate accounting of operations and maintenance; was 0.25 in earlier examples).
M = Maintenance Costs (=$0.005/kWh)
E = Electricity Produced per year (=22.4MWx8760 hours=200 million kWh)
FC = Fuel Consumed per Year
= EP/Efficiency = 3xEP
CF = Cost of Fuel (=$4.60 or $2.30/GJ, $0.0165 or $0.0082/kWh 5.8
= or 2.9 CFA/kWh; derived from $28/barrel for oil or one half that for gas.)
EF = Electricity Consumed in Alternative Electric Air Conditioner (=9.3 MWx8760 hours=81 million kWh per year)



(a) Cogeneration System



(b) Conventional System

Figure 1
Comparison of Cogeneration and Conventional Utility Systems for Large Air Conditioning Loads

VE = Value per kWh of electricity sold to utility.
CE = Cost per kWh of electricity purchased from utility.

We will ignore electric consumption by the facility other than that used for air conditioning in the conventional system, assuming that power for lights and internal use is purchased from the utility in both cases. In the case of the cogeneration, then, all electric power produced is sold to the utility. This is one form of accounting used in cogeneration systems; it is called "arbitrage". Whether it is advantageous or whether the cogenerator would choose to meet his or her own needs for electricity and sell only the excess to the utility, buying only such power as could not be provided internally ("net buy/sell") will depend on VE and CE and on knowledge of the cogenerator's demand for power. This option is one of many which we must leave out now but which must be addressed in the evaluation of actual proposals for cogeneration systems.

The total benefits, B, of operating the cogeneration system will be the income from the sale of electricity minus the costs of operating the system plus the savings accruing from not operating the conventional system. We assume the capital costs of the absorption and electric air conditioners roughly balance each other, and find

$$B = ExVE - KxPxR - 3xExCF - ExM + ECxCE$$
$$= Ex(VE - 3xCF - M) + ECx(CE/VE)xVE - KxPxR.$$

Figure 2 shows B as a function of the value of electricity, VE, for the two parametric fuel costs listed above, and for CE/VE=0.8, 1.0 and 1.2. It should be clear from Fig. 2 that the value of the cogeneration system depends quite strongly on VE, what the utility will pay for electricity, on CE, the cost of purchased electricity, and on the price of fuel. Regions where natural gas is now being flared are prime candidates for these technologies, and the lower fuel price was chosen to indicate the favorable economics that inexpensive fuel would make possible.

Cogeneration can be an economic and socially attractive conservation measure but as the above discussion should indicate, it is complex to evaluate. In addition to the factors discussed above, a variety of points must be considered. Among these are:

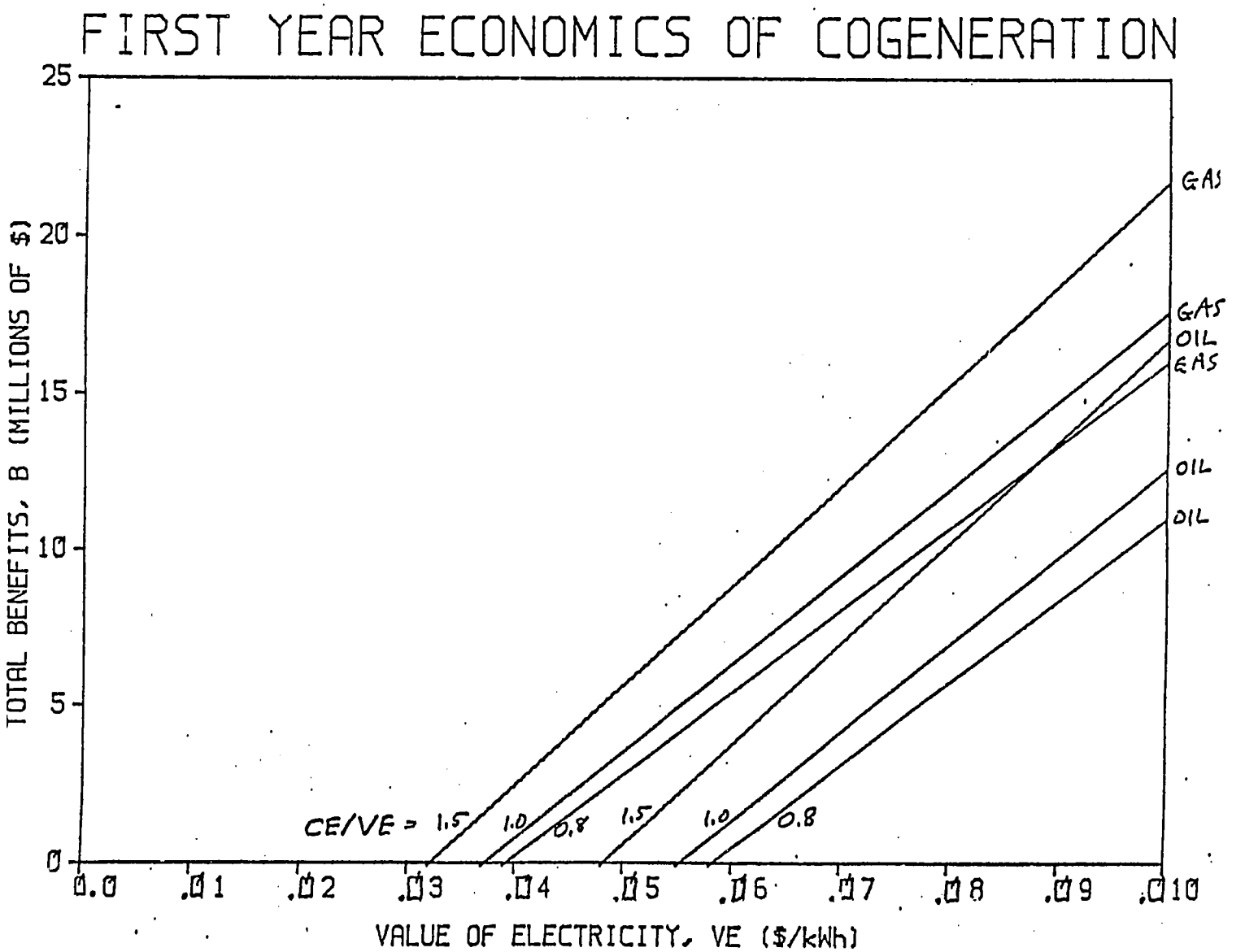
- Load factors (we have assumed the machines run 100% of the time; in fact, they will not.)

- Variations in thermal load; the need for load following operation, thermal storage or other controls.

- Financing methods

- Establishing the value of electricity to the utility; should average or marginal costs be used?

- Environmental impacts: Many cogeneration technologies produce more pollutants than do standard electric generation technologies.


FIRST YEAR ECONOMICS OF COGENERATION
TOTAL BENEFITS, B (MILLIONS OF $)
25
20
15
10
5
0
0.0
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
VALUE OF ELECTRICITY, VE ($/kWh)
GAS
GAS
OIL
GAS
OIL
OIL
CE/VE = 1.5
1.0
0.8
1.5
1.0
0.8

Discussion of many of these questions can be found in the bibliographic references.

FOOTNOTES

1) The capital recovery factor is given by

$$CRF = P/C = I/[1 - 1/(1 + I)^{**}N] + D$$

where C is the total capital required, P is the payment per year (or other uniform period), D is the insurance and operations and maintenance cost per year, I is the interest per year, N is the number of years and "**" indicates exponentiation, raising (1+I) to the power N. For our example, I = 0.05, N = 5 and D = 0.02.

2) In computing a range of values such as 40-110 $/kW, I will always present the widest range possible for a given set of inputs. For this example, the low end, 40 $/kW, is the quotient of 10 $/m^2 (the smaller price) and 0.24 kW/m^2 (the larger power), while the upper end of the range is the quotient of the larger price and the smaller power.

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2) Solar Products Specifications Guide, SolarVision Inc., Church Hill, Harrisville, NH, 03405, U.S.A. (This annual publication is a compendium of manufacturer's specifications for a wide range of solar and conservation equipment.)

3) Energy Users News, Fairchild Publications, 7 East 12th St. New York, NY, 10003. (A weekly newspaper for energy managers and professionals, contains very up-to-date information on conservation technologies for large facilities.)

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SECTION 6

THE TRANSPORTATION SECTOR

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6.1 TRANSPORTATION/ENERGY ANALYSIS — PRINCIPLES AND PRACTICE

T. O. Carroll

1 INTRODUCTION

Almost without exception, energy earmarked for transportation equals or exceeds energy consumed by any other sector of the economy of developing countries. Moreover, transportation equipment almost invariably utilizes higher priced fuels, such as lighter distillates--gasoline or diesel. Thus, both the high level of demand from the transportation sector and the types of fuel demanded aggravate the balance of payments problem for the oil-importing developing country.

The energy requirements for transportation increase rapidly with economic development.[1] In fact, demand for both passenger and freight transportation tends to increase in greater proportion to that of the overall economic growth.

