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ENERGY IN DEVELOPING COUNTRIES SERIES

ENERGY CONSERVATION IN KENYA'S MODERN SECTOR: PROGRESS, POTENTIAL AND PROBLEMS

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Errata

p. 10 PI should be PJ

p. 23 Residential kerosine should be 2,940; pipeline electricity should be 53.5. The title should properly read: "Composition of Commercial Energy Use."

p. 100 Last sentence should read: Pipeline required 53.5 TJ of electricity in 1979.

10/13/82

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INTRODUCTORY NOTE

Economic and social developments in the developing countries will require growing quantities of energy services, particularly those performed by commercial fuels such as oil. To the extent these additional services can be secured through greater efficiency in the use of fuels, more of the output of these economies will be available to foster higher living standards and investment. The pay-off to energy conservation, already high, jumped again with the oil price increases of 1979/80.

The tasks of using energy more efficiently is exceedingly complex in developing economies, as it is elsewhere. Higher costs provide universal incentives to substitute other factors for energy and to substitute among energy forms and services, but extensive barriers to change such as restrictive market conditions, foreign exchange shortages which may inhibit importation of energy efficient equipment, and subsidies on fuels to protect the poor, limit success. Moreover, adjustments that save energy are to some extent end-use, technology, site, and culture specific. Thus, while generalizations about appropriate policies may be useful, examination of specific situations is required before the analyst can be reasonably confident that policies designed to save energy will first, do so, and second, achieve savings at a cost sufficiently low that the economy is left better off.

"Energy Conservation in Kenya's Modern Sector" by Lee Schipper and his associates of the Lawrence Berkeley Laboratory reports on an investigation of the potential for commercial energy conservation in Kenya. Kenya is more affluent than many of its neighbors, with a per capita income of just over $400 a year, but remains poor. Relief from some of the growing burden of paying for energy could improve the prospects for growth in the modern sector of Kenya and improve living standards throughout the country.

Energy statistics are not well developed in Kenya, a common situation, and hence before analysis could begin, energy balances showing how and where energy is used in the economy had to be constructed. On the basis of these data, trends in energy intensities in the modern industrial, household, commercial, and transportation sectors were estimated and used as a guide to the future potential for energy savings. The authors conclude that "current energy intensities can be reduced in all sectors using cost effective conservation measures,"--by in excess of 20 percent over the next five years or so. The authors suggest, among other measures, those that would reduce import barriers on energy efficient equipment, energy audits for industry, energy-conscious commercial building codes, and training and education in energy saving techniques.

The purposes of this study, as with many in this series, are two fold. The first is to extend knowledge of energy demand and conservation in the subject country. The second, equally important, is to develop a methodology which will be helpful to energy analysts in assessing conservation potential and practice in other countries.

This discussion paper is one of several relating to energy conservation in the developing world. The others include: John Jankowski, "Industrial Energy Demand and Conservation in Developing Countries" and Eduardo Moran and Pierre Vernet, "Industrial Energy Consumption in a Developing Country: The Ecuadorian Case." Work of a somewhat different nature but addressed to the same issues is nearing completion in India, under the direction of Dr. R.K. Pachauri, at the Administrative Staff College of India (Hyderabad). The Indian work contemplates an analysis of the effect of increases in energy prices on the amount of energy consumed in industry, and on consequent shifts in the amounts of other factors of production consumed.

All of these studies have been funded by the Agency for International Development under the ARDEN (AID-RFF Development and ENergy) Co-operative Agreement No. AIL/DSAN-CA-0179. Lee Schipper and his associates served as consultants to Resources for the Future in performing this study. Joy Dunkerley and Scott Noll coordinated their work with the larger ongoing effort at Resources for the Future.

This paper is issued with the dual purposes of informing the research and policy communities of results obtained from work in progress and of eliciting comments on our efforts.

Milton Russell
Director, Center for
Energy Policy Research

Chapter 1

INTRODUCTION

The severity and lasting impacts of the oil price shocks of 1973 and 1979 have convinced many governments, in both the developed and developing world, that energy issues need to be considered seriously in all aspects of national economic policy and planning. While many non-oil-producing developing countries survived the first price shock without serious economic impacts, the second shock in 1979 may have had much harsher and more permanent effects (Fesharaki, 1980). For this reason, some bilateral and multilateral aid organizations have started according high priority to energy issues. At the same time, many developing countries have initiated activities and policies designed to help reduce oil imports, develop domestic energy supplies, and promote the more efficient use of energy resources. Recently there has been increasing interest in the potential for energy conservation in developing countries. In this study, we examine energy use and conservation in Kenya, both to provide a data base for further work and to assess the role of conservation in the energy strategy of a developing country.

Purposes of the Study

This study has several specific goals. First, we characterize and analyze in some detail the flows of energy in Kenya, a representative developing economy. This is the subject of Chapters 2 and 3. Such characterization has not previously been done to the degree we regarded as necessary for planning purposes. In light of the limitations in data availability, methodology, and resources for such purposes (Schipper and Mbeche, 1979; Schipper, 1980), we wished to determine how far such characterization and analysis could be taken. Our study should help policy

makers and future researchers facing similar limitations to decide the quantity and quality of energy data they need and whether it can be obtained.

Second, we wished to determine whether energy conservation is actually practiced to a measurable extent in Kenya and to determine the future potential for saving energy in Kenya in a manner consistent with the country's aspirations for social development and economic growth. These are the subjects of Chapter 4.

Third, we wished to obtain an indication of barriers to more efficient energy use in Kenya, and to make some recommendations about how to overcome these barriers through government policies and actions and desirable external assistance programs (see Chapter 5).

Finally, this study may be useful in helping energy analysts assess the resources needed to accomplish similar analyses elsewhere. Kenya suffers from many of the problems facing other developing countries, such as a high dependence on imported energy which results in a foreign exchange burden, a high dependence on biomass as a source of fuel for rural families, and an imminent shortage of wood. Because of these commonalities, the Kenyan experience can be generalized in some degree to other developing countries, although the sociopolitical differences among societies must be kept clearly in mind.

Scope and Method of the Study

The study concentrated on the use of commercial energy sources. With the exception of solar heating, neither renewable nor "traditional" fuels were assessed, although it has long been recognized that "traditional" fuels dominate the total energy flow in Kenya (on a calorific basis). The problems of renewable energy sources in Kenya, particularly relating to the production and use of firewood, are currently the subject of a major study by the Beijer Institute, Stockholm, in cooperation with the Ministry of Energy in Nairobi. In many ways, however, the most pressing problem for many developing countries today is the effect of the high cost of oil imports on their economies. Improved energy efficiency would provide measurable relief from high import bills. This study seeks to contribute much needed information about how oil and related commercial energy sources of energy are used in these countries.

During the course of the study, we found a surprising amount of useful but unpublished information in various places in Kenya. While conditions for accessing and using this information vary, knowledge of its existence gives us confidence that the basic assumption of this work is correct: it is possible to construct a useful picture of energy use in Kenya. We obtained our most detailed information on the industrial and buildings sectors. Residences and the transportation and agricultural sectors proved to be much more difficult to survey. For reasons of practicality, we have treated sales and consumption of fuels as identical, we have ignored stock changes, and we have not attempted to determine the "useful energy" at the point of end use (Leach and coauthors, 1978).[1]

Because of the preliminary status of this work, we are able to construct national energy-flow tables for the entire Kenyan economy only for the year 1979, on which we concentrated our initial effort. Future researchers could, with additional effort, reconstruct detailed energy balances for the years 1975-78. In order to assess the extent of energy conservation, it is necessary to relate observed changes in energy use to economic output. Many difficulties were encountered in obtaining measures of output or activity. No data were available for individual firms; we therefore undertook a partial economic survey of industrial firms in Kenya, to measure their output. Relating energy use at the individual firm level allows us to determine differences in use among firms and industries. Data for other sectors are out of date; most recently published data on the number of automobiles, for example, date from 1974, and the definition of "automobile" has itself varied. The last year included in a published

1. Useful energy is defined as energy reaching the task and doing useful work. Heat supplied to a boiler that never heats water, or hot gas streaming around a poorly designed cooking pot, does not count as useful energy. This definition is helpful for comparing efficiencies of energy end-use devices. It is important to take account of the efficiency of end use when comparing commercial and traditional energy resources (for example, fuelwood for cooking), because the latter are usually used very inefficiently. Thus, a much lesser quantity (calorific content) of oil or gas efficiently burned in a modern stove can substitute for a much greater quantity (calorific) of fuelwood or charcoal burned in a traditional, very inefficient stove. Because we do not assess traditional fuel use in this study, such comparisons are less important.

census available to us was 1969, and manufacturing output by industry was last surveyed in 1977.

Three elements are required for a full assessment of Kenyan progress in conservation of commercial energy. First, a detailed understanding of the flows of fuel and electricity is needed; such information had not previously been available in Kenya, and the present study partially remedies that deficiency. Second, a picture of conservation measured at the level of the individual firm needs to be obtained by studying the energy intensity of the firm over time, and reviewing its experiences in trying to economize on energy use. Finally, an assessment of the obstacles encountered by firms trying to conserve energy is important. This involves judgments about the effectiveness of their efforts, measured against our own estimates of possible savings (based partly on experience in other countries). Together these elements allow for informed recommendations about future energy conservation policies and credible predictions about additional conservation potential in particular firms or industries, as well as in the country as a whole.

Time and resources have limited this study to surveys of the largest energy users in Kenya. We are forced to resort to significant approximations in order to arrive at the overall flow of fuel and power in the Kenyan economy and, with a few exceptions, we are not able to examine the use of energy by all firms in each sector. Even so, such a study can serve as a basis for specific recommendations about the kinds of future surveys and analyses that may be needed for the successful implementation of energy policies for the sectors using commercial fuels.

Since very little energy-related information has been published by government or private sources in Kenya, most of our information was collected through personal visits to firms and institutions. For many of the sources, the number or extent of the visits was inadequate and approximations were necessary to fill gaps in the sectoral energy-use summaries. The most limiting resource in this study was the small number of Kenyan counterparts who could devote time to data collection.

The reader should bear in mind that this report is based mostly upon original and partial data from fieldwork. There is no body of information in Kenya with which to compare the data, although some comparisons with data from other countries are possible and useful. We have assumed

throughout that our sources in Kenya have provided accurate information to the best of their ability, with no leaning to understatement or overstatement of either energy use or output. We have found some misprints and obvious copying or systemic errors in data given us or published by official sources, and these errors are indicated in the tables. Considering both the preliminary nature of the study and the inherent difficulty in obtaining the required information, we nonetheless believe that a valid picture of Kenyan energy use has been drawn. Furthermore, we feel that the methods developed here can be usefully applied in other developing countries.

Energy Conservation in the Developing Country Context

Until recently, energy conservation has not received serious consideration in developing countries, either in energy systems studies or in government energy policies. Probably the most important reason for this lack of attention is that conservation has usually been considered to connote curtailment of energy use through restrictions in economic activity, that is, reductions in the provision of goods and services that people want. Such a course would be antithetical to the major societal driving force in developing countries, and could hardly be expected to be an enthusiastic component of government policy.

In the industrial countries, much evidence has accumulated that energy conservation is compatible with economic growth. The relevant question is whether this compatibility can exist only where development has already reached an advanced stage and commercial energy use is large in absolute terms, or whether conservation can also be a viable adjunct to a developing society's economic goals. This question has been difficult to answer because of the almost complete lack of detailed information on patterns of energy use in developing countries.

For these and other reasons we attempted to determine the degree to which energy conservation is taking place in Kenya, by examining the use of energy in its "modern" sector. "Modern" refers to that part of the economy using equipment and providing goods and services in facilities comparable to those in the major developed countries. Therefore, in principle, manufacturing, commercial buildings, hotels, electrified homes, and automobiles are all covered by this study. In these sectors the experience

and expertise of industrialized countries may be helpful to energy planners in developing countries. Not included are the informal (noncommercial) sector and the use of renewable energy sources in modern industry as well as in the so-called "cottage" industries (including small service shops), nor are firewood and charcoal, the energy sources used in most Kenyan households. Where possible, we indicate the uses of these unrecorded fuels in commercial establishments, though we have not attempted to quantify them systematically.

For the purposes of this study, energy conservation is defined specifically as reductions in energy use per unit of output, that is, energy intensity, aimed primarily at reducing the costs of using various forms of energy for producing goods and services. Additionally, changes in the output mix of individual firms are reflected in changing energy intensities. In a few cases we note the effect of output mix on changing energy requirements; mostly, however, we assume that changes in energy use per unit of output are due to changes in technology or operations that are motivated primarily by higher energy prices. These changes are brought about by the substitution of capital and labor for energy. For the country as a whole, energy use per unit of aggregate output is the result of changes in the amount of energy used in producing a unit of like product and changes in the mix of final demand. These are often motivated by energy prices, though government development strategies may influence the overall mix of manufacturing output to a greater degree than does the price of energy. Also, changes in personal behavior, such as less automobile driving in response to higher gasoline prices, reduce aggregate energy demand. Such changes, often called "belt-tightening," are not strictly energy conservation, as defined herein.

With this definition of conservation, the level of energy savings in a sector can be defined as the product of the amount of reduction in energy intensity in the sector during a given period, times the activity level (that is, output) today. Put another way, energy savings is the difference between energy use after conservation has been realized and energy use that would have taken place at the same level of output with no conservation. This is important to bear in mind, because there may be energy conservation and energy savings even though output has grown enough to increase total energy use. Thus, conservation and savings are not inconsistent with

increased economic activity and energy use. An important signal that energy conservation is taking hold is a slowing of the rate of energy-use growth relative to the rate of economic growth.

This definition of conservation emphasizes its importance to a developing country's economy. These countries have shown increasing concern over the strains placed on foreign exchange earnings by oil prices. Conservation allows the real output of goods and services to increase at a higher rate than that of the energy consumption, therefore conservation eases the relative burden of oil-import costs.

Conservation efforts in developing countries have been hampered by inaccurate impressions sometimes held about the impact of saving energy. To the extent that conservation was identified with using less energy per se, rather than using energy more efficiently in the economic sense, it became associated with nondevelopment. Development can indeed proceed in tandem with more efficient energy use, because more efficient energy use reduces the cost of producing goods and services.

Chapter 2

AN OVERVIEW OF ENERGY IN THE KENYAN ECONOMY

As a background to the more detailed analysis of sectoral energy consumption and related measurement of output we present here an analysis of trends in aggregate energy consumption and production in Kenya, and the social and economic factors affecting the amount and type of energy consumed. These include demographic trends, level of economic activity and its composition, and energy prices.

In many countries the data needed for aggregate analysis are easily accessible from national or international sources. In the case of Kenya, basic data are difficult to obtain and are of questionable reliability. For this reason and also to assist those undertaking similar assessment exercises in countries with an inadequate data base, we explain our methodology and point out data deficiencies at some length.

Energy Production and Consumption Data

The Central Bureau of Statistics published in 1978 a volume entitled Statistics of Energy and Power. This volume contains data on electricity generation and on quantities of oil produced and consumed in the Kenyan economy as a whole, and a breakdown of oil sales by total weight for a few classes of "outlets," not necessarily final consumers. The Statistics of Energy and Power is useful in showing both aggregate consumption and the changing roles of various energy sources. But the data contained in this volume have certain limitations. There is little information on sectoral or subsectoral uses of each fuel type. Clear conversion factors from quantities of fuel to energy units are lacking, which makes it difficult to use the data for energy analysis, since it is primarily the calorific content of fuels that is important to users. Finally, the series ends in

1977. For 1978 and 1979, we have relied on the Statistical Abstract (1979), the Economic Survey 1980 and results gathered from our own work. In some cases we have modified official data. For example, we increased the official figures for coal consumed in 1979 by a factor of more than three to reflect the known consumption of this fuel in the cement industry, historically close to 80 percent of total coal consumption.

These data are summarized in table 2-1. Primary consumption includes all energy losses in conversion. Secondary (end-use) energy consumption reflects energy actually used in the economy, net of energy-sector conversion. Losses in the energy supply sector are considerable in Kenya (see the gap between primary and secondary energy in figure 2-1) in part because of the low efficiency of thermal electric power plants, and in part because the East African Oil Refinery (EAOR) refines a considerably greater volume of oil than is used in Kenya. The excess is exported.