Attempts have been made in many developing countries to control this expansion of energy use in transportation. Some countries use import barriers and/or higher gasoline prices to constrain demand for travel. Others have, through combinations of import tariff and pricing, encouraged a shift to more energy-efficient diesel or, as in Brazil, alcohol. Odd-even driving day practices are in effect in Lagos and Caracas. Such individual policy measures do limit energy utilization in the transportation sector somewhat. However, it is imperative that the extensive set of linkages between the physical and economic characteristics of a nation and its transport infrastructure be understood before effective overall strategies can be formulated.

2 CHARACTERISTICS OF TRANSPORTATION IN THE DEVELOPING COUNTRIES

Though per capita vehicle ownership in the developing world remains much less than that of the developed countries, the density of vehicles (vehicles per km of paved road) is comparable all over the globe (see Table 1).[2] Motorized transport in the LDCs serves predominantly urban areas. Thus, while typically only 20% of the population in a developing country resides in or around a city (the corresponding figure for developed countries is 60-80%), the overall magnitude of the problems accruing from urban motor congestion are similar in both the developed and developing worlds. For proof, one need only observe the congestion that plagues such cities as Tokyo, Nairobi, Mexico City, and New York City.

Meanwhile, car registrations have outgrown road building in the developing world by a factor of one-half during the past 10-15 years.[3] Consequently, it would seem likely that the problems associated with the movement of larger numbers of vehicles over limited roadways are likely to become even more severe in the future. Low developing country per capita income presently restrains automobile ownership (see, for example, Figure 1), but by the

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Table 1
Characteristics of Transportation

		1960	1975	%
Developing Countries	Cars	3,106,000	13,614,000	338
	Truck	2,373,000	5,750,000	142
	Total Fleet	5,479,000	19,364,000	254
	km of paved roads	166,852	457,586	174
	veh/km of paved road	32.8	42.3	
	vehs/1000 inhabitants		12.8	
Developed Countries (Europe, Japan, USA)	Total Fleet	107,825,000	268,842,000	150
	km of paved roads	2,077,390	6,042,970	190
	veh/km of paved road	51.9	44.5	
	vehs/1000 inhabitants		349.5	

Source: International Road Federation (IRF).

Table 2
Growth of Population and Automobiles in Selected Cities Annual Rate of Growth 1960-70

City	Population %	Automobiles %	City	Population %	Automobiles %
Abidjan	11.0	12.7	Istanbul	6.0	12.2
Seoul[1]	8.5	22.0	Mexico City[3]	5.8	10.5
Lagos[2]	7.9	15.5	Bombay	3.7	8.2
Kuala Lumpur	6.5	11.3	Singapore[4]	2.6	6.7
Bangkok	6.2	12.0	Buenos Aires[5]	2.4	12.1

Note: The data for this sector are generally weak and not closely comparable
[1]Figures for 1961-70.
[2]Figures for 1964-69.
[3]Figures for 1962-71.
[4]Figures for 1966-71.
[5]Figures for 1968-69.

Source: Annex 2.

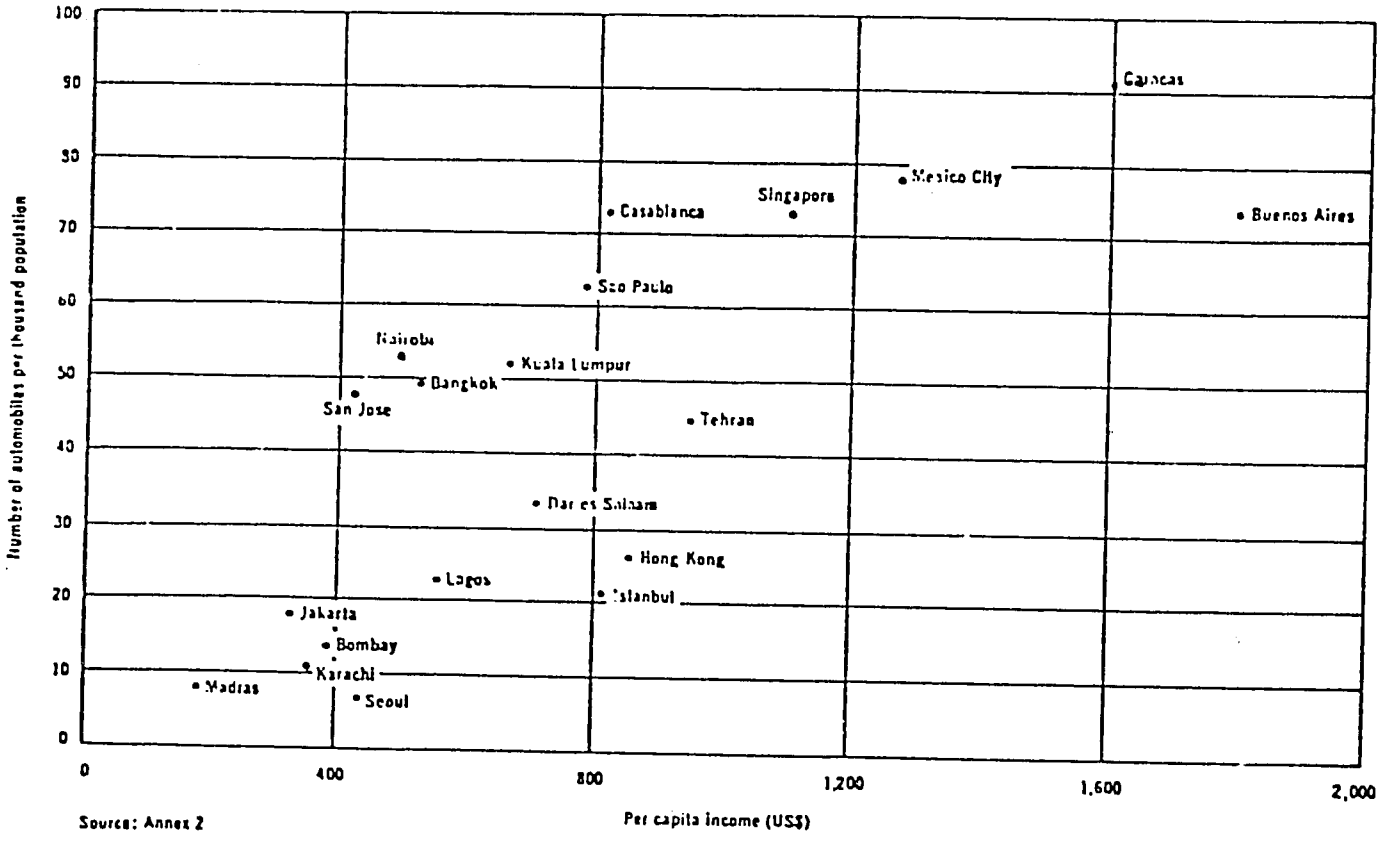

Figure 1. Automobile Numbers and Income Levels

same token, a hike in incomes would bring the automobile within the grasp of greater numbers of people. Indeed, the data in Table 2 show the growth rates for auto registrations in selected cities are nearly double that of population growth.

Freight transportation (ton-mi per GNP) appears closely tied to economic structure. Bolivia, for example, with its lead exports and petroleum industry shows a transport intensity of 6.8 ton-mi per GNP, while Israel, an agricultural nation, registers 0.5 ton-mi per GNP.[4] Additionally, freight intensity seems to increase only slowly with time. In Korea, for example, freight travel demand increased from 1.2 in 1960 to only 1.6 in 1974. Regardless, even with constant intensity, freight traffic grows in proportion to GNP, exacerbating further the problems of congestion, particularly in urban areas.

3 VEHICLES AND MODES OF TRANSPORTATION

The energy intensity of alternative modes of travel widely varies. Because of its obvious influence on energy consumption at the national level, we will now examine some of the characteristics of the spectrum of vehicles available to meet passenger and freight travel demand in the LDCs.

Table 3
Transport/Energy Efficiency

Energy Efficiency			Time-Energy Efficiency	
Mode	Pass-Mi/Gal	Mode	Mi/Hr	(Pass-Mi / Hr) (Miles / Gallon)
Commuter Train	120	Jumbo Jet	400	11200
Motorcycle	110	Jet	400	8000
Volkswagen	58	Corp Jet	300	4500
Bus (Urban)	40	Commuter Train	30	3600
Auto (General)	35	Motorcycle	30	3300
Taxi	32	Volkswagen	30	1740
Jumbo Jet	28	Auto (General)	30	1050
Jet	20	Train (Intercity)	50	850
Train (Intercity)	17	Helicopter	60	480
Liner	15	Taxi	15	480
Corp Jet	15	Bus (Urban)	10	400
Auto (Urban)	10	Auto (Urban)	20	200
Helicopter	8	Liner	10	150
Yacht	6	Yacht	15	90

Source: T.O. Carroll and E. Udell "Solar Energy, Land Use, and Urban Form" in R. Burchell and D. Listokin Energy and Land Use (Rutgers University Press, New Jersey, 1982).