The accounting convention regarding hydroelectricity contributes a significant uncertainty to the interpretation of the aggregate figures in table 2-1. We show, for example, the primary equivalent of hydro-energy, as well as its secondary (output) equivalent; that is, electricity output in thermal plants as well as the fuel consumed to produce it. The actual efficiency of thermal electricity production is approximately 23 percent. However, in computing the primary energy equivalent of produced hydroelectricity (that is, the amount of oil that would have to be consumed to produce the same amount of electricity in a thermal plant) the customary figure of 36 percent efficiency has been used. The inconsistency between these two figures makes it difficult to use aggregate energy consumption for comparisons over time because of the irregular effect of the hydro-thermal mix.

Trends in Energy Use

Even with these data limitations, however, it is still possible to trace well established trends in energy use in Kenya. The average growth rate in energy use has been high. Total consumption rose by 80 percent over the ten year period (1969-1979) or by an annual average rate of 5.4 percent. Total final use rose by 83 percent. The sharper rise in final use means that out of a given total energy input into the economy a rather larger part was delivered to consumers. The increase in consumption

Table 2-1. Kenyan Commercial Energy Consumption 1969-1979
(PJ)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Primary Energy Use	46.20	51.90	57.12	61.92	66.09	66.98	68.70	75.34	79.31	83.82	83.59*
Coal, Coke Imports	.95	2.43	2.39	1.18	2.09	1.95	1.34	1.88	1.83	1.46	1.54
Oil	40.00	43.64	48.41	53.90	56.90	56.60	58.27	65.21	67.27	69.46	70.19
Crude Imports	88.68	92.17	106.21	104.89	112.78	121.46	118.19	104.46	106.75	99.13	103.41
Fuel Exports	-49.75	-54.89	-62.32	-60.10	-62.98	-61.45	-54.45	-55.41	-52.73	-38.28	-29.85
Stock Changes	1.07	6.36	4.52	9.11	7.10	-3.41	-5.47	16.16	13.25	8.61	-3.37
Hydroelectricity[a]	5.25	5.8[illegible]	6.32	6.84	7.10	8.43	9.09	8.25	10.21	12.90	11.86*
Production	1.11	1.21	1.22	1.44	1.47	1.97	2.33	2.10	2.70	3.86	3.70*
Imports	.79	.89	1.06	1.02	1.09	1.07	.94	.87	.98	.78	.58
Energy End Use	36.99	41.84	45.88	49.13	53.52	53.83	54.99	52.18	63.68	66.50	67.71
Coal, Coke Imports	.95	2.43	2.39	1.18	2.09	1.95	1.34	1.88	1.83	1.46	1.54
Oil[c]	33.89	37.01	40.84	45.02	48.26	48.48	49.97	46.33	57.45	60.28	61.28
Primary Demand	40.00	43.64	48.41	53.90	56.90	56.60	58.27	65.21	67.27	69.46	70.19
Refinery Losses	-3.21	-3.31	-3.72	-3.92	-3.78	-4.78	-4.79	-4.48	-4.31	-5.10	-4.73
Electric Utility Use	-2.88	-3.36	-3.89	-5.03	-4.93	-3.81	-4.01	-13.58	-5.53	-4.08	-4.18
Electricity[d]											
Hydroelectricity[e]	1.89	2.10	2.28	2.46	2.56	3.04	3.27	2.97	3.68	4.64	4.27*
Thermal Electric Util.	.62	.71	.85	1.02	1.21	.98	.92	1.72	1.13	.93	.96
Fuel Input	2.88	3.36	3.89	5.03	4.93	3.81	4.01	13.58	5.53	4.08	4.18
Transformation Losses	-2.26	-2.65	-3.04	-4.01	-3.72	-2.83	-3.09	-11.86	-4.40	-3.15	-3.22
Station Service	-.05	-.05	-.05	-.07	-.13	-.09	-.08	-.12	-.10	-.09	-.09*
Losses and Unaccounted	-.32	-.36	-.43	-.48	-.47	-.52	-.44	-.61	-.30	-.73	-.25

Note: Detail may not add to totals due to rounding.

*Values are estimated where data are not yet available or seem inaccurate; the value given in the Economic Survey 1980 for local production of hydropower (equivalent to 4.71 PJ) seems too high in light of the value given for total electricity demand; we estimate utility hydro production by subtracting all other sources of electricity production from total generation (station service is also estimated); if our estimate of hydro production is too low, total primary energy use may be somewhat understated.

[a]Primary equivalent of hydroelectricity is calculated using a nominal 36 percent conversion efficiency.

[b]Includes Bureau of Statistics estimated industrial hydroelectricity self-generation of .72 PJ each year.

[c]Includes oil used to generate electricity by industry. The Bureau of Statistics estimate industrial thermal electricity self-generation at .18 PJ each year.

[d]Excludes industrial thermal electricity self-generation which the Bureau of Statistics estimate at .18 PJ each year.

[e]Includes hydroelectricity generated by utilities and industries, and hydroelectricity imports.

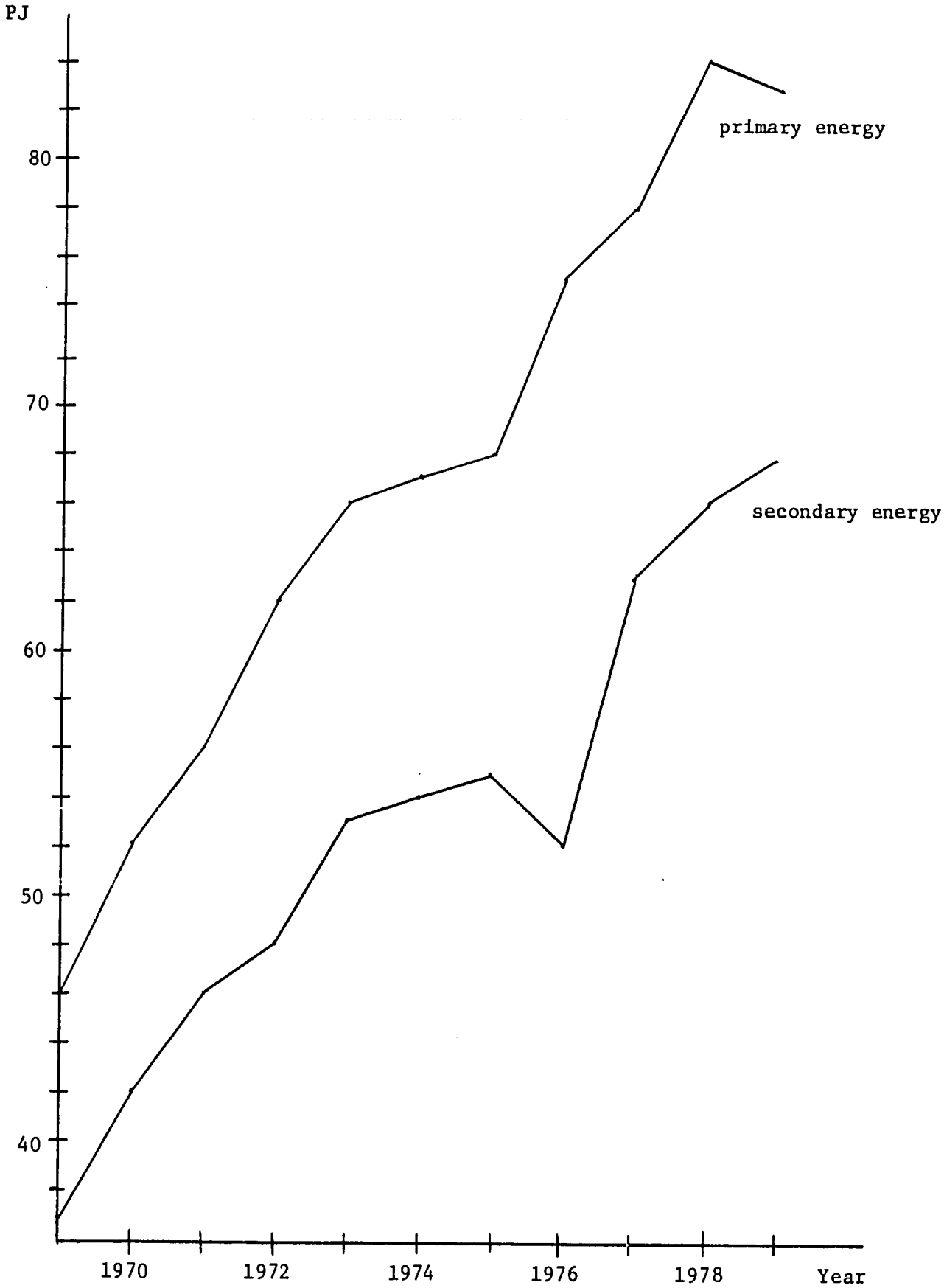

Figure 2-1. Primary and Secondary Energy Consumption

in Kenya was much more rapid than in industrial countries but very similar to the rates experienced in many other developing countries over the same period.

As figure 2-1 also shows the overall rise in energy consumption was not steady. Before 1973, energy consumption rose very sharply indeed by over 10 percent a year. Between 1973 and 1975 consumption stabilized. After 1976 consumption started rising again by an average of 8 percent annually.

Kenya depends essentially on two forms of commercial energy--oil and electricity. Coal consumption is very small, accounting for 2 percent of the total. The modernization of the railroad, and the dissolution of the East African Community, which split off the Kenyan Railways from what had been a larger operation, reduced even further the railroad demand for coal.

Petroleum Products. Oil products provide 90 percent of total final consumption. All of the oil consumed is imported. Since all coal and oil, as well as some hydroelectricity are imported, Kenyan energy dependence is very high; foreign sources provided 88 percent of total primary energy supply in 1979 down only slightly from the 93 percent figure provided from abroad in 1969. Petroleum imports substantially exceed domestic consumption due to the large export of refined products to neighboring countries. In 1969 net petroleum exports were 50 percent larger than local consumption. Over the years this balance has changed and now net exports are equivalent to about one-half domestic consumption. The Kenyan refinery operation also means that refinery uses of petroleum are a significant part (about 5 percent) of total domestic consumption.

This trade in petroleum products is of major importance to the Kenyan economy. Table 2-2 reflects the stress on external trade balances imposed by increases in the price of imported petroleum. From 1970 to 1979, the cost of imported petroleum fuel and lubricants increased from 9.4 percent to 23.7 percent of total import costs, primarily as the result of increases in price (5KL/ton vs. 39KL/ton) rather than increases in import quantity (2,206,000 vs. 2,369,000 tons). At the same time, of course, the East African Oil Refinery in Mombasa generated foreign exchange through the sale of refined oil products, which rose from 11 percent of total exports in 1970 to 17 percent in 1979.

Table 2-2. Kenyan Balance of Trade, 1970-1979
(Millions of Kenyan pounds)

	1970	1975	1977	1978	1979
Total Imports	158.0	362.9	531.4	661.2	619.7
Petroleum products	14.8	95.8	117.1	117.8	146.8
(percentage of total)	(9.4)	(26.4)	(22.0)	(17.8)	(23.7)
Total Exports	108.8	238.0	501.8	395.7	412.8
Petroleum products	12.3	48.7	72.4	60.3	68.0
(percentage of total)	(11.3)	(20.5)	(14.4)	(15.2)	(16.5)
Total trade balance	-49.2	-124.6	-29.6	-265.5	-206.9
Petroleum trade balance	-2.5	-47.1	-44.7	-57.5	-78.8

Source: Economic Survey 1980 (Nairobi).

Proceeds from exports of refined products help finance oil import bills. At the beginning of the period the petroleum trade balance was very small; the deficit was about 0.5 percent of GDP. Since then the situation has generally deteriorated. In 1978 and 1979 oil exports as a percentage of total oil imports fell rapidly, both because of reduced foreign demand for this exported fuel and a corresponding growth in domestic energy demand. By 1979 the net trade deficit in petroleum products amounted to KL78.8 million or 4.0 percent of GDP.

Electricity. Total electricity consumption rose rapidly over the period--by more than 8 percent a year. Again such rates of growth are typical and even somewhat low for countries in an early stage of development. In Kenya, hydropower is more important than thermal generated electricity, accounting for about 80 percent of the total. Imports from Uganda provide an important contribution to the overall energy balance in Kenya. The ample Ugandan hydroelectric resources, little used because of the economic stagnation accompanying the recent political instability there, have been sold to Kenya at very low cost. This has been an important source of foreign exchange for Uganda, and had provided valuable

electric power to Kenya. However, as the Ugandan economy stabilizes, there will be less electricity available for export to Kenya.

Thermal generation (based entirely on oil) increased steadily up to 1973 but then fell back sharply in response to higher oil prices. The poor rains of 1976/77 led to a virtual doubling in generation in 1976 but since then it has fallen back to the 1974 level. About 10 percent of the total thermally generated electricity is self-generated by industrial users.

Population and Demographic Trends

A substantial part of the rapid increase in energy consumption is related to population growth. Both the rate of population growth and of fertility in Kenya are among the highest in the world. According to a report prepared by the U.S. Bureau of the Census (1980), Kenya's population grew by an average annual rate of 3.3 percent between 1950-77. Kenyan women have an average of 8 children in their lifetime. Even more striking, since 1950 the population growth rate in each quinquennium has been accelerating. During 1950-55 the five year annual growth rate was 2.8 percent. In the 1970-75 period annual population increases were 3.6 percent. World Bank data show that the population grew from 11.2 million in 1970 to 15.3 million in 1979, an annual increase of almost 3.7 percent. Part of the rise in energy consumption is related to population growth. In addition, per capita energy consumption rose by an average of 2 percent a year (see table 2-3).

Of major relevance to commercial energy consumption, the percentage of the population living in urban centers increased sharply. Although the population is still overwhelmingly rural, the percentage of Kenyans living in towns of greater than 2,000 inhabitants has risen from 10 percent in 1969 to about 15 percent today. The average growth rate in towns of more than 10,000 inhabitants since 1969 has been 7 percent/year, almost twice the rate of increase of the population as a whole. This has important implications for commercial energy use since urban populations are now able to afford the superior commercial fuels at the same time that supplies of traditional fuels are more difficult to obtain.

The population will continue to rise rapidly in the future. Half of the present population is under the age of 15. If growth were to continue at the present rate, the population in the year 2000 would be 34 million.

Table 2-3. Trends in Population Growth and Energy Consumption, 1970-1979

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Annual growth rate (%) 1970-1979
Energy consumption (PJ)	51.9	57.1	61.9	66.1	67.0	68.7	75.3	79.3	83.8	83.6	5.4
Population (10^6)	11.2	11.7	12.1	12.5	12.9	13.4	13.9	14.4	14.7	15.3	3.5
Energy per capita (GJ)	4.6	4.9	5.1	5.3	5.2	5.1	5.4	5.5	5.7	5.5	2.0

Source: Table 2-1 of this report; and World Bank, Atlas (Washington,D.C., World Bank) (various issues).

Based on the trend of the past decade, over a quarter of those people would live in urban areas. These trends provide a powerful momentum for further rapid increases in per capita energy consumption.

Economic Activity

Energy consumption is also related to the level and composition of economic activity. Table 2-4 gives data on Kenya's GDP in constant 1972 Kenyan pounds for 1970-79. The average rate of growth over the period is 4 percent annually. Though the course of growth was rather uneven, the 1973 oil shock appears to have significantly depressed the economy. Real growth fell from 5.5 percent in 1973 to about 2.4 percent in the following two years. The economy recovered in 1977 as a result of the world coffee boom, but since then Kenya has experienced low rates of growth. In 1979 the annual growth rate was again below 3 percent stemming from relatively low worldwide market prices for coffee and tea, substantial increases in the cost of imported petroleum, and declines in agricultural output due to adverse weather conditions.

Table 2-4. Real Gross Domestic Product, GDP Per Capita and Energy/GDP Ratio.

	Real GDP		GDP per capita		
	Millions 1972-KL[a]	Annual growth rate (percent)	(KL)	Annual growth rate (percent)	Primary Energy/GDP (MJ/KL)
1970	593.6	--	53.0	--	87.4
1971	603.1	1.6	51.5	-2.8	94.7
1972	632.3	4.8	52.3	1.6	97.9
1973	667.2	5.5	53.4	2.1	99.1
1974	685.4	2.7	53.1	-0.6	97.7
1975	700.0	2.1	52.2	-1.7	98.1
1976	732.0	4.6	52.9	1.3	102.9
1977	800.2	9.3	55.0	4.0	99.1
1978	835.5	4.4	56.8	3.3	100.3
1979	859.4	2.9	56.2	-1.1	97.3

Source: GDP data derived from World Bank, Kenya: Into the Second Decade (Baltimore: Johns Hopkins University Press, 1975); Central Bureau of Statistics, Statistical Abstract 1979 (Nairobi) and Economic Survey 1980 (Nairobi); Population data from table 2-3 and energy data from table 2-1, this report.

[a]KL = Kenyan pounds.

Given the rapid rise in population, these relatively modest rates of economic growth imply quite low--about 1 percent--increases in annual *per capita* income between 1970-79. This rate of increase is lower than most developing countries but about average for Africa, falling between the high growth economics of North Africa and the negative growth economies in much of southern Africa.

The composition of economic activity also affects energy consumption. Rapid increases in output of the energy-intensive industrial sector relative to less energy-intensive agriculture could lead to increases in energy consumption well in excess of GDP. During the 1970s, however, the structure of the Kenyan economy, as measured by the percentage shares of various sectors in GDP, did not change dramatically. The figures in table 2-5 show that the shares of the agriculture, construction, and manufacturing sectors increased slightly, while the shares of transportation and communications decreased. Agriculture continues to be the dominant sector of the GDP, accounting for about one-third of total GDP and employing about three-quarters of the country's labor force. As we shall see in the next

Table 2-5. Total GDP by Source at Current Prices, 1970 and 1979

	1970		1979		1970-79 Annual growth rate
	(Million KL)	(percent)	(Million KL)	(percent)	(percent)
Agriculture, forestry & fishing	173.0	33.1	679.0	34.4	16.4
Mining & quarrying	2.4	0.5	5.0	0.3	8.5
Manufacturing	62.2	11.9	249.8	12.6	16.7
Electricity & water	12.0	2.3	42.3	2.2	15.0
Construction	62.4	5.1	117.5	5.9	7.3
Wholesale & retail trade, hotels & restaurants	55.8	10.7	209.2	10.6	15.8
Transport & communication	40.8	7.8	114.7	5.8	12.2
Government services	76.5	14.7	290.3	14.7	16.0
Other services	72.8	13.9	267.2	13.5	15.5
Total GDP factor cost	521.9	100.0	1,975.0	100.0	15.9

Source: Central Bureau of Statistics, Economic Survey 1980 (Nairobi).

chapter, changes within the industrial sector had implications for energy consumption but in general compositional factors may not have had a major influence on energy consumption.

Since the Kenyan economy is relatively small, each of these events had a noticeable impact on the energy/GDP ratio. From an aggregate standpoint, therefore, we can observe a leveling in the energy/GDP ratio since 1973, with yearly variations explained in part by exogenous factors.

Energy Prices

The movement of these indicators points to the effect of energy prices. As is well known, the real price of imported crude oil rose five-fold between 1970 and 1979. The rise in prices of petroleum products to final consumer was, however, much less (see table 2-6). The price of gasoline doubled in real terms between 1973 and 1980, gasoil rose by 80 percent and kerosine by 70 percent. The price of LPG and electricity, however, stayed constant in real terms. A combined index of energy prices would show retail energy prices rising by 70 percent over this period and wholesale energy prices by 150 percent.

While the rise in consumer energy prices was therefore much lower than the rise in prices of imported oil, it was nevertheless substantial and appears to have had a significant effect on consumption and on the economy. Thus energy consumption, GDP per capita and the energy/GDP ratio rose sharply in the early 1970s (see figure 2-2). In the two years after 1973, both energy consumption and GDP fell by a similar amount so that the energy/GDP ratio flattened out. Subsequently both energy consumption and economic growth recovered, but unlike the pre-1973 period, energy consumption rose in line with GDP per head, not faster, implying a moderating effect of high prices on energy consumption. The influence of energy prices is again illustrated in 1979 when energy consumption, GDP per head, and the energy/GDP ratio all fell.

There were in this period many other developments which can influence energy consumption--political difficulties with neighboring countries, good and bad harvests, and commodity markets which still remain for an agricultural country like Kenya a major determinant of economic activity. It is in practice impossible to weigh the contribution of these individual factors to change in energy consumption over such a short period. The

Table 2-6. Real Energy Prices, 1973-1980 (1972)(KSh)[a]

	Nairobi Wholesale Prices					
	Premium gasoline (KSh/liter)	Gasoil, auto diesel fuel (KSh/liter)	Heavy diesel fuel (KSh/liter)	Jet turbo fuel (KSh/liter)	Residual oil (KSh/liter)	Electricity (KSh/kWh)
Feb. 1973	1.06	.71	.40	.50	.27	.162
June 1974	1.37	1.01	.72	.57	na	na
June 1975	1.62	1.05	.70	.79	na	.163
March 1976	1.68	1.17	.84	1.39	.60	na
April 1977	1.47	1.03	.75	1.39	.60	na
June 1977	1.47	.99	.72	.97	.53	.175
June 1978	1.56	1.09	.73	na	.54	.171
April 1979	1.55	1.06	.72	na	.55	na
June 1979	1.67	1.04	.71	na	.55	na
June 1980	2.29	1.37	.95	na	.76	na

	Nairobi Retail Prices				
	Regular gasoline (KSh/liter	Gasoil, auto diesel fuel (KSh/liter)	Illuminating kerosine (KSh/liter)	LPG (KSh/liter)	Electricity (KSh/kWh)
June 1973	1.43	1.06	.82	2.71	.328
June 1974	2.08	1.46	1.18	3.54	.293
June 1975	2.14	1.46	1.13	3.34	.290
April 1977	2.03	1.49	1.22	2.97	.283
June 1978	2.07	1.50	1.13	2.63	.256
April 1979	2.10	1.54	1.17	2.63	.286
June 1980	2.68	1.84	1.39	2.64	.302

Note: na = not available

Source: Fuel prices provided by Shell except for turbo which is from the Statistics of Energy and Power, Table IV. Retail electricity prices for 1979 and 1980 estimated from EAPL tariff information derived from average revenue over normal domestic electricity customers.

[a]Wholesale prices deflated by the GDP deflator and retail prices by a consumer price indes for middle income families living in or near Nairobi. Prices given in Kenyan shillings.

evidence, however, suggests that increases in energy prices in 1973 were a major cause of the decline in per capita energy consumption and in the energy/GDP ratio in those years. This finding has important implications for conservation potential.

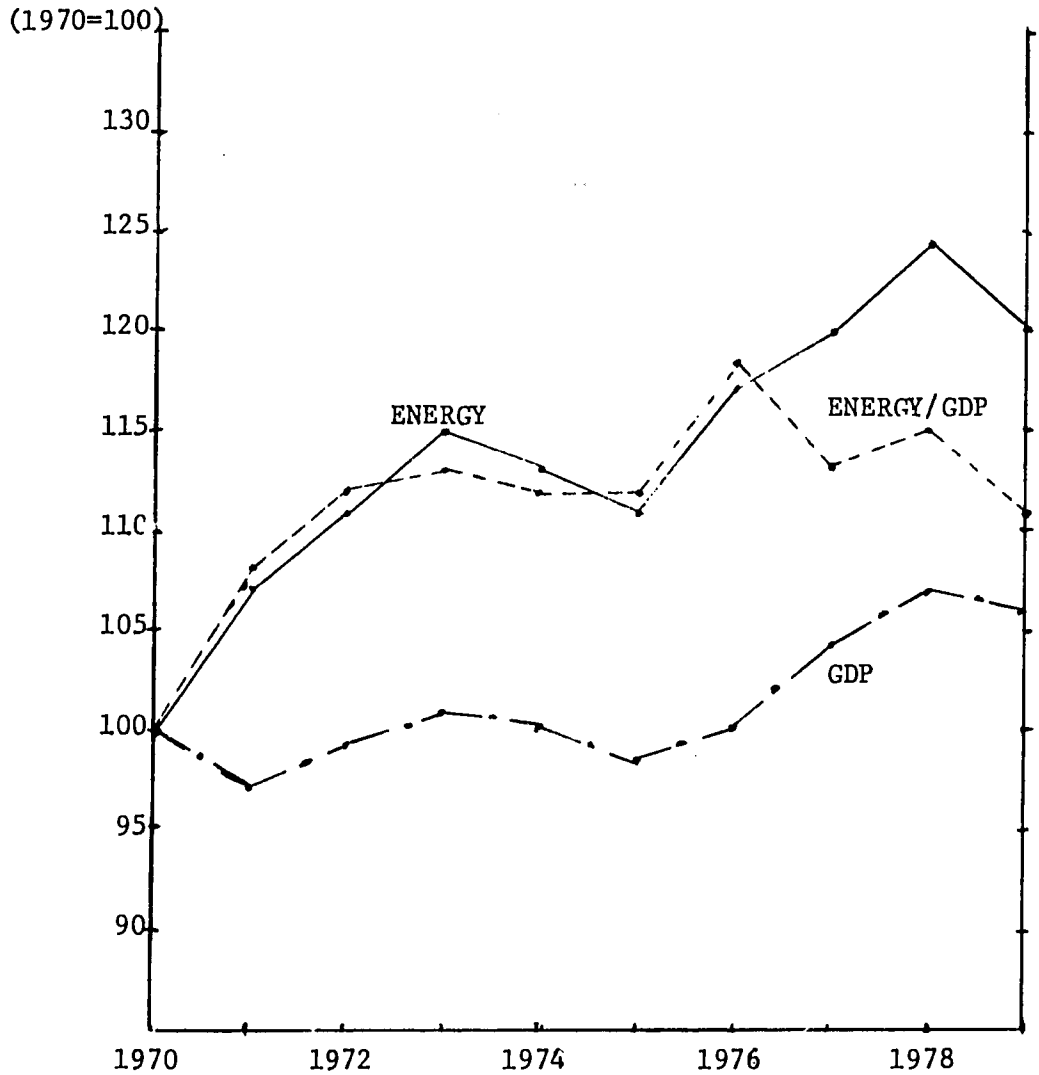

Figure 2-2. Per Capita GDP, Energy Use Per Capita and Primary Energy/GDP

Chapter 3

SECTORAL ENERGY USE ANALYSIS

The identification of energy conservation potential within a country requires detailed energy consumption data at the sectoral and individual use level. Because of their highly aggregated nature and lack of detail about use categories, the Official Energy Balances--even with our modifications--were of limited utility for end-use analysis. We therefore undertook new surveys of energy use. Our methodology, which will be of particular interest to those undertaking energy assessment in other developing countries, is described in detail in Appendices A-F. In brief, we met with representatives of all the major oil companies, the electric power company, suppliers of solar water heating equipment, industrial consumers and some important users of transportation fuels. Using the information obtained from these sources, we were able to disaggregate total Kenyan industrial and commercial energy use for one year in some detail. The power company data were the most complete; the oil company (Shell/BP) data covered perhaps 50 percent of industrial fuel use; and the supplier and user data covered up to 100 firms and institutions. Unfortunately, it was necessary to extrapolate product use by sector from the Shell data to the entire economy as detailed in Appendix C. These data were aggregated by activity (where possible) to correspond to economic indicators of output given in the Statistical Abstract (1979).

For measures of output, we relied on indices of output for large firms published in the Statistical Abstract, as well as information supplied during interviews with individual energy users. These output measures were then used to relate fuel and electricity consumption in each sector or industry to economic activity in that sector or industry. Our data on indices and quantity of output are unfortunately not complete, but time constraints prevented further data gathering.

Total Energy Flow

Table 3-1 presents the Kenyan energy flow for 1979 by sector and by fuel. The disaggregation of consumption by fuel type within each sector by fuels is based upon Shell data only, and is therefore approximate. Where industry data are the product of extrapolation, disaggregation cannot distinguish among fuel types. In such cases, we present figures for total fuel use.

While Shell supplied fuel data from as early as 1972, data on individual users were not as complete for 1977 as for 1979. Therefore, we found it impossible to make the same industry-by-industry breakdown for the years before 1979. However, we did repeat our sectoral breakdown procedure for 1977, modifying our results with figures obtained from oil companies for resale (residential) kerosine and LPG, consumption of fuel by East Africa Power and Light Company (EAPL), EAOR, and Kenyan Railways, and separating transportation and commercial energy use into a few well defined subsectors. These breakdowns are shown in Appendix C, table C-1.

From table 3-1 we see that the major end user of energy is the transportation sector, currently accounting for 50 percent of the total energy consumption in Kenya. This is an exceptionally high share. In most of the developing countries, transportation accounts for about 20-25 percent of the total. All of the energy consumed in this sector is now in the form of liquid fuels. In fact, the transportation sector consumed fully 53 percent of Kenyan liquid fuel supplies in 1979. Although motor vehicle transport accounts for the largest single use in this sector--20.7 petajoules--the combined petroleum requirements of domestic and international aviation run a significant second at 15 petajoules, almost all consumed as jet fuel. Again, the percentage of consumption accounted for by aviation is exceptionally high. This results from Nairobi's position as a major airport in a north/south air corridor.

Table 3-1. Composition of Energy Use in Kenya, 1979
(Terajoules)

Sector	Fuel									Total fuel	Electricity[b]	Solar	Total energy
	LPG	Gasoline	Jet fuel	Auto-diesel	Kerosine	Heavy oils[a]	Aviation gas	Crude oil losses	Coal				
Residential	540.0				2849.0					3480.0	1029.6	1	4510.6
Commercial	245.5			106.0	102.0	463.0				916.5	1307.3	5	2228.8
Schools & Hospitals										276.0	126.1		
Hotels										509.8	157.8		
Other										130.7	1023.4		
Industrial	144.5			1571.6	725.0	11980.0			1310.0	15730.6	2155.7		17886.3
Energy				182.8		3995.2		4730.0		8909.0	193.8		8140.0[c]
Refinery								4730.0		4730.0	140.3		
Electric powerplants				182.8		3995.2				4178.0	53.5		
Pipeline													
Construction	0.2			762.7	4.8	34.8				802.5	27.0		829.5
Agriculture	0.3	543.8		4620.8	74.0	1329.8				6568.7	107.0		6675.7
Transportation		13881.7	14748.5	8771.2	28.7	2158.4	255.6			39844.1			39844.1
Road		13878.0		6769.2	28.5	6.5				20682.2			
Int'l aviation			13273.7							13273.7			
Domestic aviation			1424.8				255.6			1730.4			
Rail				1510.0		1045.0				2555.0			
Marine		3.7		492.0	.2	1106.9				1602.8			
Other									330.0	330.0			330.0
Total	930.5	14425.5	14748.5	16015.1	3874.2	19961.2	255.6	4730.0	1640.0	76582.3	4820.4	6.0	80445.0[d]

Source : Survey as described in appendices.

[a] Includes industrial diesel oil and fuel oils.

[b] Electricity counted at 3.6 MJ = 1 kWh and therefore reflects end use consumption.

[c] Includes only losses incurred in electric power production and in oil refineries.

[d] Total refers to column, not addition of row entries. See footnote c.

The industrial sector is second to transportation in total energy consumption. About 21 percent of Kenyan fuel supplies and about 45 percent of total generated electricity are consumed in the industrial sector.[1] Seventy-five percent of industrial fuel use is in the form of diesel oil and fuel oils used in boilers to generate process steam.

As noted in Chapter 2, the energy sector incurs large losses in both the generating of electricity and the refining of petroleum products. Consequently, 10 percent of Kenya's total energy use is in the energy transformation sector.

The residential and the commercial sectors together account for about 8 percent of total commercial energy consumption. These two are major consumers of electricity, accounting for about one-half of the total used in Kenya. They consume only about 6 percent of all fuels however. Many household tasks such as cooking are performed in Kenya with noncommercial fuels, wood and charcoal. Residential and commercial are the only sectors in which solar energy is used (see below).

Industrial and Commercial Sectors

Industrial and commercial energy use, which is the major focus of this report, is dominated by oil and electricity, though a few firms use coal and several utilize wastes from sawmills or agricultural operations. In the industrial sector liquid fuels dominate (on a calorific basis), while in the commercial sector electricity and liquid fuels have nearly equal shares (see table 3-1). In the industrial sector, a few industries--cement, oil refining, paper--account for a disproportionate share of fuel and electricity use. These firms produce important raw materials for the rest of the Kenyan economy, and export a substantial fraction of their production. We examined these industries in considerable detail. In the commercial sector, liquid fuel use is concentrated in hotels, schools, hospitals, and laundries, while electricity is used in both these and other establishments where fuel use is small, such as office buildings, warehouses, and pumping.