3.1 PASSENGER MOVEMENT

The transport/energy efficiency (passenger-km output per kilojoule input) for modes of passenger transport is shown in Table 3.[7] The parameters will vary somewhat for different countries because individual vehicle characteristics differ, and vehicle performance is dependent upon the setting of each country. The commuter rail or metro is, of course, the most transport/energy efficient mode. However, it is also the most capital-intensive of passenger transport systems and the least flexible in adapting to the changing patterns of land use and industrial activity that accompany development. The automobile, on the other hand, is by far the most common means of transport in most countries, providing almost unlimited ability for point-to-point travel.

Fuel consumption is a function of average speed. For example, the U.S. auto fleet is designed to maximize efficiency in the 30-50 mile per hour range, as shown in Figure 2.[8] Above this speed, air drag and rolling resistance lower fuel economy. At average speeds near 10 miles per hour, which are common in urban areas, the stop-and-go movement of traffic degrades fuel economy. More alarming is the relationship between average speed and unit cost of vehicle operation at lower average speeds. In Figure 3, the cost of mini-bus or bus service is generally well below that of automobile travel.[9] However, at average speeds common in the inner districts of urban centers, the operating costs of bus service can exceed the cost of auto operation. Thus, in addition to being a less flexible and less convenient form of trav-

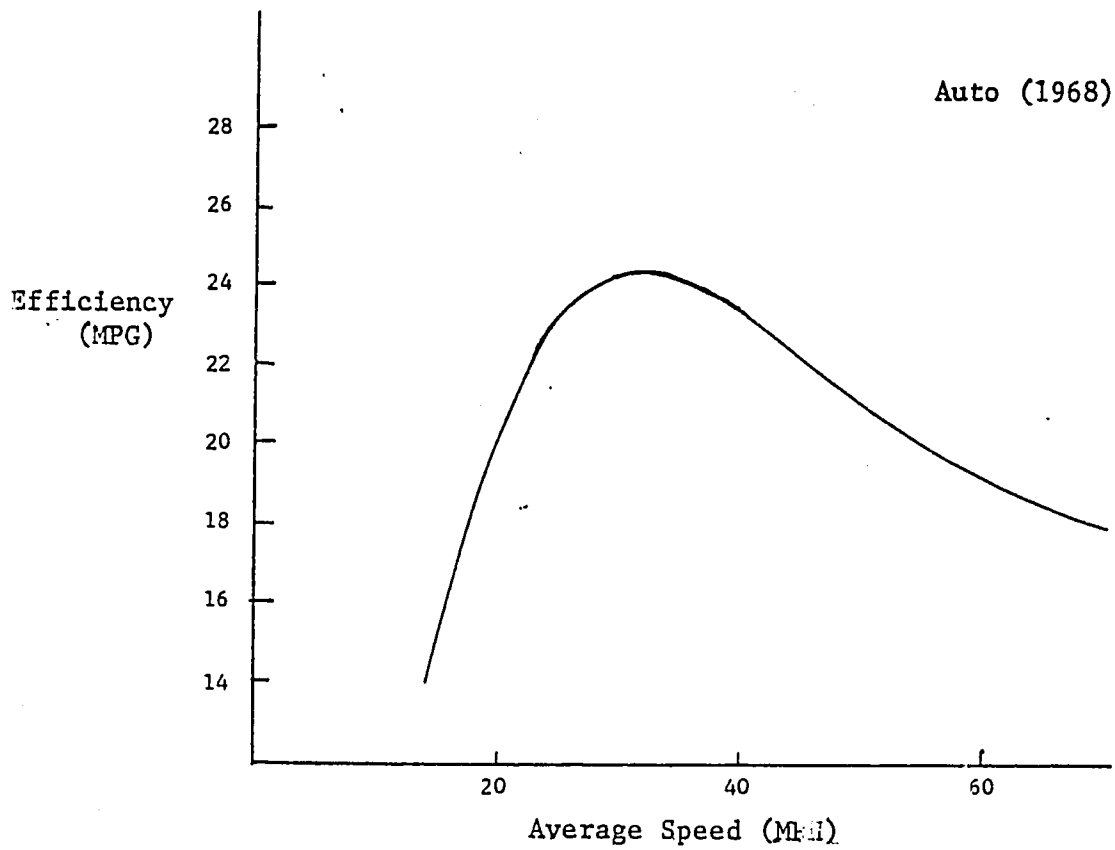

Figure 2. Automobile Efficiency vs. Average Speed

Source: R. B. Sawhill et al. "Vehicle Characteristics of Fuel and Travel Time on Urban Arterials and Freeways." Forty-ninth Annual Meeting (United States Transportation Research Board).

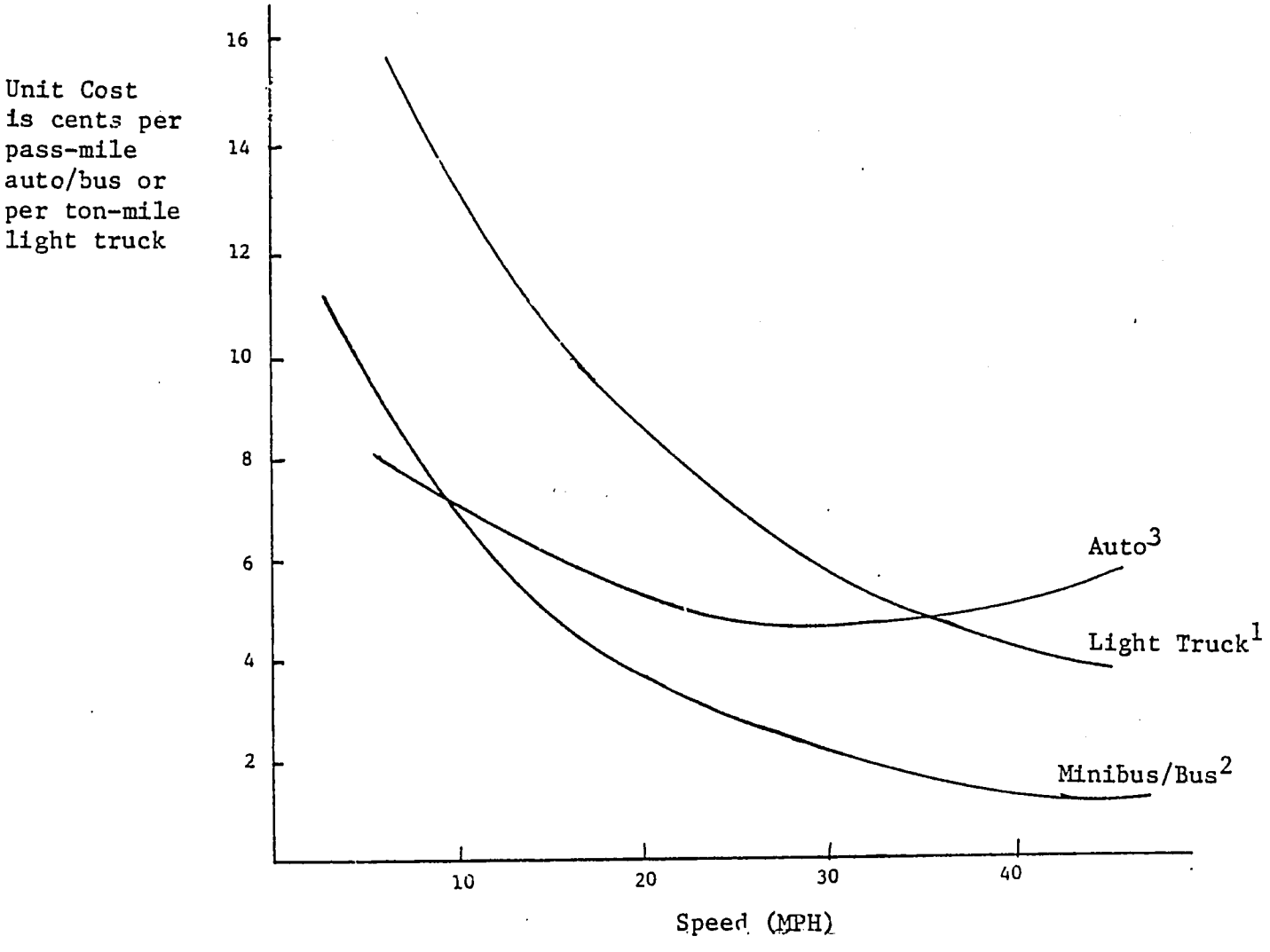

Figure 3. Operating Costs vs. Average Speed

[1]Assumes 5 ton gross weight.
[2]Assumes 22 passenger/40 passenger minibus/bus, respectively at 70 percent capacity.
[3]Assumes average occupancy of 2.