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1. Note, however, that electricity use accounts for only about 6 percent--5 PJ out of a total 81 PJ--of Kenya's total energy consumption.

Electricity use in the industrial and commercial sectors is well documented by EAPL. For many years they listed the consumption of each large customer (over 7000 kWh/month) in their billing records under Tariff 4 (Commercial) and Tariff 5 (Industrial). Business customers using less than this amount were grouped in Tariff 3 (Small Commercial). Starting in 1979 several user groupings were combined, which makes it difficult to separate residential consumption from that of small shops. We estimated the consumption by small shops in 1979 on the basis of data supplied by EAPL showing the numbers of consumers in different consumption intervals.[2] Total commercial and industrial electricity use is shown in table 3-2. For completeness we include official estimates of electricity generated by industrial establishments using commercially purchased fuels, noncommercial biowastes, and hydroelectric generators. To avoid double counting, this self-generated electricity is omitted from the overall totals of purchased energy shown in tables 3-1 and 3-6.

Industry consumes one-half of all electricity used by the agricultural, commercial and industrial sector. Within industry, the largest call for electricity is in the food processing industry, primarily for pumping and refrigeration. In this industrial subsector there were 121 establishments using 148 GWh or electricity at an average of 1.23 GWh per user. On contrast, the cement industry consumed 124 GWh in 1979, primarily in grinding operations, but the majority of energy consumption was distributed among only five accounts. Consequently, the average electricity use per establishment was about 25 GWh. The other major electricity users in the industrial sector are the textile manufacturers.

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2. Based upon pre-1979 EAPL sectoral breakdowns, we estimate the consumption of electricity by small shops for manufacturing and services to be 132.7 GWh; this is considerably less than that for heavy industry, but comparable to the services sector. As these shops produce a variety of non-energy-intensive materials and goods, their energy/output ratio is probably very low, hence their contribution to the GDP may be considerably higher than their energy share suggests. When the tariffs were revised in 1979 many firms formerly classified as shops and light industry were moved into the main commercial/industry tariff, greatly increasing the number of customers in this category. As a result, comparison of Tariff B + C with earlier years' data (Tariffs 4 + 5) is not possible at this time.

Table 3-2. Agricultural, Commercial and Industrial Electricity Use in 1979

Sector	Consumption (GWh)	Percent of Total
Agriculture	27.93	2.5
Forestry, Fishing	1.90	0.21
Mining	6.13	0.5
Industry	528.58	47.0
Food Processing	148.47	
Textiles, Clothing	80.57	
Wood Mfg.	8.81	
Paper Mfg.	23.74	
Printing	11.16	
Rubber Mfg.	15.71	
Chemical Mfg.	19.56	
Plastic Products	19.35	
Glass Mfg.	9.65	
Cement Mfg.	123.97	
Other Non-Metallic Mfg.	5.68	
Basic Metals Mfg.	32.02	
Machinery Mfg.	24.14	
Transport Mfg.	5.65	
Construction	1.34	0.1
Refining, Pipeline	55.47	4.9
Services	181.16	16.1
Public Services	20.04	
Commercial Trade	1.79	
Offices and Banks	22.67	
Transport Services	33.49	
Storage, Warehousing	5.25	
Communications	15.91	
Miscellaneous Services	16.64	
Restaurants	.55	
Educational Services	16.64	
Medical Services	18.39	
Hotels	45.38	4.0
Game Lodges	1.06	
Hotels	42.78	
Hostels and Clubs	1.54	
Small Shops, Industry	132.72	11.8

Table 3-2 (continued)

Sector	Consumption (GWh)	Percent of Total
Off-Peak Non-Residential	60.00	5.3
Street Lighting	10.00	0.9
Unclassified and Other	5.13	0.5
Total Electricity Sales	1055.72	93.8
Self Generation (not counted by EAPL)[a]	70.00	6.2
Total Agricultural, Commercial and Industrial	1125.72	100.0

Source: See text of Appendix D.

[a]Self-generation, estimated by Ministry of Power and Communications, includes sawmills, sugar mills, and paper mills, commercially purchased fuels and hydroelectric generators.

Outside industry, the major consumers of electricity are services (16 percent of total), small shops and industry (12 percent), and hotels (4 percent).

The use of electricity by industry is encouraged by low tariffs. The tariffs, which are always substantially below the national average, declined by about 20 percent in real terms from 1972 to 1978. Tariffs paid by both large and small commercial users are rather higher than the national average but here too they have declined by 20 percent since 1972.

Fuels. From table 3-1 it will be recalled that industry accounted for 20 percent of all fuel consumption, the energy sector for 12 percent, and agriculture for 9 percent. Use of fuel by the commercial sector is only 1 percent.

Within the industry sector (see table 3-3), the cement industry is the largest consumer, accounting for one-third of industrial fuel consumption.

Imported coal is also used in large quantities by a cement mill and in smaller amounts elsewhere.[3] The cement industry includes only a small number of companies, yet consumes more energy (fuels and electricity) than any other industry. By contrast, the food industry, which is next to cement in terms of energy use is represented by over 100 firms of varying sizes. The large number of firms reflects the domestic demand for food products, as well as exports of processed agricultural and food products such as coffee, canned fruits, and meat. Opportunities for energy conservation are large in both industries, but energy use is considerably more dispersed in the food industry. This dispersion may make energy conservation somewhat harder to achieve.

The other major consumers of fuel are textiles and paper. Together, the cement, food, textiles and paper industries account for 75 percent of all industrial consumption of fuels, as well as 63 percent of electricity used by industry.

The traditionally highly energy-intensive steel industry accounts for only 2 percent of industrial fuel use, and about 10 percent of industrial electricity. This unexpectedly small consumption of fuel is due to the use of scrap or billets rather than iron ore for feedstock. Of the two feedstocks in use in Kenya scrap steel requires more energy for ingot production than billets, yet scrap costs less than billets, which are imported. One manufacturer is progressively increasing the percentage of scrap in his feedstock, raising energy use considerably, in order to reduce overall costs.

Sectoral Energy Intensities

In order to estimate the energy intensity of the subgroups of the industrial sector, these data on energy consumption must be related to measures of output, in this case value added by the various industries expressed in constant (1972) Kenyan pounds. This is done in table 3-3.

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3. Consumption data for coal were published in the Statistics of Energy and Power through 1977, and through 1979 in the Economic Survey. Unfortunately, the 1979 figure, 11 million tons oil equivalent, seems low, either because information was not complete or because of a misprint. We have adjusted this quantity upwards for 1979 from the ratio of the cement mill's usage to total coal used in 1978.

Table 3-3. Energy/Industrial GDP Ratios by Industry, 1979

	Energy use (TJ)			Industrial GDP (Million 1972 (KL)	Energy/GDP (GJ/thousand 1972 KL)		
	Fuel	Electricity	Total		Fuel	Electricity	Total
Food	3217	535	3752	54.06	59.5	9.9	69.4
Textiles	1354	290	1644	11.79	114.8	24.6	139.4
Paper	1684	86	1770	6.06	277.9	14.1	292.0
Industrial chemicals	837	70	907	5.01	167.2	14.1	181.3
Rubber	281	57	338	3.68	76.4	15.4	91.8
Clay and glass[a]	794	37	831	.62	1280.6	60.3	1340.9
Cement[b]	5570	446	6016	4.70	1185.1	95.0	1280.1
Metal products[c]	330	202	532	18.55	17.8	10.9	28.7
Transportation equip.	96	20	116	16.86	5.7	1.2	6.9
Miscellaneous[d]	1568	412	1980	13.66	--	--	--
Total	15731	2155	17886	134.99	116.5	16.0	132.5

Note: Energy/GDP ratios based on more detailed data than shown above.

[a]Energy data only for the glass industry.

[b]Fuel data exclude an estimated 1310 TJ of coal consumption. Industrial GDP for non-metals manufacturing.

[c]Includes both raw steel and finished products.

[d]Energy/GDP figures omitted since both energy and electricity consumptions are residuals.

Clay and glass is by far the most energy-intensive industry, followed by cement. The least energy intensive are food, transportation equipment and metal products. Textiles, paper and industrial chemicals are moderately energy intensive. By and large, those industries which are fuel intensive are also electricity intensive.

Consumption of industrial energy depends both on energy/output ratios and growth rates of each individual industry (see table 3-4).[4] Comparing the two we see that the two most energy-intensive industries are growing relatively slowly. Output for the glass industry (1,281 GJ/thousand kl) has less than doubled since 1972 while that for cement (1,185 GJ/thousand kl) has increased by only 43 percent over the 1972-79 period. The moderately energy intensive paper industry (270 GJ/thousand kl), by contrast, grew by over 140 percent since 1975, in part to meet export demand. The fastest growing Kenyan industry, transport equipment, which has grown more than six-fold since the early 1970s, has the lowest energy intensity of those industries listed, only 5.7 GJ/thousand kl. If trends in industrial growth continue as in the past, the average energy-intensiveness of the industrial mix may decline.

Transportation Sector

Total transportation fuel use was inferred from data provided by Shell and other oil companies. The division between wholesale and retail sales of the various fuels is known; we have estimated allocations of automotive diesel fuel and stationary fuel uses (for example, buildings). Although an accurate division of fuel use by road transport mode was not possible, data from some trucking and bus companies did allow us to arrive at partial totals. The quantities of each kind of fuel consumed in 1979 are shown in table 3-1. The figures for 1977 are shown for comparison in Appendix C.

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4. Figures for GDP by industry were not actually published for 1979, and for 1977 only for large industries. Therefore, we approximated this breakdown by noting the corresponding 1977 GDP figures given in the Census of Industrial Production, and multiplying each industry's output by the 1979 index of physical output (shown in table 3-4, which is a measure of real output growth since 1977. This procedure is somewhat inaccurate since relative price changes among the outputs of different industries can be appreciable, particularly for energy-intensive industries such as refining, cement, and paper.

Table 3-4. Quantity Indices of Manufacturing Production (1972=100)

	1975	1976	1977*	1979*
Food Manufacturing	123	151	163	167
Beverages and Tobacco	136	146	170	192
Textiles	143	141	184	215
Clothing	85	101	150	237
Leather and Footwear	184	181	190	182
Wood and Cork Products	141	135	153	176
Furniture and Fixtures	95	93	105	87
Paper and Paper Products	88	141	170	220
Printing and Publishing	148	1576	238	335
Basic Industrial Chemicals	89	84	76	126
Petroleum and Other Chemicals	117	133	151	182
Rubber Products	103	146	170	204
Plastic Products	244	310	383	610
Clay and Glass Products	96	77	170	190
Non-Metallic Minerals, Cement	114	124	144	143
Metal Products	118	178	207	240
Non-Electrical Machinery	65	48	50	46
Electrical Machinery	139	159	193	243
Transport Equipment	102	111	178	663
Miscellaneous Manufactures	107	123	137	129
Total Manufacturing	121	143	165	199

*Provisional

Source: Derived from Central Bureau of Statistics, Economic Survey 1978, Table 11.2, and 1980, Table 11.2 (Nairobi).

It may appear surprising that, according to our analysis, the transportation sector is by far the largest consumer of fuels in Kenya. However, this is due in part to our having limited the accounting to commercial fuels. As transportation uses essentially no noncommercial fuels, our accounting of fuel uses in this sector is virtually complete. By contrast, the industrial sector still uses a considerable quantity of renewable and traditional fuels; this is one reason for its relatively smaller share of commercial fuel consumption. More important, the transportation sector in Kenya is large because of the importance of Nairobi as a hub for road, rail, sea, and air travel throughout East Africa and the western Indian Ocean.

Within this sector, jet fuel is the most heavily used fuel type. Kenya's tourist economy relies on continual traffic of intercontinental jet aircraft, and the Nairobi airport has become a focal point for African air travel.[5] Jet fuel is often counted as an export, because it is sold to foreign carriers, but the importance of tourism for the domestic economy suggests that jet fuel should not be left out of the domestic accounting. When jet fuel is removed entirely from the balance, the transportation sector falls considerably in relative importance. In our analysis we counted the full quantity of jet fuel consumed with the domestic transportation sector.[6] Using air traffic statistics, we estimate that at most 10 percent of the turbo fuel and essentially all of the aviation gasoline "avgas" used in Kenya are for domestic flights.

The role of Kenya as a focal point for African transportation also extends to truck freight, since virtually all movements of freight to Uganda, Rwanda, and Burundi, as well as some shipments to and from Zaire, transit Kenya. Two-thirds of the liquid fuels consumed in road transport are gasoline, and the balance autodiesel used in the extensive truck traffic. The large share of gasoline in the liquid fuel balance is more difficult to explain. One possible explanation is that the vehicle fleet using gasoline is very inefficient.[7] A more likely explanation is that the distance travelled by gasoline-consuming light trucks and matatu (the Kenyan equivalent of a jitney or minibus) are significantly underestimated.

Unfortunately, we do not have corresponding measures of transportation sector activity to relate to these data on transportation. But some

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5. A similar situation exists in Hawaii, where jet fuel accounts for roughly 30 percent of the energy consumed or sold in Hawaii.

6. An alternative, though not commonly used, accounting scheme would be to apportion jet fuel between inland consumption and bunkering by taking the ratio of embarking passengers to total passengers traveling through Nairobi, in order to make consumption figures reflect actual arrivals of passengers who stay in Kenya.

7. If we presume that 80 percent of the gasoline is used by automobiles traveling roughly 850 million km, then automobiles require 0.4 liters of fuel/km. This is a very high figure by international standards. By comparison, the U.S. auto fleet requires about 0.16 l/km, and fleets in Europe average near 0.1 l/km.

general conclusions about transportation activity can be drawn from the accompanying graphs. The level of transportation activity is sensitive to the overall performance of the economy. Indeed, most of the indicators grew more rapidly than GDP. The high economic growth of 1977 and 1978 were reflected in increases in truck freight movements (from 1.17 billion km in 1975 to 1.6 billion km in 1978) and automobile and rail passenger traffic (figure 3-1).

Between 1972-75 auto ownership (not graphed) was rising at 7.4 percent per year, but at only 4.8 percent after 1975. Yet as seen in figure 3-1 the slowdown in auto ownership has been more than compensated for by an increase in total vehicle kilometers traveled. The most notable exceptions to this general expansion, rail freight (down from 2.18 billion ton/km in 1976 to 2.01 billion in 1979; not graphed in figure 3-1) and aircraft passenger movements, were affected by the border closing with Tanzania and the political disruptions in Uganda. The recent decrease in the number of flights may be due in part to the introduction of fuel efficient wide-bodied aircraft between Europe and Kenya.

The transportation system is, as we have seen, closely connected with tourism. Available data show a steady growth in tourism with the coastal region surpassing Nairobi as the prime attraction. The number of bed-nights in hotels is also rising rapidly (figure 3-2).

These transportation trends have important implications for energy use for two reasons. First, most transportation activities are more energy

figure 3-1

intensive than the aggregate GDP. And second, truck transport is more energy intensive than the rail transport that it is apparently displacing. Also, the growth of tourism in the coastal region affects electric power use noticeably because of the need for air conditioning in coastal hotels. A better understanding of these trends in transportation and service demands and their energy intensities is important for predicting future energy needs.