Source: Adopted from Wilbur Smith and Associates, "Singapore Mass Transit Study" (1974).

el, buses, at lower average speeds, lose their comparative cost advantage over the automobile as well.

Average speed of travel is an important element of modal choice.[10] We often find people driving their cars in urban areas despite the obvious energy inefficiency in doing so. The energy ranking of modes of travel in Table 3 would seem to suggest trains and buses are greatly preferred to automobiles when, in actuality, this is a highly inaccurate portrayal of current use. If estimated vehicle speeds are factored in, we obtain a measure of rapidity of travel (pass-km/hour) and energy efficiency (km per liter) for each mode of transit that correlates closely with present usage.[11] Our "time-energy efficiency" now ranks modes according to distance traveled, number of people moved, rate of travel, and fuel economy. The resulting similarity between real and formulated rankings emphasizes the implicit economic value of time and its importance in transportation planning.

3.2 FREIGHT MOVEMENT

The comparative transport/energy efficiency of freight transport modes is shown in Table 4.[12] The range of values here is great because, more so than passenger modes, the types and performance of freight vehicles are dependent upon such local conditions as terrain, traffic conditions, materials shipped, and average loads. Although the relative advantage of rail and water transport over truck and air transport is clear, taking advantage of these more energy efficient modes requires that large volumes be carried. However, aside from the movement of selected mineral or energy resources, the production, distribution, and use of goods in developing countries involves transporting small loads over large areas. Given these conditions, it is not surprising that road transport is the most rapidly growing component of freight movement in developing countries.

Road freight exhibits scale economies, as shown in Figure 4. Most significant is the fact that, for the same vehicle weight, diesel engines are 30 percent more efficient than gasoline engines.[13] However, since, as seen in Table 4, energy cost as a percentage of total cost of freight movement is not large, higher prices for petroleum fuel have not had substantial impact on this transport sector.

Table 4
Freight Energy Efficiency

	Ton-miles/million Btu	Energy Cost/Total Cost
Pipeline	540 - 6000	0.7 - 0.8
Water	620 - 2000	n.a.
Rail	620 - 3300	0.08 - 0.12
Truck	150 - 900	0.1 - 0.2
Air	15 - 130	0.3 - 0.4

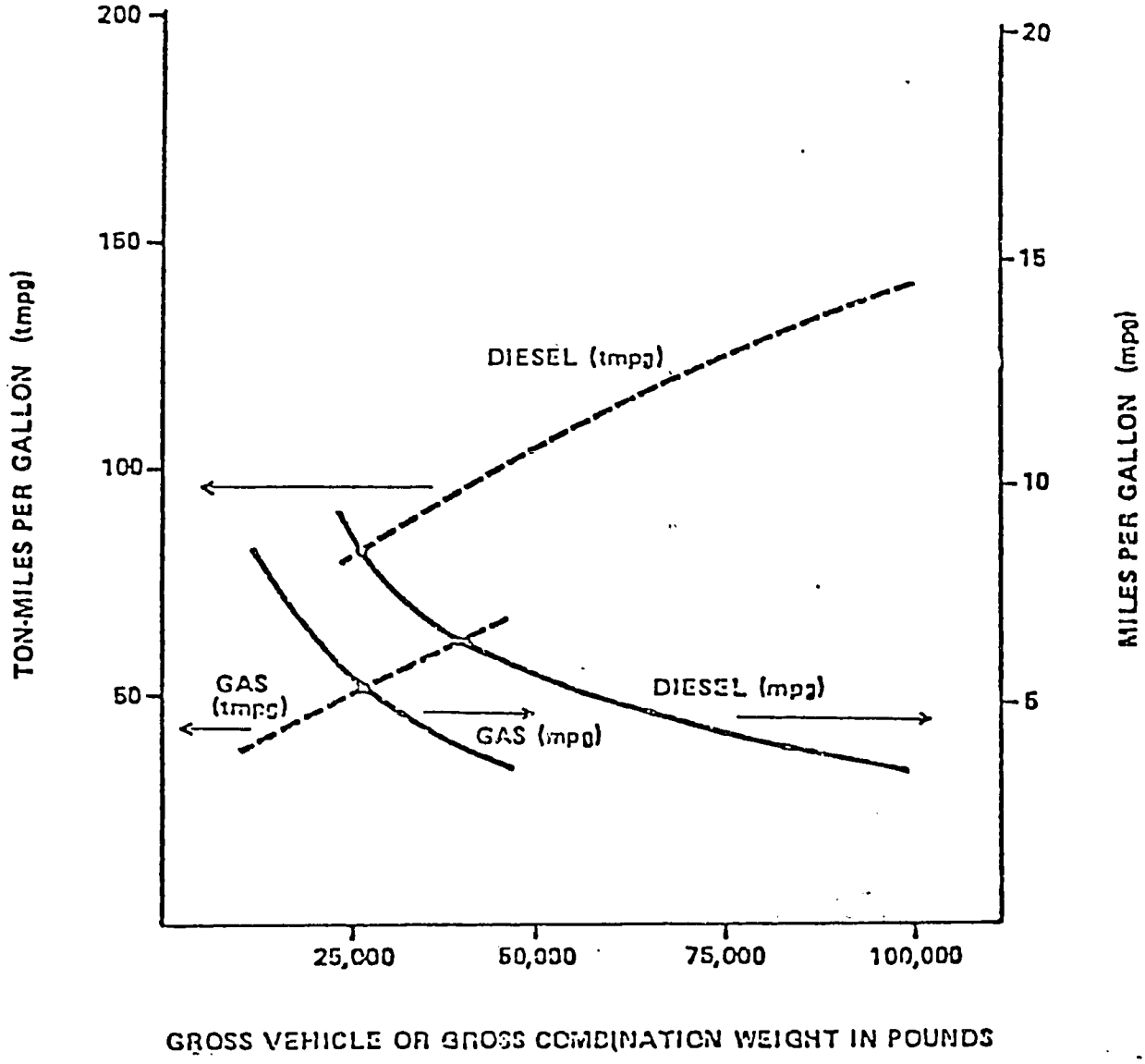

Figure 4. Fuel Efficiency vs. Gross Vehicle Weight

Source: U.S. Department of Transportation et al., Interagency Study of Post-1980 Goals for Commercial Motor Vehicles, Executive Summary, Washington, D.C., July 1976, p. 6.

5 ENERGY USE FOR TRANSPORTATION

There are two approaches to the analysis of energy demand in the transportation sector. The first is based on using "elasticity" of demand; the second involves evaluating specific "policy planning" interventions. Each has insights to offer, and we will compare and suggest how these should be used in conjunction with a national energy assessment.

The "elasticity" approach is a relatively simple concept. It is based on an explicit analytical relationship between fuel consumption E (in liters) on the one hand, and gasoline price, per capita national income, and perhaps other parameters on the other. Their relationship is written in the form:

$$E = k\ P^a Y^b \tag{1}$$

where k is a constant, P is the price of gasoline, and Y is per capita income.

The elasticity approach possesses a certain elegance of simplicity but falters when applied to actual situations in developing countries. The concept, of course, is based upon a statistical analysis of the past. The strong assumption must be made, therefore, that future behavioral patterns will mirror those of previous years. But, in developing countries, conditions which determine travel behavior can change rapidly, and the fragile infrastructure is much less absorbent. For example, sharp increases in the price of gasoline have prompted the exceedingly swift introduction of diesel passenger vehicles (diesel fuel is heavily subsidized because of its use in agriculture) in many LDCs. As a result, extrapolating future transportation behavior on the basis of past actions is a very inexact business.

The "policy/planning" approach relies upon separate estimates for travel demand (measured in passenger-kilometers or tonne-kilometers) and for the energy efficiency of particular transport vehicles (measured in passenger-km or tonne-km per liter). In this sense, the policy planning approach enjoys an advantage over the elasticity approach, in that it is based on data generally available to developing countries. Fuel consumption is expressed as:

$$E = \sum_m \frac{D_m}{e_m} \tag{2}$$

Where D_m is travel demand for mode "m" (passenger-km or tonne-km) and e_m is the fuel specific transport/energy efficiency (passenger-km or tonne-km per liter) of that mode. Because there is, in this approach, a separation of travel demand and vehicle energy intensity, consideration can be given to a range of policy options appropriate to the situation found in many developing countries. The case study later in this paper will provide such examples.

It should be emphasized that, for the purposes of government decision-making, it is often the relative impact of alternative policies rather than their exact results which is crucial. Thus, while overall estimates of pass-km or tonne-km moved may be less than precise, the impact of various policies on fuel consumption can be weighed against each other with some confidence.

6 POTENTIAL ENERGY SAVINGS IN TRANSPORT

A Word Bank estimate of potential energy savings in transport is found in Table 5.[14] While only small savings could be obtained through curtailment

Table 5
Developing Countries: Potential Fuel Savings in Transport Sector, 1980s

(Savings as percentage of sector's energy consumption)

	Share of Sectoral Consumption	Savings From				
		Vehicle Efficiency	Regulatory Measures	Better Use	Demand Reduction	Cumulative
Trucks	35 - 45	6	2	10	5	23
Buses	8 - 12	2	(.)	5	(.)	7
Private cars	25 - 35	20	2	2	5	29
Shipping	5 - 10	2	5	5	(.)	12
Air	5 - 10	20	5	5	(.)	30
Rail	2 - 5	1	(.)	5	(.)	6

(.) Less than half the unit shown.

Source: World Bank staff estimates.

or travel reduction, technical and regulatory measures could reduce automobile and truck fuel consumption by 20-30%. Automobile fuel efficiency, which is expected to continue to rise over the next decade, could be capitalized on by developing countries through high import tariffs, hiking the price of gasoline, or the imposition of graduated annual registration fees which discriminate against automobiles with large displacement engines. In Korea, for example, a strong government program combining a steep increase in gasoline prices, higher import taxes on cars and spare parts, and regulations raising the cost of locally produced cars and trucks reduced energy consumption by 45% between 1973 and 1975.

The technical efficiency of trucks is not expected to keep pace with that of automobiles. However, there are large, though potentially difficult to realize, savings to be gained from changes in trucking operations. More efficient scheduling of pickup and delivery, increased back-hauling, and the use of more fully-loaded large trucks in place of frequent small loads would conserve fuel, but also require coordinated action from fleet operators and individual owner-drivers, as well as shippers. Unfortunately, while Table 5 indicates 10% fuel savings to be gained, there are as yet no documented examples of such results.

Shifting passenger travel from automobile to bus can, in many cases, provide travel at 3-4 times the fuel efficiency per passenger-kilometer. However, the provision of alternative transportation services requires care. Bus routes must be chosen close to desired origins and destinations, and, as noted above, must not critically add to travel time. The same may be said for any shift of truck traffic to rail. The Brazilian revitalization of rail

service, which included roll-on/roll-off equipment, has not met with great success. But in India, improved railroads now carry 90% of freight traffic.

Other travel modes are also responsive to conservation measures. Jet aircraft engines have been redesigned in recent years. Even ships have changed operating speeds, and sometimes fuel mix, to achieve energy savings. But, since the consumption shares of such modes are usually small when measured against overall national energy use for transportation, the corresponding savings gained are generally not significant.

MODULE A2. TRANSPORTATION ENERGY CASE STUDY

1 INTRODUCTION

This case study, from the Dominican Republic, illustrates the principles and practices involved in developing country transportation energy analysis. Approximately one-tenth of this Caribbean nation's 10 million inhabitants live in the Santo Domingo metropolitan area, and the congestion resulting from the automobile, publico (taxi), and autobus traffic is as thick as any other urban center in the world. Rapidly increasing oil imports and their effect on the national balance of payments lie at the heart of the energy problem in the Dominican Republic. In 1980, Dominican oil imports amounted to more than 500 million U.S.$ in foreign exchange, or more than 40% of foreign exchange earnings. An estimated 30% of the 1,000 KBOE of oil is consumed by passenger and freight transportation.

A steep increase in diesel (gasoil) fuel demand is expected as a result of continued substitution of diesel-powered for gasoline-fueled vehicles (particularly in inter-urban transport services), and because of the expanding diesel truck fleet. Additionally, diesel minibuses are being introduced into the mass transportation fleet, until now dominated by "publicos" (taxis) (as seen in Figure 2). Registration of large diesel trucks used in distribution have increased steadily as demand for agricultural and manufactured goods has risen.

2 TRANSPORTATION ENERGY AUDIT

The Transportation Energy Audit for the Dominican Republic is shown in Table 1. National energy consumption estimates require the specific parameters shown for passenger and freight traffic. In each case, we determine a) the number of vehicles and, where significant, the breakdown into gasoline and diesel-powered vehicles; b) fuel efficiency expressed in kilometers per liter; and c) each travel mode's annual fuel consumption rate. It should be noted that information needed for the transportation energy audit is rarely found in one agency or source, may indeed be entirely unavailable, and/or sometimes appears in a form difficult to incorporate into the audit. Naturally, the best field conditions are where transportation studies have recently been undertaken.

In the Dominican Republic, the numbers of autobuses, average occupancy, and fuel consumption are obtained from the agencies noted, but not the distance traveled. In principle, a set of three parameters in the transportation energy audit can be used to calculate the fourth (that is, using the columns in Table 1, (1) x (3)/(4) = (5)). This was done as shown in footnote C. Similarly, some judgment was necessary concerning the fuel consumption of publicos to complete the energy audit in Table 1.

Table 1. Transportation Energy Audit (1980)

Metropolitan Santo Domingo Passenger	#Vehicles[1]	Cap/occup.[7]	Distance Traveled	Fuel Eff.	Fuel Consumption[4]
private	42000	5/1.3	17000 km/veh-yr[a]	35 km/gal[5]	20 million gal/yr[11]
publico (taxi)	7600[2]	5/3	60000 km/veh-yr[b]	30 km/gal[b]	5000 gal/dy for 3800 vehicles daily
minibus	0[3]	22/13	60000 km/veh-yr	20 km/gal[12]	Ind. est. 14 gal/veh
autobus	450	30/18	60000 km/veh-yr[c]	12 km/gal	5000 gal/dy for 300 vehicles daily[6]

Nationwide Freight	#Vehicles[1]	Cap/Loading	Distance Traveled	Fuel Eff.	Fuel Consumption
camionetas (small trucks)	26600	n.a./1.5 tonne	24000 km/veh-yr[9]	30 km/gal[9]	n.a.
large trucks	15500	10 tonne/2 tonne	35000 km-veh-yr[8]	15 km/gal[8]	n.a.

Notes:

[1]Obras Publicas (Public Works Department).

[2]Only half the publico fleet is permitted to operate each day.

[3]Minibuses are just now being introduced into the public transport fleet.

[4]ONATRATE (Office of Road Transport).

[5]the private auto fuel efficiency was given by auto dealers.

[6]SIDCHODESNA (Union of Chauffeurs of the National District).

[7]The occupancy rates were estimated by a variety of observers.

[8]FENATRADO (National Transport Federation). Data on fuel efficiency of trucks was also obtained from "Tables for Estimating Vehicle Operating Costs on Rural Roads in Developing Countries," Transport and Road Research Laboratory, Crowtherne, Berkshire, UK (1976).

[9]The fuel efficiency of small trucks was given by dealers. The fleet mix is about 85% gasoline-powered and 15% diesel-powered vehicles. Data are not sufficient to assign different fuel efficiency to each engine type.

[10]Annual tonnage carried was taken from Oficina National de Estadisticos (National Statistical Office). Obras Publicas provided fleet mix by gross weight. From these sources, we compute weighted-average truck capacity and fleet average tonnage carried.

[11]The private vehicle fleet has 96% gasoline engines. However, diesel-powered autos are increasing rapidly because diesel fuel price is low (heavily subsidized).

[12]This is the fuel efficiency of a new diesel Datsun 22-passenger minibus.

Computation Notes

[a]The annual distance traveled by private vehicles was determined from vehicles, efficiency, and consumption; that is, col(3) = (4) x (5)/(1).

[b]The fuel efficiency of publicos was assumed to be 30 km/gal. Publicos are restricted to driving every other day, and we allow 20% downtime for maintenance. With these assumptions, the computation is the same as in note a.

[c]We assume 300 driving days annually. The computation is the same as in note a.

3 ANALYSIS OF PROJECTED ENERGY DEMAND AND CONSERVATION POLICY

In this section, we will analyze energy consumption trends in the transportation sector. Later, we will look at examples of conservation opportunities and their impact.

3.1 PASSENGER TRAVEL

Base year (1980) demand for passenger travel in the Dominican Republic is shown in Table 2. These figures are simply the product of occupancy, distance traveled, and number of vehicles from the transportation energy audit. The breakdown of demand into private auto, publicos, and autobus, is typical of most developing countries. At present, private autos are the least energy efficient mode of transport and consume 80% of passenger transportation fuels while carrying only 50% of passenger-km traveled.

Energy demand projections in Table 2 are based upon auto and public transit forecasts and assume constant vehicle efficiencies to the year 1990. We note that travel demand (pass-km) has increased at an annual rate of 7.5% over the past five years. Obras Publicas reports a 4.3% annual rise in ridership or public travel demand. For the sake of simplicity, assume fuel efficiency of each transportation mode remains unchanged between now and 1990.

In an effort to cope with increasing travel demand, the Dominican government has decided to replace 30% of publicos with minibuses. The diesel-powered Datsuns carry 22 passengers and have a fuel efficiency rate of 19 km/gal, or 10,500 passenger-km/boe at an average 60% load factor. In Table 2, we show the fuel consumption of these minibuses which now carry 30% of public travel demand. Interestingly, the total fuel requirement for passenger travel has been reduced from 1190 thousand boe to 1150 thousand boe, a rather small net change.