Residential Sector

As information on energy consumption in this sector contained in a recent "Household Fuels Survey" (cited in the Economic Survey 1980) was incomplete, we had to rely almost exclusively on energy suppliers for

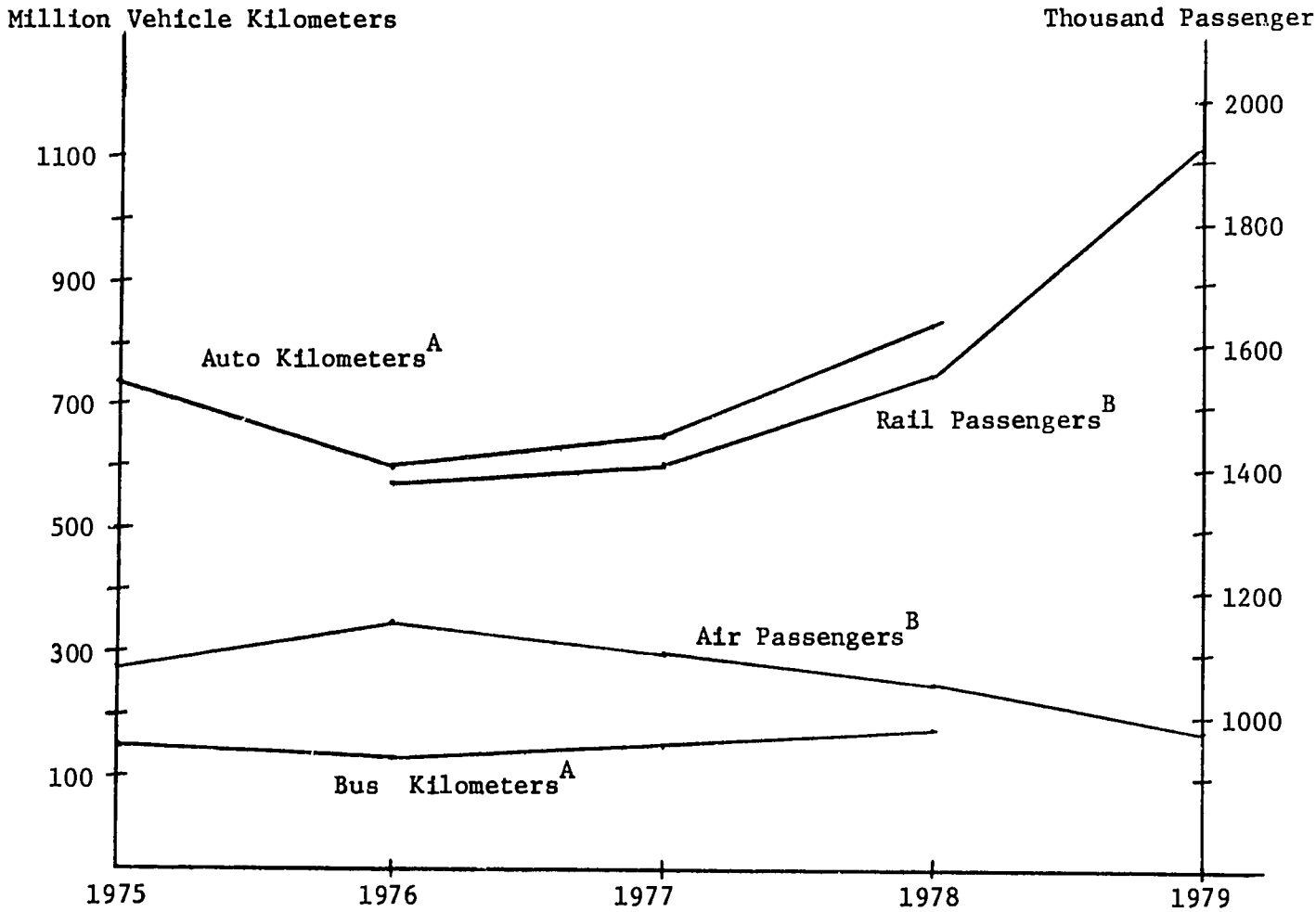

Figure 3-1. Passenger Travel

Sources:

A. Automobile Association, Kenya Road Safety Report, 1980.

B. Economic Survey 1980 (Tables 14.9 and 14.10) and Statistical Abstract 1980 (Tables 174 and 180). ("Air Passengers" is the total number of embarcations and transit passengers in Nairobi and Mombassa).

information to complete our energy balance in the residential sector. A survey by McGranahan and coauthors (1979) examined energy use in a variety of urban households but did not calculate total consumption for the entire country. We found no other independent studies of electricity and fuel use in the modern residential sector, though there is a growing body of literature on energy use in rural households. Most residential electricity consumption was identified as such by EAPL; residential use of fuels was not so identified. Consequently, we inferred this information from quantities of LPG and illuminating kerosine sold in small packages through resale outlets, as reported by each oil company.

The residential sector accounts for 5 percent of total commercial fuel consumption and 20 percent of electricity. On a calorific basis, fuels outweigh electricity. Firewood and charcoal, not treated in this study, are, however, the dominant fuels for residential use in Kenya. Openshaw (1979) estimates that the residential use of these fuels is five times that of the sum of all commercial energy forms. To make an aggregate estimate of the total residential consumption of liquid fuels--kerosine and LPG--we used estimates of country-wide sales from each of the oil companies (see table 3-5). The estimates are based upon sales of packaged kerosine, bulk kerosine sold for resale, as well as gas cylinders. We may have overestimated residential consumption of these two fuels, as they may also be used in small shops.

Our results correlate closely with the preliminary figures from the Household Fuels Survey which indicated a total of 3225 TJ of kerosine consumed in 1978/79. On the other hand, the survey found 755 TJ of LPG consumed in residences, much higher than our estimate (540 TJ). We believe that the survey figure is questionable, as this amount would be over 75 percent of all the LPG used in the country. Total consumption of both of these fuels increased sharply from 1972 through 1979 (see table 3-5). It was not possible to trace consumption per household as we could not determine the number of households using these fuels. The oil companies indicated that there are on the order of 100,000 to 200,000 LPG cylinders in circulation, a portion of which are always at terminals being refilled. This number can be taken as an upper limit of households using LPG. In <u>per capita</u> terms, however, consumption of both fuels rose from 1972 to 1979, by 70 percent in the case of LPG and by 43 percent for kerosine.

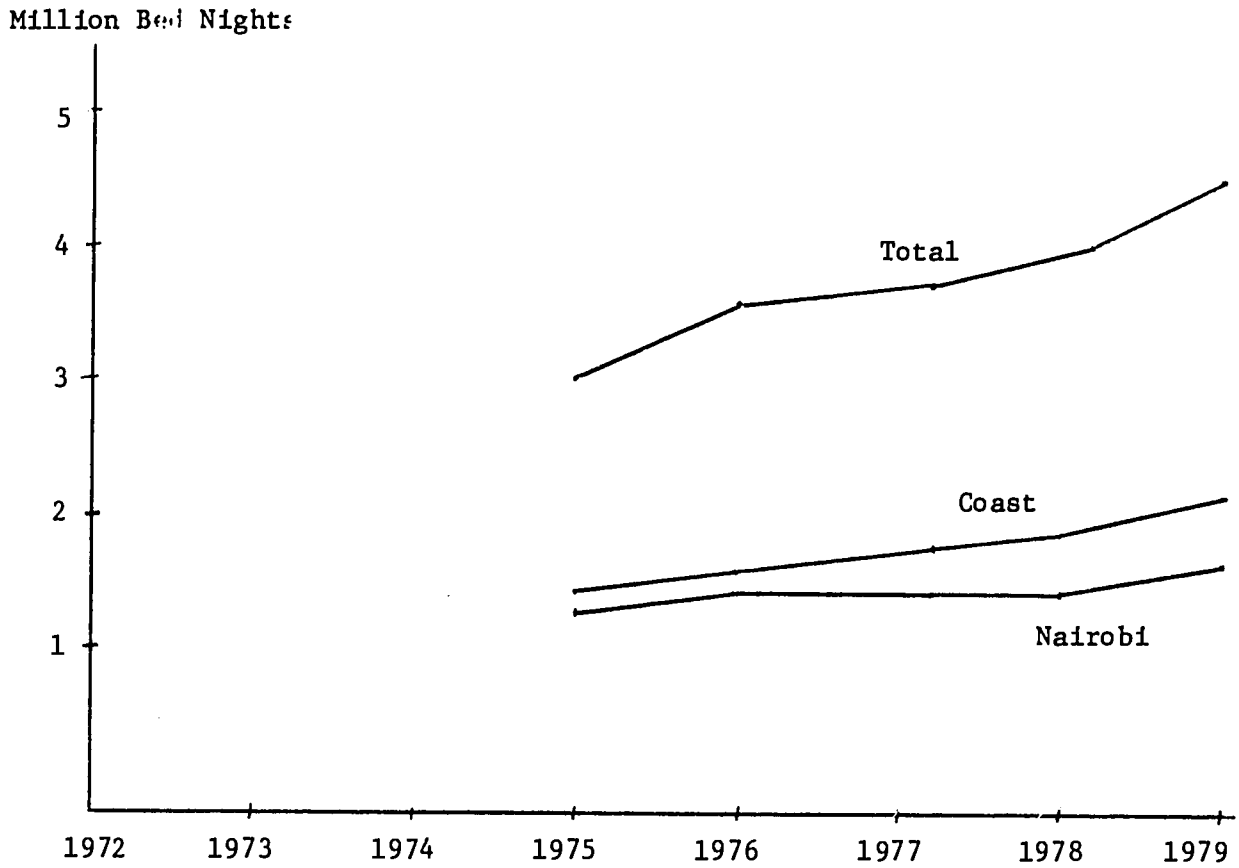

Figure 3-2. Tourism Growth

Source: Data for 1972-1975 from Economic Survey 1978 (Table 13.7).
1976-1979 data from Economic Survey 1980 (Table 13.5).

Table 3-5. Residential Fuel Use

	LPG		Kerosine	
	Total (TJ)	Per capita (MJ)	Total (TJ)	Per capita (MJ)
1972[a]	253	20.9	1615	133.6
1977	384	26.7	2012	139.7
1979	540	35.3	2939	192.1

Source: Data for 1977 and 1979 were obtained from each oil company. Data for 1972 extrapolated from 1972 Shell sales.

[a]1972 data extrapolated from Shell sales. Yet, when Shell's sales in 1977 and 1979 were extrapolated to the entire industry, they were inconsistent with the actual industry-wide figures shown. Therefore, we multiplied the 1972 Shell approximations by the average of the differences between these approximations by the actual industry-wide data for 1977 and 1979. The results are 253 TJ for LPG and 1615 TJ for kerosine in 1972. See Appendix C for explanation of 1972 fuel use extrapolation.

Declining prices of LPG must have stimulated consumption but other factors were also important. In 1980, for example, kerosine supplies were limited. According to oil company sources, this cutback was due in part to government price controls, which had the effect of making kerosine production unprofitable. LPG growth was similarly restricted, though in this case the problem was a continuing shortage of storage cylinders. Recently, the shortage of cylinders became so acute that at least two companies contemplated selling their stocks to competitors or even flaring LPG!

Residential electricity includes consumption under a variety of tariffs--small, typically consuming an average 10kWh a month, and normal applying to larger houses, with monthly averages which vary from 260 to 750 kWh. Many of the residential consumers also subscribe to an additional tariff, an interruptible service used primarily for hot water (with electronic signal interrupter). As some subscribers to the interruptible tariff might be classified in other sectors, for example, hotels, we

estimated the "residential" component of this consumption (see Appendix D for a more complete derivation).

In 1979 the tariff structure was revised. Normal and small residential customers were combined with small shops. Fortunately, we were provided with the numbers of customers in various consumption intervals for 1979 and 1980. We assigned all those using fewer than 30 kWh/month in 1979 to the "Small" classification, and all those using between 30-250 kWh/month to the "Normal" group. After this adjustment, we found that the growth in numbers of customers in each class for 1978/79 was consistent with earlier years, which allows us to compare each group's usage over time (see table 3-6). Electric pricing rates have been pegged to consumption levels. Up to 1978 this system was highly regressive with small residential users paying four times more per kWh (135 Kenyan cents per kWh)[8] than "normal" residential users (36 Kenyan cents). Additionally, electricity for residential hot water heating, available primarily to the higher income families, is sold at off-peak tariff prices (21 Kenyan cents per kWh). Off-peak prices are only one-seventh the "small user" tariffs.

In 1979, a tariff system was introduced to reflect fuel-cost increases and also to reduce regressivity. For small consumers (under 30 kWh/month) the net charge works out to be at least 65 Kenyan cents/kWh--a major reduction in rates--while larger consumers (households with higher incomes, using at least 500 kWh/month) pay a substantially increased rate of 51.3 Kenyan cents/kWh. This results in a much narrower differential between the two. The reduction in tariffs to small users is expected to stimulate consumption in this category.

Perhaps due in part to the previously high tariffs for small users, only 6 percent of the population in Nairobi, and less elsewhere, were connected to the EAPL grid in 1976. This fraction had grown by 1979 to at least 6 percent of the estimated total number of households in all of Kenya. Since there are additional households (servants' families, households sharing electric service, some households using rural electrification services) not counted in table 3-6, we estimate that the upper limit to the proportion of households in Kenya with access to

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8. 2,000 Kenyan cents equal 1 Kenyan pound.

Table 3-6. Electricity Consumption and Average Price[a] by Category of Consumer[b]

	1972			1975			1977			1978			1979	
	GWh cons.	kWh per user	Average price	GWh cons.	kWh per user	Average price	GWh cons.	kWh per user	Average price	GWh cons.	kWh per user	Average price	GWh cons.	kWh/ user
Normal Residential	120.5	3042	25.7	148.5	3320	26.1	172.4	3372	36.8	190.6	3408	36.0	214.3	2762
Small Residential	9.9	240	113.5	15.1	291	108.7	17.3	297	133.9	18.5	297	134.9	11.7	239
Residential Hot Water[c]	117.9	5223	12.4	134.6	5240	14.9	111.0	4210	21.3	116.5	4258	21.2	54.0	2477
Staff Housing[d]	2.5	2379	10.6	2.7	2622	10.5	3.2	2606	22.9	3.1	2501	22.4	3.2	2133
Commercial	103.8	347174	23.6	136.0	369584	26.6	154.7	347676	40.5	173.5	376438	40.5	226.8	na
Small Commercial	100.5	6590	41.8	127.3	6985	44.7	146.4	7119	65.9	147.6	6614	67.6	132.7	na
Industrial	251.5	911163	17.9	311.9	836070	22.0	542.9	1016751	31.0	633.8	930659	31.5	623.5	na
Total[e]	794.8	na	28.8	1001.4	na	25.9	1203.6	na	37.8	1300.6	na	38.1	1339.0	na

na = not available or not applicable

Source: 1972-78 data from Mr. P. Okwany of EAPL. 1979 data derived from Central Bureau of Statistics, Economic Survey 1980, Nairobi, table 10-6.

[a]Kenyan cents per kWh. One Kenyan shilling equals 100 cents and 20 shillings equal one Kenyan pound. 1979 price data not available.

[b]Categories as grouped in EAPL tariff data for 1972-78. Tariff structure changed in 1979 and therefore data may not be comparable to earlier years. 1979 data classified as Normal Residential: 30-250 kWh/month, and Small Residential: less than 30 kWh/month.

[c]Consists primarily of the largest residential consumers and is an off-peak, interruptible service.

[d]Includes dwellings built for EAPL employees and housing by other companies for their employees.

[e]In addition to the categories listed above, includes all other electricity consumption such as street lighting.

electricity is 7 percent. A survey reported in the Economic Survey 1980 indicated that in 1978 electricity was accessible in 344,700 households in owned or rented housing, in the major urban centers. Of this number, 119,000, or one-third, used electricity in 1978.

The largest consumption (over 90 percent of the total) is under the normal residential and residential hot water tariffs. The small residential and "staff" housing (which includes dwellings built by EAPL and other companies for their employees) together account for under 10 percent of total residential consumption. The share of normal residential is rising while that of residential hot water (even excluding 1979 where data may not be comparable with earlier years) is falling.

Total consumption of electricity in the residential sector rose by 30 percent from 1972 to 1978 or by an average of 4.6 percent annually. Virtually all of this increase was accounted for by a rise in the number of accounts. Average electricity consumption per household remained stable between 1972 and 1978. In general terms, consumption per household might have been expected to rise. Retail electricity prices declined markedly over the period, and incomes grew, if rather slowly. Electricity consumption is usually closely correlated with income. Table 3-7, for example, shows that "lower class estates" use an average of only 10 kWh per month, whereas the largest estates use over 750 kWh/month. Additionally, it is primarily the upper income dwellings which have installed the interruptible hot water service.

The main reason for the stability in household consumption may lie in the distribution of households within the normal residential tariff category. This group will include a wide range of households and household incomes. If the new subscribers in this group are predominantly lower income families, their typically low consumption would bring down the average of the group, even though no other households within the group were increasing consumption in response to lower prices and higher incomes.

Solar Energy

Solar energy is as yet a very small part of total energy consumption. Because of the exceptional interest, rapid development (admittedly from a very low base) and potential for the future, we undertook a survey of solar energy use in Kenya. Our surveys included four suppliers of solar hot

water heating equipment, who represent nearly the total Kenyan solar market. Data on type of customer, hot water production (collector area), and cost were obtained from three suppliers, and from these data, the total contribution of solar energy to Kenyan energy flow was calculated.