Other conservation measures would do more. For example, a substantial hike in the duty assessed import vehicles,[2] or an outright ban,[3] could dramatically reduce travel by private automobile. If implemented in the mid-80's, and given the 4% annual increase in automobile registrations, a policy of this nature would result in a full 1/3 reduction in travel by private auto and an overall energy savings in the transportation sector approaching 20%.

While restricting automobile imports appears quite effective in reducing the overall demand for oil, a deeper look reveals something more; namely, that merely counting barrels of oil equivalent is insufficient if the true impact of a conservation measure is to be evaluated. In our Dominican example, while we would initially note that a net reduction in fuel consumption of 190 thousand boe would occur, what may be more significant is that gasoline demand (automobile) will decrease by 250 thousand boe, while demand for diesel (mini-bus) will increase by 60 thousand boe. Since the Dominican Republic operates a refinery, these shifts in demand may be inconsistent with the refining petroleum product mix. Thus, the real economic value of the energy savings accrued by restricting automobiles would not be known until this factor were weighed.

Table 2
Mass Transport Analysis: Minibus/Auto Impact Bans

Passenger	Passenger-km Travel Demand (million pass-km)				Fuel Efficiency[2] (pass-km/boe)	Annual Fuel Consumption (thous boe)		
	Base 1980[1]	Projected 1990	Minibus	Plus Import Ban		Projected 1990	Minibus	Plus Import Ban
Private	940	1940	1940	1300	2100	920	920	620
Publico (taxi)	590	910	640	960	4100	220	150	230
Minibus	---	---	270	590	10500	---	30	60
Autobus	340	490	490	490	9100	50	50	50
	1870	3340	3340	3340		1190	1150	960

[1]From Table 1, cols. (1)x(2)x(3). Only half of publico fleet is permitted to operate each day. Two thirds of autobus fleet operates each day.
[2]The product of occupancy rate and fuel efficiency from Table 1 (cols. (2)x(4) scaled to boe).

3.3 ECONOMIC EVALUATION

An economic assessment of the impact of conservation measures must look at more than just energy savings. For, while foreign exchange dollars for oil imports may be saved, aiding a country's balance of payments situation, regulatory measures may also lead to additional monetary costs. As we have in the Dominican study, a policy to restrict automobile imports makes sense only when coupled with an expansion in the minibus fleet sufficient to carry a large chunk of the additional passenger ridership. In this case, 2900 more minibuses would need to be added to the fleet at a capital cost of $40 million.

Although subsidizing transit fares helps in the recovery of operating costs, capital investments - such as the cost of 2900 minibuses - are paid back through achieved fuel savings associated with government policy as shown in Table 3. In this simple example, the rate of return on Dominican policy limiting auto transport and expanding public transport is 15% annually. Additionally, although it has not been included, the foreign exchange not spent on imported automobiles would represent a further contribution toward improved balance of payments.

In this case study, the economic evaluation is oversimplified. In practice, one would look more closely at the public transport operation costs and fare structure to obtain a detailed picture of expenditures and income. The change in petroleum product mix away from gasoline and toward larger fractions of diesel fuel could have a significant impact upon the economics of domestic refining. Finally, petroleum fuel prices are regulated by government, subsidized for some groups and taxed for others, in an effort to achieve social goals. A more complete economic evaluation would include a look at the distributional effects of energy conservation measures.

Table 3
Economic Analysis
Minibus/plus Automobile Import Restrictions

Capital Cost	2900 vehicle @ $13500 veh.[1]	= 40. million[2]
Fuel Savings	230 thous. boe @ $34/bbl[3]	= 7.8 million
	Rate of return (10 yr.)	= 15%

[1]Mid '82 foreign exchange cost (excluding import duties, taxes, etc.) of Datsun 22-passenger diesel minibus.
[2]An additional foreign exchange savings of $190 million over the ten-year period can be credited for the 29000 automobiles not purchased because of government policy measures.
[3]Platts' Oilgram: Price f.o.b. Rotterdam, October 1, 1982.

4 A FINAL COMMENT

The analysis of conservation measures provides quantitative results and qualitative information with which decisionmakers may judge the merits of alternative actions. In the Dominican Republic, the energy savings and their economic value associated with reduced levels of automobiles are significant. But, despite the attractiveness of these energy savings, higher vehicle import duties, import quotas and/or fuel prices may be difficult to achieve within the social and political climate prevailing in the country. Gasoline price increases in Egypt, for example, were met by street riots. In short, while analysis identifies desirable options, the decisionmaker must also be astute in judging which of the alternatives considered can be successfully implemented.

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TRANSPORTATION/ENERGY CASE STUDY

1. Most of the data for this case study were taken from the report, "Energy Strategies for the Dominican Republic," of the Comision Nacional de Politica Energetica, Dominican Republic (September 1980).

2. The present import duty is 35%, whereas in Columbia the duty is 350%.

3. Such bans are in existence in a number of countries.

4. See Transportation Section, Figure 4.

6.2 THE POTENTIAL F. . ENERGY CONSERVATION IN THE DAKAR TRANSPORTATION SYSTEM

Claude Garrigues

Basic data were obtained from a survey made by SONED and SCET International for the Ministere de l'Equipement released in May 1981.

It reviews urban transport systems used in Dakar. Their characteristics are given in the attached table.

This table indicates that:

- Private cars are very energy intensive, require a lot of space and, consequently, a lot of investment. 33,000 cars consume 41% of the fuel used in the Dakar area, require 86% of the space available, and provide only 33% of the transit needs.

- In contrast, the 264 SOTRAC buses consume 20% of the fuel, require only 2% of the space, but provide 37% of the transit needs. Their efficiency in terms of km x trip/consumption is 3.3 times higher than cars.

- Shifting 1% of the transit demand from cars to SOTRAC buses means a yearly savings of 1600 tep/year or US m$ 0.6.

This indicates that government should promote SOTRAC buses and discourage the use of private cars.

A lot has been already done. SOTRAC runs 400 buses and the average rate of occupancy has been reduced from 29% to 27%, and we assume that mass transit has increased its share of the market from 56% in 1980 to 65% in 1981.

This procures a savings of 15,000 tep or US m$ 5.6.

Is that a maximum? We do not think so. In Tunis, the rate is 68% and we assume that a rate of 70% could be attained in Dakar.

This means a saving of 8,000 tep or US m$ 3.0.

SOTRAC

As for Sotrac itself, the average consumption is 391/100 km for the buses equipped with an M.A.N. diesel engine and 451/100 km for the buses equipped with a FULGAR diesel engine.

Of course, Sotrac is going to shift to M.A.N. diesel engines, which means the final figure will attain 391/100 km.

RECOMMENDATIONS

The following are some recommendations for energy conservation measures in the transportation and building sectors in Senegal.

- Making walking and bicycle riding more pleasant and less hazardous than at present.

- Favoring collective transports by:
  - giving more possibilities to the Dakar public transport company
  - making traffic conditions easier for collective bus

  Potential saving: 8,000 tep/US$ 2,900,000.

- Training drivers of the Dakar public transport company to save gas oil.
  Potential saving: 600 tep/US$ 220,000. Cost of training: US $38,000.

- Setting up commuter trains between Dakar and Rufisque.
  Potential saving: 4,300tep/ US$ 1,500,000.

- Setting up a non-stop working day.
  Potential saving: 4,000tep/US$ 1,400,000.

- Giving the national railway company the possibility to recapture its normal share of the transport market.
  Potential saving: 9,000tep/US$ 3,200,000.

- Promoting central air-conditioning units instead of individual ones.
  Potential saving: 19,000tep/US$ 6,800,000.

- Promoting building techniques and urbanism adapted to local needs and not following the European patterns of the late 1960s.

- Promoting a solar water heater adapted to local conditions and not following the European patterns.
  Potential saving: 2,700tep/US$ 1,000,000

- Discouraging the use of plaster as it is more fuel intensive than cement.

- Economizing on superfluous cement.

- Promoting stabilized earth.

- Promoting natural and passive air-conditioning systems, the use of insulating material against sunheat, double roofing, double wall, suppression of openings on east and west sides, utilization of plants in a patio or as a roof and wall covering.

- Promoting air humidification instead of air conditioning in dry and hot environments.

- Promoting tree planting in urban areas.

It is difficult to ascertain the potential for energy conservation contained in these measures. It is certainly considerable and in any case larger than 50,000 tep. So we think it is worth conducting a comprehensive survey to gather numerical data and evaluate the cost efficiency of each item in this long list of recommendations and the possible impact on Senegal and any other country.

Table 1
Main Characteristics of Transportation Modes
(average day)

Transportation Vehicle	Consumption (1/100 km)	Transit Demand (Nb)	Transit Demand %	Vehicles (Nb)	Space Requirements	Total Space Required (1)	Total Space Required %	Energy Efficiency (2)	Comments
Collective private buses	20	180,000	19	500	1.8	900	2	30	(1) Number of vehicles x space required
Authorized taxis	15	75,000	8	1,600	1	1,600	4	11	(2) $\frac{\text{km x Person-trips}}{\text{Fuel Consumption}}$
Private cars	10	315,000	33	33,000	1	33,000	86	21	
Motorbikes	4	30,000	3	8,000	0.3	2,400	6	25	
Buses	41.5	350,000	37	264	2.5	660	2	70	
		950,000	100			38,560	100		

SECTION 7

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APPENDIX B

AGENDA

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APPENDIX B
INTERNATIONAL SEMINAR ON ENERGY EFFICIENCY AND CONSERVATION
DEUX FEVRIER HOTEL LOME, TOGO
March 30-April 8, 1983

AGENDA

Tuesday, March 29, 1983	Arrival and Registration
Wednesday, March 30, 1983	
9:00 A.M.	Registration
10:00-11:00	Welcoming Remarks Dr. David J. Jhirad, Seminar Chairman Mr. David Rhoad, United States Agency for International Development (USAID) Dr. T. Sakho, Deputy Executive Secretary, Economic Community of West African States (ECOWAS) The Minister for Public Works, Energy and Hydraulic Resources, Government of Togo
11:00-11:30	BREAK
11:30-12:15	Objectives of the Seminar The International Importance of Energy Efficiency Dr. David J. Jhirad, Brookhaven National Laboratory, Upton, New York 11973, USA
12:15-1:00	Costs and Benefits of Industrial Energy Conservation in the Developing Countries Mr. Barry G. Tunnah, E/DI Europe, Ltd., London, England
1:00-3:00 P.M.	LUNCH
3:00-3:45	Review of the Energy Situation in West African Countries Representatives from ECOWAS and Mr. Asif Shaikh, Energy/Development International, Washington, DC, USA
3:45-4:45	BREAK
4:45-6:00	Energy-Efficiency as an Important Element of West African Energy Strategy Mr. Claude Garrigues, Energy Consultant, Le Pecq, France
6:30	Reception given by the Institute for Energy Research of the State University of New York at Stony Brook, New York. Le Soleil Bar, Poolside.

Thursday, March 31, 1983

9:30-11:00 A.M.	Case Studies of Energy Efficiency: Tunisia and Togo Mr. Barry Tunnah
11:00-11:30	BREAK
11:30-1:00	Case Studies of Energy Efficiency: Senegal and Morocco Mr. Claude Garrigues
1:00-3:00 P.M.	LUNCH
3:00-3:45	Case-Studies of Energy-Efficiency in the Industrial and Power Sectors Dr. H. N. Sharan, Sharan Engineering Ltd., Winterthur, Switzerland
3:45-4:30	Case-Studies of Energy-Efficiency in Buildings Dr. Richard B. Curtis. Lawrence Berkeley Laboratory and Aerolithos, Inc., San Mateo, California
4:30-4:45	BREAK
4:45-6:00	Buildings and Electric Utility Systems I: The Utility Side Dr. Richard W. Leigh, Brookhaven National Laboratory, New York, USA

Friday, April 1, 1983

9:30-11:00 A.M.	Case Study of Energy-Efficiency in the Transportation System of Dakar, Senegal Mr. Claude Garrigues
11:00-11:30	BREAK
11:30-1:00	Discussion of Energy Efficiency in Transportation
1:00-3:00 P.M.	LUNCH
3:00-4:15	Woodfuel Utilization in West Africa Dr. H. Sharon, Mr. Philippe Simonis, Mr. Asif Shaikh
4:15-4:30	BREAK

Friday, April 1, 1983
(continued)

4:30-6:00	Financing Energy-Efficiency Projects in West Africa: Activities of Bilateral Donor Agencies Speakers: Mr. Asif Shaikh; Mr. David Rhoad

Saturday, April 2, 1983

9:30-11:00	Preventive Maintenance in the Electric Power Sector, the Tennessee Valley Authority (TVA) Experience Mr. Paul H. Shoun, Chief, Power Operations Planning Staff, Tennessee Valley Authority, Chattanooga, Tennessee, USA
11:00-11:30	BREAK
11:30-1:00	Discussions of Forthcoming Field Trip to the Phosphate Plant Mr. Barry Tunnah/Mr. Claude Garrigues
1:00-3:00 P.M.	LUNCH
3:00-4:30	Films on Energy Technology

Monday, April 4, 1983

	Field Trip to the Phosphate Plant Leader: Mr. Barry Tunnah
8:30 A.M.	Buses leave from Hotel Deux Fevrier
6:00 P.M.	Buses return to Hotel Deux Fevrier

Tuesday, April 5, 1983

9:30-11:00 A.M.	Field Trip Review Mr. Barry Tunnah, Mr. Claude Garrigues
11:00-11:30	BREAK
11:30-12:15	Energy Efficient Electric Power Systems: Analysis and Design Dr. H. N. Sharan
12:15-1:00	Technologies for Waste Energy Recovery in Industry Dr. David J. Jhirad
1:00-3:00 P.M.	LUNCH

Tuesday, April 5, 1983

3:00-3:45	Energy-Efficient Buildings: Analysis and Design Dr. Richard B. Curtis
3:45-4:45	BREAK
4:45-6:00	Buildings and Electric Utilities Systems II: Air Conditioning Dr. Richard Leigh

Wednesday, April 6, 1983

9:30-11:00 A.M.	Analyzing Energy-Efficiency in Transportation Mr. Claude Garrigues
11:00-11:30	BREAK
11:30-1:00	Energy-Efficiency in Transportation: Analysis and Case Studies Dr. T. Owen Carroll, The Institute for Energy Research, State University of New York at Stony Brook, N.Y.
1:00-3:00 P.M.	LUNCH
3:00-6:00	Buildings and Electric Utility Systems III: Cogeneration Dr. Richard Leigh

Thursday, April 7, 1983

9:30-10:15 A.M.	Financial Analysis of Energy-Efficiency Measures from the Enterprise Perspective Mr. Barry Tunnah
10:15-11:00	Sensitivity of Financial Analysis to Government Incentives Dr. David Jhirad
11:00-11:30	BREAK
11:30-1:00	Panel Discussion • Economic and Policy Analysis of Energy-Efficiency Measures from a National Perspective • International Experience with Effective Strategies for Enegy Demand Management Dr. David Jhirad, Dr. David Brookes

Thursday, April 7, 1983

4:30-4:45	Group Discussion of Conclusions and Recommendations
4:45-6:00	Group Discussion (continued)

Friday, April 8, 1983

9:30-11:00	Closing Ceremony: Mr. Robert Tubman, Managing Director, ECOWAS Fund Mr. Y. Amefia Dr. David Jhirad

APPENDIX C

LIST OF SUPPLEMENTARY MATERIALS DISTRIBUTED AT THE SEMINAR

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LIST OF SUPPLEMENTARY MATERIALS DISTRIBUTED AT THE SEMINAR

1. Africa Bureau, Office of Regional Affairs, Agency for International Development, Guidelines for Preparing and Approving Energy Initiatives for Africa (ETA) Project Activities (In English and French).

2. G. Anandalingam and David J. Jhirad, Analytic Tools for Techno-Economic Assessments of Industrial Energy Efficiency in Developing Countries.

3. G. Anandalingam, D.J. Jhirad, V. Mubayi, and J. Weingart, An Analysis of Incentives for Industrial Investment in Solar Energy in Developing Countries.

4. Energy Management Training Program for Developing Countries (EMTP) 1983 Program Brochures (in English and French).

5. ENERSAVE: For Industry and Commerce, a series of ten handbooks on various aspects of energy conservation, produced by the Office of Energy Conservation, Ministry of Energy, Mines and Resources, Government of Canada (in English and French).

6. Identifying Energy Conservation Options Using the Cost of Conserved Energy Methodology in the Residential Sector, adapted by Lee Schipper from a paper by Alan Meier, Janice Wright, and Arthur H. Rosenfeld.

7. Identification des choix en matiere d'economie d'energie: cout des mesures d'economies dans le secteur residentiel. (French version of Item 6).

8. Lee Schipper, Notes on Energy Management in Hotels.

9. Lee Schipper, Notes sur la gestion de l'energie dans les hotels.

10. Lee Schipper and Stephen Meyers, Energy Conservation in Kenya's Modern Sector: Progress, Potential and Problems.

11. Proceedings of the Economic Community of West African States (ECOWAS) Energy Symposium: Energy for Survival. Freetown, November 2-6, 1981, National Academy of Sciences.

APPENDIX D

MATERIAL FROM THE OFFICE OF TOGOLAIS DES PHOSPHATES (O.T.P.) (Ex-COMPAGNIE TOGOLAISE DES MINES DU BENIN)

Registered Office: Kpene (Togo)
P.O. Box: 379 Lome (Togo)
Telephone: 21-39-01 and 21-32-38
Telegraphic Address: Phosphat-Lome
Telex: 5214 Phosphat-To and 5287 OTP-To

1. TOGO

Togo, a country of some 56,000 km^2 is bordered by Benin to the east, Ghana to the west, and Upper Volta to the north. The Coastline is situated by the Gulf of Guinea.