Based on data provided by the solar equipment distributors, we made estimates of the total area of solar hot water collectors installed between 1975 and 1980 and the annual energy savings attributable to those installations (see Appendix E). These estimates are uncertain because of a number of factors, including: the actual number of installed systems, the relative proportion of active and thermosyphon systems, seasonal fluctuations

Table 3-7. Residential Electricity Use by Housing Type and Tariff Category, 1977

Housing type[a]	Electricity use[b] (kWh/month)	Tariff[c]
"Lower Class Estates"	10	Small
"Middle Class Estates"	258	Normal
Executive Housing		
Normal Use	565	Normal
Hot Water Use	444	Off-peak
Large Estates		
Normal Use	752	Normal
Hot Water Use	462	Off-peak

Source: Schipper (1980); East African Power and Light Company.

[a]The descriptions of the housing are only approximate and reflect the outward appearance or purpose of the housing project. The last two samples probably include hot water and cooking for servants.

[b]Based on six-month averages of limited sample (10-20 households) of electricity billing data.

[c]Users in the "small" tariff category pay about four times the amount that "normal" tariff users pay for each kWh delivered. "Off-peak" rates are about one-half of "normal" rates.

in performance arising from cloud cover, variations in energy output caused by installation techniques, and geographic locations. In spite of these limitations, however, we believe that our estimates represent a reasonable approximation of the energy contribution attributable to solar domestic water heating in Kenya. Table 3-8 shows the area of solar collectors installed between 1975 and 1980. The three reporting companies together represent a combined market share of (at minimum) 90 percent. Our survey coverage is therefore fairly complete.

Table 3-8. Installed Solar Energy and Collector Area in Kenya, 1975-80

Year	Cumulative square meters	Additions square meters	Annual energy displaced (TJ)	Annual percentage in cumulative square meters
1975	44.6	44.6	0.14	---
1976	199.6	155.0	0.61	339
1977	484.4	284.8	1.48	143
1978	1295.1	810.7	3.96	167
1979	1979.5	684.4	6.053	53
1980	2947.0	967.5	9.014	49

Source: Data provided by the three largest of four firms selling solar water heaters in Kenya and therefore accounts for at least 90 percent of the total solar market.

Displaced energy was estimated by apportioning delivered energy to the fuels that otherwise would have been used to heat water in houses, flats, hotels, lodges, farms and schools. Fuel oil burned in hot water boilers is primarily used to provide hot water in hotels and schools; LPG or wood is used in remote lodges; and electricity is used in homes. For this calculation, we assume hot water would otherwise have been produced by electricity. If the alternative assumption had been made that fuel would have been used to produce hot water, the estimate of energy displaced would be roughly 50 percent greater, since the efficiency of fuel use is lower than that of electricity at the point of application.

The total area of solar collectors increased sixty-fold from 1975 to 1980. About 85 percent of the sales were to commercial or institutional customers, the rest to domestic users (see table 3-1). The energy impact of these installations, as shown in table 3-7, grew from 0.14 TJ in 1975 to over 9 TJ in 1980. Additionally, there are installations in hotels and homes that were completed before 1975, whose impact we estimate is of the order of 1-2 TJ. We judge the overall growth in solar energy use to be 34 percent per year from 1975 (about 2 TJ) to 1980 (about 11 TJ).

Chapter 4

CONSERVATION IN KENYA: PROGRESS AND POTENTIAL

The information most directly available in this work on conservation progress came from the interviews we conducted with several dozen Kenyan firms. These interviews are recounted in Appendix G, in which we paraphrase the written submissions or verbal descriptions of the conservation problems faced and approaches taken by these firms. From the information supplied by the respondents, we developed quantitative indicators of conservation, primarily in the form of energy input to product output ratios which are summarized in the tables appearing in this chapter and discussed in more detail below. Although it is difficult if not impossible to evaluate the statistical accuracy of our data because of both the limited sample size and reliance on firm records or managerial reporting, we feel that the process of gathering primary data was extremely useful in illuminating the status of energy conservation activity in Kenya. Our findings on conservation progress and estimates of future potential are detailed in the following sections.

Industry Sector

Our interviews and examination of data on industrial energy use showed a clear distinction among firms in Kenya. Some firms, notably the most energy-intensive ones (cement, refining, some steel companies) showed a keen awareness of the economic benefits of energy conservation and of systematic energy accounting. Managers could pinpoint increases or decreases in energy use relative to output and, significantly, the reasons why these came about. Interviews with multinational firms, even those whose energy intensity is relatively low in Kenya (that is, energy costs lower than 7.5 percent of total costs) revealed a similar awareness. The largest and best

documented conservation gains came from a firm that is a subsidiary of a multinational firm.

The majority of firms, however, had difficulty in finding the data we sought. Only one-third of firms responded promptly to our requests. The lack of response could be due to a lack of interest about energy, but it is more likely caused either by misunderstanding of the importance of the data to the firm in regard to economizing, or by a real inability to find the information because of weaknesses in internal accounting. Some firms were understandably reluctant to spend time searching for information that they did not see as useful. When we explained that information on fuel use relative to output is very important for measuring progress in saving energy and money, we often found increased interest among management.

The status of conservation among these latter firms is mixed. In one firm the engineers complained that the firm would not be likely to invest a small amount to fix obvious leaks, improve boiler efficiency, or "optimize" a process, even if the returns for such investments were large. One of our guides pointed out that the boilers we had just viewed were run at unnecessarily high pressures. An engineer at a metal-processing firm told us he was satisfied simply to be able to start the equipment in the morning.

The managing director of a very large and energy-intensive firm listed difficulties that held back his conservation effort: poor organization, varying oil quality and high demand for product that made high mill capacity amore important factor than energy economies. The progress made toward more efficient energy use in his firm was slow, in spite of the increasing size of his fuel bill. In contrast, a manufacturer of food and household items had just hired an engineer who planned to make important process modifications to reduce energy use. Several firms had discovered sources of biomass scrap from other factories that would substitute for a considerable fraction of their oil use; however, others have discontinued use of such scrap from boiler fuel because of pollution problems. In all, we found activities related to conservation scattered through the firms we visited, but no clear trend. Those firms that had made efforts to economize had generally succeeded; many firms simply had not tried.

The data in table 4-1 summarize many of our observations about conservation in a number of specific firms. Fuel use decreased in the two

vehicle assembly plants, one of which is a multinational firm. We see steady progress in the tire company, which even adjusts its measure of output, "pounds of tire," for changes in materials and tire characteristics to make data comparable over time. The tire recapping plant reduced fuel intensity by shifting production to a new facility. The first listed cement mill (process 1) reduced 1979 energy intensity compared with 1977, yet one of the engineers complained that it is difficult to organize the factory staff for conservation. The second cement mill (process type 2 and 3) reported mixed success but expects much future progress. In the paper mill, high demand for paper required that equipment run at high capacity and forced some purchase of electricity; the drop in energy intensity in 1979/80, brought about by installing insulation, was greater than the increase in energy intensity caused by purchases of electricity. In the steel mill, increases in the melting of scrap increased energy use in 1977, compared with 1975, but by 1979 the energy intensity of smelting had fallen, and the intensity of oil use for rolling had also dropped. Understanding process energy use at this level of detail is important for ascertaining how much energy use has changed because of increased efficiency, and how much because of changes in production processes.

In some firms we found increases in energy intensity, particularly in electricity, in spite of clear efforts to conserve energy. This is shown in the data of table 4-1 for two food processing firms. In the first, the evidence of conservation is clear for both fuel and electricity. In the second, a creamery, fuel use intensity is clearly decreasing, but electricity use is increasing. We believe that this increase reflects mechanization of older facilities by this firm. Several other firms whose data are shown in the case studies in Appendix G revealed the same mixed results. While fuel intensity was being reduced or at least held constant, electricity intensity was increasing significantly. This increased electricity intensity does not rule out the presence of conservation practices by these firms; in the case of the creamery, electricity intensity would have been even higher in 1979 had measures not been taken to reduce it. The effects of capacity utilization and scale economies also need to be kept in mind when interpreting energy intensities. We noted several firms that reduced energy intensities markedly over time without any apparent conservation efforts. In almost every case where this was observed,

Table 4-1. Summary Indicators of Energy Conservation in Kenya: Energy Intensities in Industries

Type	Electricity (kWh/output)	Fuel (MJ/output)	Output unit	Year	Notes
Motor (1)	--	1950	Vehicle	1978	
vehicle	610	1780		1979	
assembly (2)	561	5000		1977	Part-year
	481	3550		1979	
Tires	2480	35600	Ton	1975	
	1670	22900		1978	
	1600	19940		1979	
Tire	860	21700	Ton	1977	
recapping	960	13700		1979	
Oil	11.5	1260	Ton	1973	Crude losses
refining	16.0	1560		1977	
	14.6	1710		1979	
Cement (1)	77.0	5800	Ton	1975	Whole mill
	81.2	6200		1977	(Wet kiln)
	73.8	6020		1979	
(2)	86.0	3950		1976	New dry kiln only
	80.0	3920		1977	
	71.0	3980		1979	
(3)	55.0	4280		1976	Older dry kiln only
	61.0	4230		1977	(coal fired,
	62.0	4450		1979	all years)
Paper	--	4800	Ton	1977/78	purchased
	105	4400		1978/79	electricity only
	196	3900		1979/80	
Steel	797	--	Ton	1977	Electric melting
	676	--		1979	
	221	3420		1977	Rolling, all
	223	3270		1979	other functions
	590	4065		1977	Factory totals incl.
	670	3840		1979	miscell. processes
Food	98.0	6280	Ton	1975/76	
	50.0	4480		1978/79	
Creamery	47.8	2010	10^3 liters	1972	3 percent wood-fired
	51.1	1830		1975	12 percent wood-fired
	96.8	1480		1979	no wood

Source: Field survey data.

the output of the firm had risen by as much as five-fold over the time period. Similarly, firms whose output fell during slack years showed increased energy intensities in spite of reported conservation efforts, some of which we observed personally. The oil refinery (table 4-1) used more fuel/output in 1979 than in 1973 because of its expansion far beyond utilized capacity, though a concerted conservation effort reduced intensities somewhat in 1979 relative to 1977. Similar effects can be seen in data from hotel #1; while intensities were lower in 1979 relative to the years before expansion, they were higher than in 1978, the first post-expansion year.

In general, the majority of firms seem hard pressed to respond to higher energy costs for several reasons:

- Lack of on-site expertise in retrofitting existing equipment. Competent engineers are often preoccupied, indeed overworked, just keeping the plant functioning.
- Lack of domestic sources of hardware to improve the energy performance of existing equipment. The necessity to import some conservation equipment causes problems with import formalities and restrictions for those firms attempting to invest in conservation.
- Inability to organize production workers and management. The majority of firms we visited had difficulty providing data that should be on hand in every manager's office. Few firms had production workers trained in the art of fine-tuning factory operations.
- Belief that little could be done to reduce energy use in the firm's operations.
- Overwhelming management concern with other parts of the operation of the factory.

Those firms that have made concerted efforts to economize on energy use have, for the most part, succeeded. Many firms, however, have yet to take the necessary steps to achieve appreciable savings. These observations should not be taken as applying only to Kenyan firms; the same problems have been found repeatedly in countries that have emphasized conservation, such as in the United States (Yergin and Stobaugh, 1981) and Sweden (Statens Industriverk, 1980). Firms in Kenya have far fewer

contacts with international energy data and with other firms experienced in energy conservation. Therefore, it is much more difficult for them to take the first steps in an energy conservation program.

In the short term, when the factors that have been detrimental to conservation are overcome, the potential is excellent for saving energy by retrofitting of existing equipment in Kenyan factories. Two factories in Nakuru--the Pyrethreum Board and the Kenya Milk Cooperatives--illustrated the effectiveness of retrofit. The Pyrethreum Board has added new steam valves, instrumentation, insulation on steam pipes, and installed a sawdust-burning boiler to complement the existing oil-fired boiler. The creamery has added thermostats to refrigerators, which has reduced the use of compressors by 60 percent, while synchronization of motors has reduced electricity use even more. Conservation measures such as these are frequently appropriate for factories that operate both continuous and batch process, where it was formerly customary to run some equipment at full speed even when no load was present. One Kenyan glass factory installed a heat recovery system in a relatively new glass machine, with a substantial reduction in energy intensity. Thus, there appears to be considerable potential for economic retrofit of existing industrial equipment in Kenya.

Such examples are representative of the near term potential for reducing fuel and electricity intensity in nearly every Kenyan plant. Since our interviews suggest that the majority of firms have not taken advantage of even the easiest methods for reducing energy costs, it is reasonable to project the levels of savings observed in some firms to all. We suggest that it is possible and economically attractive in Kenya to achieve a reduction of fuel use per unit of output of 15 to 20 percent in three to five years through process modification or retrofitting of heat saving technology. This near-term potential has already been realized, or at least recognized, in a few of the largest and most energy-intensive firms, but too often such firms have not acted or even assessed the potential for energy savings because of the misguided belief that consumption is irrevocably determined by the equipment already in place. Many factories have identified training of line personnel as an important step toward improving energy performance; however, there is a great need for assistance both in training and in the actual performance of energy audits. Staff in both Kenyan cement mills, where energy costs are

typically 25 percent of production costs, expressed the view that better organization and management are essential to reducing energy intensities and costs.

In the longer term, there is even greater promise for improved energy efficiency as new equipment replaces old. Our studies of the glass, textile, steel, tire, and paper industries showed that replacement and expansion almost always lead to reduced energy intensity. (By new equipment we do not assume the development of entirely new technologies, only application of those in general use in most of the world.) It is beyond the scope of this study to compare Kenyan energy use with that in other countries, but a brief examination of the Swedish and U.S. literature suggests that new factories in the paper, steel, glass, chemical, and other energy-intensive industries are more energy efficient.

Commercial Sector

Our surveys concentrated on certain key buildings that are typical of the commercial sector in Kenya: hotels, offices, and hospitals. We found a large number of orders for solar hot water systems from hotels and other institutions, in spite of many barriers that hinder this development. Visual examination of buildings in Nairobi shows that the majority were built with the characteristics of the Kenyan climate clearly in mind. Facades pointing north and south are shaded by overhangs to minimize solar heating, while the few eastern and western exposures are carefully covered with louvers. Unfortunately, several impressive new office structures have been built with mechanical ventilation, or with facades pointed east and west, thereby maximizing the discomfort from insolation and increasing cooling needs dramatically. Conversations with many building engineers in Kenya gave convincing evidence that cooling needs in Nairobi can be minimal if buildings are properly designed.

In hotels, as in other institutions, we found a mixed approach to conservation. Some of the well-managed larger hotels have considered energy conservation opportunities carefully. Solar collectors have been installed at more than a half-dozen beach hotels and are planned for the Norfolk Hotel, a famous landmark of Nairobi. On the other hand, determining the actual use of energy by guests--for lighting, air conditioning, and hot water--seems to have been ignored. Our data show decreases in

energy use per guest-day for some hotels, but a significant potential for savings remains.

Direct experience as guests in major hotels, plus interviews with staff in others, revealed many opportunities for mundane but rewarding conservation in use of hot water and reductions in cooling loads. Similar observations were made in lodges and camps. Careful energy surveys and metering demonstrations are needed to monitor energy consumption and to eliminate unnecessary use. Lacking equipment and resources to make accurate audits, hotel engineers, employees, and managers deserve commendation for holding down energy use as much as they have, but considerably more remains to be accomplished.

In table 4-2 some of the observations from hotels are shown. In the first hotel, we compare a figure for 1975 with that for the most recent calendar year, by which time the capacity of the hotel had doubled. The drop in consumption appears to have been caused by the resultant economies of scale. The second hotel has a much greater intrinsic air conditioning load, reflected in the 1977 figures, but the engineer has made enormous improvements, as the 1979 figures show. The third hotel supplied figures only for 1979, which show the impact of air conditioning on energy use. Examination of tourism data shows a clear trend towards a larger percentage of tourism activity at the coast, which would increase electricity use in this sector. By contrast, the last listed hotel, situated west of Nairobi, has a low electricity use (no air conditioning) but extremely high hot water use, caused, we believe, by low capacity and lack of attention to the hot water system.