Of a population of 2,500,000, approximately 400,000 live in the capital, Lome.

In the North, there are vast mountain plateaux of savannah land, and in the South, a large cultivated area where Mango, Kapok, and Palm trees can be found culminating with a forest of Coconut Palms along the shore line. The Togolese raise livestock and poultry and grow cocoa, coffee, maize, and manioc.

Due to its location between West and Equatorial Africa, Togo is the center of a large international trade. It is also a country which had the wisdom to endow itself with a legislation that guarantees private investments, allowing the development of flourishing and rapidly growing industries. The phosphate rocks constitute the main mining resource of Togo offering their contribution to the country's economic advance.

2. THE PHOSPHATE MINE

The first search for phosphate rock in 1952 was encouraging and continuing searches realized a deposit estimated to be in excess of 130 million tonnes of high-grade phosphate.

In 1954, following geological study, the development of enrichment processes and treatment trails on the semi-industrial scale, the "Societe Miniere Du Benin" was formed. In 1957 it became: "Compagnie Togolaise Des Mines Du Benin."

On February 4, 1974, the "Compagnie Togolaise Des Mines Du Benin" (C.T.M.B.) became a nationalized company with a working capital of 3,621,720,000 Francs CFA, totally subscribed by the Republic of Togo.

Since 1980, it has adopted the name of "Office Togolais Des Phosphates (O.T.P.), regrouping production and marketing of the phosphate rock.

In 1970, production rose to 1,508,189 tonnes.
In 1971, to 1,715,315 tonnes.
In 1972, to 1,927,604 tonnes.
In 1973, to 2,272,161 tonnes.
In 1974, to 2,552,854 tonnes.
In 1975, to 1,160,502 tonnes.
In 1976, to 2,068,072 tonnes.
In 1977, to 2,857,005 tonnes.
In 1978, to 2,826,614 tonnes.
In 1979, to 2,915,811 tonnes.
In 1980, to 2,932,845 tonnes.

The expansion of production of the two quarries of the mine in exploitation now, an increase in the carrying capacity of the railway and of the storage areas for the ore, and the construction of the fifth treatment unit at Kpeme must permit a production of 3,600,000 tonnes for export if the market situation is to be favorable.

Projects in hand will realize a further 1,000,000 tonnes for export.

3. THE PHOSPHATE ROCK DEPOSIT

Located at a distance of 10 to 30 kms from the sea, the deposit mined by the "Office Togolais Des Phosphates" (Ex-C.T.M.B.) exists as a tertiary formation of the sedimentary coastal basin of Togo.

The horizontal seam of phosphate deposit is 2 to 6 metres thick. The gangues that cover the deposit vary between 7 and 30 metres.

The crude ore is capable of providing a commercial mineral of quality 78/80% tricalcium phosphate in dry form. In the near future, a mineral of quality 76/78% is anticipated.

4. MINING

On the two open-cast quarries of HAHOTOE and KPOGAME, the length of the phosphate seam varies from 800 to 1,500 metres.

The covering gangues are extracted by excavator-tractors, capable of excavating between 550 and 1,000 m^3/hour. The gangues are cleared by filling-machines fed directly or with the help of conveyors.

The crude is then extracted at a rate of 900 tonnes an hour by similar excavator-tractors working in the lowest part of the quarries. Conveyors then carry the ore to the loading railway station.

5. CHEMICAL ANALYSIS

The high tricalcium phosphate content (78 to 80% on a dry basis) will allow fertilizers of high P_2O_5 concentration to be obtained.

The CaO/P_2O_5 ratio is very favorable: 1,38 to 1,40; therefore, acid consumption during dissolution will be moderate.

Due to the low CO_2 content, the acid attack will be easy with no precautions to be taken to prevent foam formation.

6. USES OF TOGO PHOSPHATE ROCK

The use of Togo phosphate rock in the manufacture of chemical fertilizers has fully confirmed its favorable characteristics.

In particular, the use in the manufacture of wet process phosphoric acid has highlighted remarkable conditions of use and the following characteristics:

- the phosphate rock can be used directly, without grinding,
- there is no need for anti-foaming agents,
- the filtration capacity of the gypsum is very high: about 8 tonnes of P_2O_5 per useful M^2 and per day for the production of 32% phosphoric acid,
- P_2O_5 extraction exceeds 96% even when the phosphate has not been ground.
- the consumption of 100% sulphuric acid is about 2,5 tonnes per tonne of dissolved P_2O_5, and
- phosphoric acid manufacture does not lead to deposition of insoluble salts and hence there is no need to interrupt production in order to carry out descaling.

Due to a moderate content of organic substances, magnesia and alkalines, the acid produced lends itself well to very sophisticated processes, e.g., alkaline phosphates and liquid fertilizers. The liquid fertilizers produced from this acid contain no solid deposits even after storage for several weeks at ambient temperature.

7. STAFF

Two thousand, four hundred thirty employees, 98% of whom are Togolese, contribute to the smooth running of the operations. Recruitment and promotion in the profession and social framework are controlled by an efficient training programme.

8. ANNEXES

The electric power is normally supplied by C.E.B., the national electricity supplier. However, if necessary, the diesel-powered generators at Kpeme enable the plant to be self-sufficient. The quarries and the plant are linked by a 63,000-volt cable.

For the accommodation and welfare of its executives and employees, the Company has built an administration centre and two residential centres.

Each residential centre is equipped with a dispensary, school, social club, restaurant, and playing fields.

9. CHEMICAL ANALYSIS OF TOGO PHOSPHATE ROCK: QUALITY 78/80%

Water content 1.75%

Content of commercial phosphate dried at 100°C (percent)

• Loss during calcination (carbon dioxide deducted)	01.40	
• Phosphoric anhydride P_2O_5	36.56	
• Siliceous substances	04.18	from 3.50 to 4.50
• Potassium oxide K_2O	00.03	
• Sodium oxide Na_2O	00.23	
• Magnesium oxide MgO	00.10	
• Calcium oxide CaO	50.82	
• Iron oxide Fe_2O_3	01.40	max 2.50
• Aluminia Al_2O_3	01.00	
• Manganese oxide MnO	00.02	
• Titanium oxide TiO_2	00.06	
• Carbon dioxide CO_2	01.64	
• Sulphur trioxide SO_3	00.35	
• Fluorine	03.74	
• Chlorine	00.06	
	101.59	
To be deducted -- Oxygen corresponding to the Fluorine and Chlorine	1.57	
	100.02	
Not determined losses	0.02	
P_2O_5 of matter dried at 100°C	79.88%	

10. PARTICLE SIZE CLASSIFICATION ANALYSIS

Number of the Tyler Screen	Gap Between Wires in mm	Accepted
32	0.495	98%
65	0.208	90%
100	0.147	66%
150	0.104	30%
270	0.053	8%

11. CHARACTERISTICS OF TOGO PHOSPHATE ROCK

The above analysis shows that the particle size is appreciably smaller than that of other commercial grade rocks, which means that when grinding is necessary, less energy is used.

Lifts of 36 self-discharging wagons each of 25-tonne capacity drawn by 1,200 HP electricity diesel locomotives, carry the crude ore on a 30-kms railway from the quarries to the treatment plant.

A bridge of 720 metres (a remarkable technical achievement) allows the railway to cross a huge lagoon. The railway is owned entirely by the company.

12. TREATMENT

The main treatment is carried out in the plant at Kpeme, on the coastal area, 35 kms east of Lome.

The ore (crude phosphate) is first carried to the unloading area and directed by conveyors either toward the treatment plant or toward the intermediary stock (capacity of this stock is 250,000 tonnes).

The plant is composed of five treatment units.

The required output of ore at the entry of each unit of 174 tonnes/hour.

The crude phosphate containing between 25 and 40% of clay is reduced to a slurry with water. The required water is taken from the sea, 400 metres from the shoreline.

The slurry is subjected to two types of eliminations:

- a high "elimination" (more than 3 mm) on sieves that removes the "coarse" particles, and

- a low "elimination" (less than 45 mm) in the hydrocyclones to remove the tiny particles that constitute the clayey gangue.

The "commercial" phosphate is then obtained by rinsing with fresh water, draining, and drying.

After drying, when the grade in (Fe_2O_3 + Al_2O_3) is above 2,5%, the iron oxides are eliminated with electromagnetic-separators.

13. LOADING

The commercial phosphate is stored in two sheds with a total capacity 190,000 tonnes.

A conveyor, supported by a metallic wharf of 1,200 metres long especially built for the company, transports the product to the loading platform at a rate of 2,500 tonnes/hour.

Weighing and sampling are automatic.

The shipping roads of Kpeme allow vessels of 50,000 tonnes capacity with a draft of 38 feet to load the ore and allow for access for oil tankers to discharge fuels.