The hotels in Kenya face increasing competition, both among themselves and from other countries, as tour operators seek the most attractive prices for beach or safari tours. In their attempts to hold down costs, hotel operators will turn increasingly to energy conservation. If one accepts our estimated breakdown of hotel fuel uses (50 percent for guest hot water, 30 percent for laundry and kitchen hot water, 20 percent for cooking and miscellaneous), it is not unreasonable to conclude that as much as 75 percent of the energy used for hot water (60 percent of fuel use) can be saved through conservation and solar energy.

Table 4-2. Summary Indicators of Energy Conservation in Kenya: Energy Intensities in Hotels

	Electricity (kWh/output)	Fuel (MJ/output)	Output unit	Year	Notes
Hotels (1)	16.1	138	guest-day	1975	Nairobi
	14.3	102		1979	
(2)	35.5	305		1977	Nairobi
	23.7	253		1979	
(3)	33.1	--		1977	Coastal
	30.1	146		1979	
(4)	21.5	--		1977	Western
	16.9	559		1979	

We encountered one important problem involving the interaction of conservation with the use of solar energy technologies that deserves careful study in Kenya and elsewhere. Hotel owners are often eager to turn to solar hot water heating systems, believing that they offer a rapid payback on investment, but may not recognize the need to integrate these systems into an overall plan of energy management. The importance of conserving the amount of hot water is often neglected. We observed few efforts to control hot water use in showers and to use heat recovery or other conservation practices in laundries or dishwashers. This lack of effort not only leads to higher hot water demand, but more important, to greater peak demand for hot water during peak bathing times in the morning, when the temperature of a solar storage system would be at its lowest. This extra demand raises the investment costs for storage and increases the need for backup heating from fuels or electricity. With careful hot water conservation practices (use of low-flow shower heads, temperature setback, and water softening), this peak can be reduced considerably. The overall investment per guest-day in solarization of hot water facilities can then be brought down markedly, as both collector area and storage can be reduced and the use of backup fuels or electricity decreased as well.

Programs of total energy management have proved quite successful in the United States, and it is important that these techniques be tried in

Kenya so that they can be incorporated into normal profit-making operations. Such programs are important not only for commercial buildings and hotels, but also for schools, hospitals, and other institutions where guests or occupants have no direct incentives to use energy efficiently.

Examination of electricity consumption records of Nairobi office buildings (table 4-3) over time indicated no real trend. Conversations with engineers at Bikro suggest that in only a few buildings have steps been taken to economize on energy use, particularly in lighting, air conditioning, and ventilation. Although we did not observe any office space that appeared to be overlighted, the potential for saving is good, because high-intensity, low-energy lamps for office and institutional use are just becoming available in Kenya. Since lighting and ventilation tend to account for the major part of electricity consumption, we foresee a reduction in energy use per unit of office space approaching 25 percent in fully air conditioned buildings and perhaps 15 percent in those that are ventilated but not air conditioned.

Kenyan schools and hospitals use 0.2-0.4 PJ of fuel, of which roughly 50-60 percent is used for heating water. The survey of these institutions

Table 4-3. Electricity Use in Nairobi Office Buildings (MWh/year)

Building	1979	1977/78	1976/77	1975	Notes
#1	2596.0	2668.8	2486.4	2467.3	Air conditioned
#2	767.9	722.9	693.3	731.1	Miscellaneous offices
#3	2458.8	2322.2	1912.0	not built	Government offices
#4	703.8	732.6	712.0	671.2	Bank
#5	2168.1	2561.1	2853.4	2319.2	Kenyatta Center
#6	916.5	708.0	863.0	not built	1976/77 based on 4 months
#7	385.3	495.6	475.3	426.0	1975 based on 5 months
#8	492.7	--	396.8	357.5	No mechanical ventilation
#9	--	199.1	205.5	208.5	

Notes: These buildings are classified as offices or banks. Consumption figures were taken from EAPL Tariff 4. We give actual 12-month averages based upon months ending January 1980, March 1978, June 1977, December 1975, unless otherwise noted. Data were not available for each building for each year. Some buildings were built after 1975, and for others, consumption records in the first year of operation date from mid-year.

tended to show little change in energy use patterns. None of the responses included both fuel and electricity consumption; two hospitals suggested we contact EAPL, while one claimed that only the monetary value of consumption, not actual quantity, was known to the hospital staff. The lack of such basic information is clear indication that conservation has not been seriously considered.

There is an excellent potential for saving up to 50 percent of the fuel now consumed in these schools and hospitals by using solar energy for all hot water use, including uses requiring higher temperatures than for tap and bath water. Another important conservation possibility for hospitals in remote sites is the use of waste heat from diesel generation to heat large quantities of water, to be stored for later use.

We have not examined stores, restaurants, warehouses, or other kinds of buildings. Judging from the kinds of equipment seen in government offices and other buildings of a service nature, we suspect that the level of energy use per unit of space and activity is low; therefore, we do not expect a significant decrease in that level in the short run.

It was difficult to assess energy use in small shops and service facilities. Most of these establishments consume less than 7000 kWh/month and therefore do not appear disaggregated on the EAPL printouts; moreover, it is uncertain how they buy their oil products. The total contribution to GDP of these activities is insignificant, as they encompass rural and cottage industries, handicraft workshops, and small assembly and textile plants. Since many shops also serve as residences, some of the electricity consumption on such premises may be miscounted; it was difficult to separate these two functions statistically. Typically, small industries and handicrafts expend only a small fraction of their outlays for energy, so we have no reason to expect that these enterprises individually see a great need to improve energy use. Collectively, however, their electricity use, as well as possibly their use of some fuels, is not inconsiderable.

Transportation Sector

In spite of difficulties in obtaining primary transportation data, we can make a number of observations related to energy use in this sector. A majority of private and company supported driving is effectively shielded from higher fuel costs. Gasoline prices in Kenya reached 6.5 KSh (87 U.S.

cents) per liter on 15 February 1981, still very low compared with most countries. Kenya is like many developing countries in that private incomes are relatively low but increasing. Energy consumption for private use of vehicles is about to overtake energy use for freight transportation. Private use tends to grow much more quickly than personal income, while freight use grows at nearly the rate of national income growth. The ownership of cars has grown rapidly. Between 1972 and 1977, the number increased by 7.8 percent annually, while real GDP grew by approximately 5 percent annually. Data do indicate, however, that the use of fuel per car has dropped somewhat (Schipper and Mbeche, 1979). There are also indications that new car buying patterns are changing, as a result of the recent increases in import duty on car weight. According to an automobile insurance executive, the distribution of new car sales before 1980 could be approximated as shown in table 4-4, which also includes our estimate of the post-1980 mix of engine sizes.

While the numbers of the smallest cars have decreased, with the increase in size explained by higher incomes and company or business ownership of the majority of vehicles, the new fleet as a whole has become less powerful, and sales of low-octane gasoline have increased at the expense of premium, thus reducing total energy use. An oil company executive suggested that the apparent drop in fuel sales per vehicle could only be explained as reduced vehicle use.

The data in table 4-5 for the transportation sector suggests that there has been a drop in the intensity of bus transportation and

Table 4-4. Automobile Sales Distribution by Engine Displacement

Year	1/4-1600 cc	1600-1750 cc	1750-2000 cc	More than 2000 cc
1980	5%	40%	40%	15%
Pre-1980	10	55	30	5
Post-1980*	(20)	(55)	(20)	(5)
1980 tax	300 KL	450 KL	600 KL	900 KL

*The post-1980 estimates are our own.

Source: K. Tarplee, private communication of unofficial estimates.

international airline transportation. It is difficult to interpret the air transportation data, however, because the distances over which embarking passengers fly, and hence the fuel requirements of aircraft, have changed with the introduction of wide-bodied aircraft. This means that the number of embarcations has increased relative to the number of flights. Since

Table 4-5. Summary Indicators of Energy Conservation in Kenya: Energy Intensities in Transportation

Mode	MJ Fuel output	Output unit	Year	Note
		Transportation		
Bus	12.4	vehicle-km	1977	Inter-city
	11.1		1979	
	12.5		1975	Intra-city
	13.6		1979	
	13.5		1980	
Taxi	4.26	vehicle-km	1979	diesel
	7.65		1979	gasoline
Airlines	13,800	passenger	1974	Nairobi int'l
	13,500		1979	

sales of jet fuel in Kenya can be counted as export earnings, however, this conservation may not be regarded as necessarily beneficial to the national economy.

The parastatal bus company in Nairobi noted a drop in energy intensity after a concentrated effort to improve operating efficiency was carried out, and both this company and its intercity counterpart indicated that the data for late 1980 (not shown) indicate substantial improvements from 1977.

The railroad shows interesting trends. If its energy consumption is examined over time, a dramatic change is seen. Total consumption fell from 6.01 PJ in 1977 to 2.55 PJ in 1979, and climbed somewhat to 3.17 PJ in 1980. During the 1977-79 period, the number of passengers increased 16 percent, passenger train-km increased 39 percent, while freight tonnage dropped 8 percent. Even though these structural indicators cannot be added, they do point to an <u>increase</u> in service with a rapid <u>decrease</u> in energy use. According to Shell, this was caused by a rapid shift from

heavy diesel and fuel oil to automobile diesel oil, which burns far more efficiently in locomotives, and upgrading of the locomotive stock as well. Since apportionment of fuel use between freight and passenger trains is not known, we cannot calculate energy intensities, but the decrease in fuel use far exceeds the changes in any of the activity levels shown in table 4-1. Unfortunately, the shift is from an abundant fuel to a scarce one, which aggravates the already unfavorable relationship between oil product demand and refinery output in Kenya.

There is a great near-term potential for reducing energy use in Kenyan busses and trucks through better maintenance and, in the long term, through purchase of more efficient vehicles. The recent improvement in energy performance by Kenya Bus Services (KBS) is encouraging. Our observation that private busses and trucks emit more smoke than those owned by large companies suggests that private vehicles are more poorly maintained, a situation which invariably leads to greater energy use. Existing vehicles in the large companies can be expected to improve their fuel use efficiency by about 10-20 percent, while those belonging to smaller companies could achieve even greater reductions.

In table 4-4 we noted some indications that the average engine size of new automobiles is decreasing, and that more drivers are switching to regular fuel. Whether and how quickly the stock will become significantly lighter is uncertain, because import restrictions now limit the total number of new automobiles entering Kenya, and thus slow the turnover in stock. Normally, increases in personal income lead to greater-than-proportional increases in the ownership and use of automobiles. Thus reductions in the energy intensity of vehicles will probably be offset by the growth in stock and driving, and total fuel use will keep increasing. They could, however, markedly slow this increase.

Improvements in traffic flow could also improve fuel efficiency. Congestion in the morning rush hour, complicated by use of automobiles to drive children to school, could be reduced considerably if school busses were widely used; changes in lunch-hour habits might decrease the enormous rush of workers who drive home for lunch. Some improvements in traffic flow due to one-way traffic on streets in Nairobi is already apparent, but traffic circles at most of the major entrances to the downtown area remain clogged at peak hours.

Because jet fuel accounts for nearly 20 percent of the energy used in Kenya, conservation could be significant. However, sales of this fuel are especially profitable for both marketers and the country as a whole, since airlines tend to pay in foreign currency. On the other hand, more efficient use of jet fuel will certainly hold down air-travel costs, which would promote tourism and increase Kenyan foreign earnings. Traffic in and out of Hawaii, for example, has shown remarkable increases in energy efficiency: Between 1972 and 1979 passenger arrivals increased by over 40 percent and the average trip length also increased, whereas fuel use over the same period increased by less than 15 percent (Siri and coauthors, 1981). One of the reasons for the increase in fuel efficiency is the use of wide-bodied aircraft, already common in Kenyan traffic. We estimate that 75 percent of the passengers traveling through Kenyatta Airport already do so in wide-bodied aircraft. The next great step in fuel conservation, then, must come from introduction of next-generation fuel-efficient jet aircraft into the fleets serving Kenya.

A thorough survey of transportation energy use and output is clearly needed to assess the potential for conservation and future demand in this sector.[1] Knowledge of car weight and performance as a function of owner income, place of residence, or type of business is important. Strategies that concentrate development in a few cities would result in different transportation needs than would decentralization strategies. The choice of strategy would therefore affect energy demand for transportation. Evaluation of these differences is essential for planning.

Residential Sector

Our survey of the residential sector was limited to electric power consumption in wired households, primarily those of upper income families, and to the use of LPG and lighting kerosine. It is difficult to characterize conservation in this sector since there was no available information on appliance ownership and efficiency. Nor is there any indication that the increase in kerosine and LPG use through early 1980 is

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1. We understand that some material on matatu, busses, and trucks has already been gathered by researchers at the University of Nairobi, but it was not made available to us.

not totally explained by rising living standards, increased numbers of households using these fuels, or wood and charcoal shortages.

Officials at EAPL expressed the belief that little change in growth patterns or consumption habits had been taking place over the past few years. Our data indicate, however, that growth in residential demand has come almost exclusively from new installations. On the basis of a survey of energy uses in OECD countries (Schipper and coauthors, 1981), we would expect to find that increased income (and therefore appliance ownership) is the dominant cause of increased electricity use in Kenya. Finding the effects of reduced utilization of a given appliance, or the effects of purchase of more efficient appliances induced by higher electricity prices, will be extremely difficult. We were not able to obtain information about electricity use from the same households over time to assess the effects of higher prices on selected households or income groups.

Solar energy technologies have made some inroads in the domestic market. A previous survey (Schipper, 1980) found that electricity use for hot water heating typically exceeded 3000 kWh/year in upper income households. From our new data, we estimate that households on the hot water tariff presently use an average of 2500 kWh/year. We found that by 1980 at least 50 detached households, out of 21,500 with electric water heaters, had installed solar equipment. Two major condominium developments, the Pan Afrique Flats and the Norfolk Towers, were being constructed with solar units. This is a significant step, as these are rental units which belong to the segment of the building sector that is slowest to adopt solar systems. In addition, the fifth unit of the Buru-Buru estate (a public development of middle income housing in Nairobi/Dandoret) encompassing hundreds of semi-detached dwellings, is to be solarized. It appears entirely possible that apartments, condominiums, employee housing, and private developments can all utilize solar hot water heating to meet the major energy demand in Kenyan middle and upper income households. We estimate the present total contribution of domestic solar hot water heating at 1.1 TJ, based on a savings of 2500 kWh (9.0 GJ) of electricity per household in a sample of 125 houses and flats.

The most important energy conservation development in the Kenyan residential sector is likely to be the widespread introduction of solar water heating. Although sales of solar heaters have been predominantly to

hotels, schools, and other relatively large users, it appears that residential solar water heating has an important future, replacing both commercial fuels and some of the charcoal now used in many homes to prepare hot water for bathing.

In, 1979 21,600 Kenyan homes purchased off-peak electricity for heating water at reduced rates (one tenth the cost of peak period electric rates), and many of the remaining normal residential consumers used electricity for hot water production (not recorded separately). Irregularities in hydropower supplies and the recent fuel costs adjustment affecting all electric power users suggest that the off-peak rate differential may become very small in the near future. Among upper income homes, electricity consumed for hot water preparation appears to account for about one-third of electricity consumption. If the off-peak tariff for this electricity were removed, the economics of solar water heating would become quite favorable.

It is possible to estimate the energy savings that can be realized in the residential sector as a result of introduction of solar water heating. The average yearly electricity consumption of an individual off-peak domestic hot water consumer in Kenya is 2500 kWh/year, according to EAPL. Taken together, all homes on the off-peak tariff, therefore, consume about 54 GWh. This is nearly half of the total consumption in this tariff class, as table D-1 in Appendix D shows. If all of this electricity were substituted by solar energy, total residential electricity consumption would be reduced by 25 percent. This may be an upper bound, however, because elimination of the substantially discounted off-peak consumption rate might cause a reduction in demand for hot water.

To estimate the conservation potential from use of more efficient appliances in upper income households requires knowledge of the kinds of appliances these homes use. Since electric stoves, freezers, refrigerators, washers, lights, and television account for most of the monthly consumption, it is not unreasonable to project a 25 percent savings in electricity use as old appliances are replaced by newer, more efficient models. These are the minimum savings expected in the United States and Europe (Rosenfeld and coauthors, 1981; Schipper and coauthors, 1981). Whether and when the most efficient models now being sold in Europe, Japan, and North America will become available in Kenya, however, is uncertain.

With regard to commercial fuels, we have too little information on their use in the residential sector to estimate conservation potentials at this time.

Summary of Conservation Progress

In Kenya, as in other market based developing countries, consumers and producers have to some extent responded to the higher price of imported petroleum by altering consumption and production patterns in favor of less energy intensive activities. However, as noted, the response to higher energy prices has not been uniform or consistent either within or across sectors. The managers of industrial firms with energy intensive production processes, including cement, steel, and refining, usually were aware of the importance of controlling energy costs through efficiency changes, even though some were unable to reduce energy intensities. The rate of capacity utilization and capital stock turnover were found to be important determinants of energy/output levels not directly related to energy management *per se*. Reductions in fuel intensities were observed to be more uniform than reductions in electricity intensities. In some cases (tire recapping, pulp and paper mill, and creamery), electricity/output ratios increased as fuel/output ratios decreased. Process mechanization, high rates of capacity utilization, and interfuel substitution appear to be the likely causes. Finally, it is important to reiterate that the majority of firms did not have the information or organizational capacity to implement energy conservation measures, even though a number of cost effective changes were identified.

In the commercial buildings sector, a variety of energy end uses are involved. These include lighting, air conditioning, refrigeration, ventilation, water heating, and mechanical lifting. The very diversity in end use applications and building types makes energy conservation in the commercial buildings sector a more dispersed activity.

Although some of the major hotels have implemented conservation and solar hot water heating measures, the energy conservation record for the majority of hotels, office buildings, schools, hospitals, and other commercial buildings is limited. In most circumstances, energy conservation has not been seriously considered, especially in the context of total building energy management. Even though the use of solar hot water heating

is expanding rapidly, little consideration has been given to the benefits of water conservation measures and the impact this would have on solar system downsizing.

Notwithstanding the lack of specific data for the transportation sector, general indications point to some conservation progress. Engine downsizing, increased sales of low octane gasoline, and reduced vehicle use have contributed to reductions in annual energy use per vehicle. However, rising personal incomes and business vehicle ownership will continue to increase the stock of private automobiles and hence the absolute amount of transport energy demanded. Bus, railroad and airline modes all have exhibited reductions in fuel intensities due respectively to increased operating efficiencies, fuel switching, and introduction of wide-bodied air carriers. The impact on transport energy consumption of shifts in passenger and freight transport modal shares has not been quantified in this study, but certainly has implications for the future transport sector energy structure.

Likewise, we were not able to quantitatively discern the energy impacts from past changes in urbanization levels, road traffic congestion, and land use patterns; however, from direct observation in Nairobi and other developing country urban areas, it is clear that inefficient traffic flows reduce fuel efficiency and impose significant user costs.

Finally, we have found that income effects are driving the absolute amount of residential energy demand upward, whereas price effects are unclear because of the sparse data on appliance ownership and usage patterns. Residential solar hot water heating has expanded rapidly in the past three years, but presently only accounts for a small fraction of residential hot water energy demand.

Summary for Conservation Potentials

On the basis of our study of energy conservation potentials in Kenya, we suggest that current energy intensities can be reduced in all sectors using cost effective conservation measures. A certain portion of the potential will be realized as producers and consumers adjust production and demand patterns in response to increasing world petroleum prices. However, as is apparent from the experience in developed countries, the response will be erratic, imperfect, and generally lag behind optimally determined

conservation levels. Inadequate and unequal access to information, lack of energy conservation management experience, and certain government pricing and taxation policies will hinder the investment rate in energy conservation measures. Indeed, these problems may impose even greater constraints in developing countries like Kenya because of the developmental funds and governmental revenues, and the poorly developed technical infrastructure. Nonetheless, with a concerted effort, the economy can benefit from energy efficiency gains without fear of thwarting future growth in real levels of national GDP.

In the industrial sector current process heat fuel use can be reduced by about 20 to 25 percent per unit of output in the next three to four years through efficiency improvements. Electricity intensities have exhibited a mixed trend. In general, although mechanization and increases in capacity utilization tend to increase electricity/output intensities, the economic gains of doing so can be leveraged by implementing conservation measures through careful attention to the turnover and utilization of the energy-using capital stock. Such measures can be expected to hold down energy intensity increases by between 10 and 20 percent.

Significant potentials for energy savings are readily apparent within the commercial buildings sector. Attention to proper building management (to minimize unwanted solar loads and provide natural daylighting where possible), investment in energy efficient lighting equipment and proper lighting levels, improved mechanical equipment efficiencies, and substitution of solar energy for electric or oil hot water heating can culminate in a 40-45 percent reduction in current building energy intensities. This is especially true of hotels, office buildings, and schools and hospitals.

Improvement of maintenance and use of existing motor vehicles of all types can reduce current fuel energy intensities by 20-35 percent. Policies to encourage the adoption of more energy efficient vehicles can further reduce the average energy intensity of the motor vehicle stock. Measures to encourage energy saving modal shifts (for example, from private automobiles to jitneys), increased load factors, and smoother traffic flow patterns would serve as energy saving complements to the strictly technical energy conservation measures. Jet fuel savings will only occur as the

existing fleet continues to be replaced by more efficient jets. A distinction must be drawn between national and international carriers because sales of jet fuel to the latter represent a significant source of foreign exchange earnings.

Introduction of more efficient electrical appliances can reduce residential electricity intensities by 15-20 percent. This appears to be especially important because residential electricity growth is explained primarily by extensive rather than intensive factors. Accelerated use of domestic solar hot water heating in the residential sector can reduce hot water energy demands by up to 50-60 percent on a per home basis. Additionally, more efficient use of cooking fuels through combustion improvements can lead to a savings of 15-20 percent.

A summary of these potentials is presented in table 4-6. Near-term savings, the product of "housekeeping" measures, are smaller than those that can be achieved on a large period of say five years. Assuming that future machines, industrial equipment, buildings, and vehicles are built and used with 20-35 percent less energy/output than the current stock, increments of economic growth would demand less energy than in the past. Roughly speaking, energy use would grow at only 65-75 percent of the rate of economic growth, thus leading to a decline in the energy/GDP growth rate. This assumes only a moderate rise in real oil prices (no more than doubling by the year 2010), growth of electricity prices at the rate of inflation, and similar economic structure in the future.

A more realistic judgment, however, must allow for changes in economic structure. Motor vehicle use has grown faster than GDP, as has manufacturing output. The average tourist now spends more bed-nights in

Table 4-6. Percentage Energy Intensity Reduction (Conservation) Potentials in Kenya by Sector and Energy Type

Sector	Fuel		Electricity	
	Near	Intermediate	Near	Intermediate
Industrial	15	20-25%	5	20-25%
Commercial	10	40-45	10	40-50
Transportation	20	20-35	--	--
Residential		15-20	5	20-50

the air conditioned hotels of the coast than in Nairobi. On the other hand, real increases in the price of energy have retarded the growth rates for transportation services and lessened the rate of growth in some energy intensive industries. Unfortunately, it is difficult to estimate the long-term differential growth rates among these important activities, as it is to predict even next year's price of oil. Moreover, the actual rate of growth of GDP will be sensitive to the cost of oil and its impact on foreign exchange and investment in Kenya. Faster GDP growth increases growth rates for transportation services but also allows more rapid expansion of new facilities and replacement of older plants and stocks. Higher economic growth also facilitates increased experimentation with an investment in new technologies that might save energy. In short, the most important factors influencing future energy demands are not known precisely enough to permit exact quantification of the impact of conservation on energy use in Kenya. However, from a general perspective, we are confident in the conclusion that a sizeable amount of cost effective energy conservation is achievable in Kenya. The question which remains is how best to realize this potential. We turn to this issue in Chapter 5.

Chapter 5

REALIZING THE CONSERVATION POTENTIAL

Major Needs: Information and Analysis

In the introduction we emphasized the importance of information about energy end use for the energy planning process. It is difficult to plan energy supply expansion, whether in oil, gas, electricity, or renewables, without a thorough understanding of existing and plausible future demands for energy services. In previous sections we have pointed out areas where the present study is incomplete, sometimes seriously so. Here we would like to review systematically the kinds of studies and surveys we believe are necessary for design and implementation of energy policies in Kenya, especially regarding energy conservation. Such activities should also be of importance in other developing countries.

Ongoing Surveys of Manufacturing and Commercial Firms. In the industrial sector, a major ongoing survey is needed. A reporting scheme requiring users and suppliers to report actual deliveries on a yearly basis, along with data on output, would greatly assist efforts for both conservation and supply planning. More importantly, such an ongoing survey would provide an incentive for major energy users to keep careful records of their energy consumption.

In Kenya, we discerned that a great deal of the needed information exists but often was difficult to locate and obtain. The oil companies have the capability to classify the sales of each of their products by the economic activity of each customer, but not all sales are yet so classified. Moreover, data on energy consumption in individual firms are usually kept by those firms, though in a form difficult to retrieve. We believe that this situation could be remedied easily.

Review of the classifications used by oil companies would be straightforward; once the data from each company were aligned, sales

figures could be summed readily and merged with EAPL data. Aggregations of energy users that match those for economic indicators could be chosen; in this way the major industries' energy use could be followed from year to year. Questionnaires could be distributed with the manufacturing census and with other routine data-collection activities covering tourism, transportation, and so on. In this way a data base covering broad sectoral energy use as well as details of energy use and output for each industry could be established. Energy planners could then follow a series of indicators of energy-use patterns and conservation on a regular basis, aiding greatly their efforts to develop successful energy policies.

Future energy use will be strongly influenced by the development strategy that Kenya follows, particularly the development of the rural and informal sectors. Little is presently known about the economic contribution or the energy demand of the informal sector; a considerable amount of survey work is necessary to provide a useful data base. To determine whether electricity is made more affordable by rural electrification through a grid or through use of dispersed sources (possibly interruptible) can only be ascertained by a detailed investigation of how power and fuels are used in small industries and less developed areas.

The Kenyan government, like those of other developing countries, can exercise a considerable measure of control over the direction of national development through its loan programs, its own economic planning, and through grants from other countries or organizations. Development strategies need to be considered from many dimensions, and energy has become one of the most important. It remains to be seen whether centralized production facilities lead to the maximum energy efficiency through economies of scale, or whether decentralized industrial production provides greater efficiency by allowing greater use of locally available renewable energy sources, and reducing transportation needs. We are not suggesting that every increment of economic planning be subjected to an "energy impact statement," but we believe it is important to understand the full energy-demand consequences of various development strategies. In Korea, for example, the government maintains a classification of industries by their energy intensity. The government encourages--presumably through loans and grants--non-energy intensive industries such as clothing and

electronics, while discouraging energy intensive industries employing technologies that are not amenable to conservation in the near- or medium-term.

Import/Export Survey. The relationship between development and energy intensity is significantly affected by international trade. In 1977 the energy embodied in imports of manufactured goods, net of exports, was at least as great as the total consumption of commercial fuels in Kenyan industry (Schipper, 1980). This hidden energy needs to be considered in energy planning. Development strategies aimed at substituting domestic production for manufactured import will increase the overall energy intensity of the economy (other things being equal). It is important to develop an accurate accounting system of the energy embodied in imports and exports in order to estimate the changes in energy intensity that will result from future import substitution.

Transportation Survey. The section on transportation in Chapter 3 stressed the importance of energy and structure-related information for energy-demand analysis. A variety of trends in the use of transportation services were discussed, yet coupling these trends to energy use is difficult. While it appears that some relevant material may have been collected in Kenya, little has been published. It is essential for Kenya to implement a system for detailed accounting of the ownership and uses of vehicles. A survey of the vehicles buying fuel at retail outlets would give a better idea of fuel use by purpose; this is an example of the kinds of surveys that would make possible a better understanding of transportation energy use.

Residential Appliance Survey. The use of kerosine and LPG in Kenyan households increased by about 10 percent per year until 1979, when supply bottlenecks virtually halted growth. Having a knowledge of how fast demand for these fuels would rise in the absence of supply constraints (for example, in response to income growth) should be an important element in Kenyan energy planning; however, there is a lack of pertinent information on appliance ownership. We recommend that surveys of appliances be conducted for all Kenyan households, covering types of appliance use as well as fuels. Such surveys would be important in estimating the potential demand for commercial fuels as replacements for wood and charcoal, and the potential role of solar systems as replacements for commercial fuels. The

imminent shortage of firewood in Kenya and the ravages of deforestation have been well documented,[1] yet the interaction of renewables and commercial fuels cannot be understood without a fuller knowledge of their uses throughout the economy.

Conservation Needs and Policies

We believe that it is possible to meet many of the information needs described in this paper as essential to development of sound conservation policy. The following is a discussion of some policies and actions that should be considered as part of Kenyan energy policy and planning.

Pricing, Taxation, and Import Barriers. There has been much debate in industrialized countries about the relative impacts on energy supply and demand of government policies regarding energy subsidies, taxes, and price controls. In Kenya the main evidence of price distortions was the price controls on kerosine and gasoline, which kept prices for the latter lower than in most other countries. It is well known that historically low gasoline prices in North America led to inefficient cars and more driving than in Europe. The importance of market forces in promoting efficient allocation of resources should be constantly recognized.

The Kenyan government should consider a policy of taxing imported oil, so that the price will more fully reflect all the social costs of importing oil. This policy would increase the incentives of private companies to invest in energy-saving techniques. It might be argued that taxing energy would hurt industry, but the opportunities for conservation are so great that the effect on production costs could be kept to a minimum by good energy management. A desirable and possibly essential adjunct to this policy would be government assistance to industry in raising the capital necessary for investments in improved energy efficiency. Since taxation of any resource in a developing country could retard development it is important that revenues collected be returned quickly to the economy. For example, such revenues could be applied to a program of energy efficiency investments.

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1. See the proceedings of the 1979 Nairobi conference, "Energy and Environment in East Africa."

On the other hand, there are existing taxes on imported products that may be deterrents to energy efficiency. One supplier of solar equipment, who imports well-known components and assembles them in Kenya, argued against the import duty (presently at least 30 percent) for solar collectors. A competitor, who assembles collectors from domestically available materials, understandably supports the duty. But the importer showed us some stainless steel fasteners, unavailable in Kenya, which have superior corrosion resistance, but which are dutied at more than 100 percent. Such duties are clearly excessive and counterproductive to efficient energy use.

Bureaucratic inefficiencies are also impediments to conservation. Large shipments of imported parts for solar systems have been held up for months awaiting customs clearance. In another case, a firm that wished to import a power factor leveler to reduce electric power demand was denied the required import permit.

Incentives. Another policy option is incentives: fiscal or other policies that reward conservation above and beyond the value of the energy saved. In Sweden, government loans and grants to firms engaging in heat-saving investments have had significant impact (SIND, 1980). The grant or loan is denied if the project is either very profitable to the firm (greater than 25 percent rate of return), or unprofitable to the society (less than 6 percent return). Although this program has helped Swedish industry, some critics argue that it has also allowed less energy-efficient firms to "profit" relative to more efficient firms by making use of government money, and they suggest that a tax on energy use would be a better incentive.

In fact, tax and incentive policies can both be used effectively to stimulate energy conservation. One short-term Swedish effort that succeeded beyond expectation was the program of energy audits established by the Board of Industry. During 1979, consulting firms were paid by the government to make brief energy audits of middle-sized firms that did not possess their own audit capability. In the Republic of Korea the Korean Energy Management Association has instituted a series of audits and inspections aimed at assisting factory personnel in reducing energy use. Our interviews suggest that a similar program in Kenya could be successful

in demonstrating the rich bounty available to firms that make the effort to conserve.

Mandates and Standards. There are situations in which the marketplace is inefficient, and government policies may be appropriate to deal with these market failures. Such failures include: the short time horizons considered by consumers purchasing appliances, cars, or houses; the lack of interest shown by builders in the energy costs of installed equipment; the lack of incentive for owners of rental property to invest in energy-saving measures. In a study of the United States building sector (Blumstein and coauthors, 1979), many important examples of market insensitivity to rising energy prices were found.

There is probably a role for minimum efficiency standards for major appliances, compressors, air conditioning systems, and motors sold in Kenya. However, only such standards as would promise clear economic and energy benefits should be considered. New commercial building codes that encourage the use of passive solar cooling would also be beneficial.

There is little need in Kenya to impose mandates or restrictions on energy use. Kenyans express strong opposition to rationing or allocation schemes, mostly out of conviction that such schemes would not be administered equitably. Furthermore, symbolic rationing schemes, such as the closing of gasoline stations on Sundays, probably would not benefit the country in the long run. During weekends Kenyans and tourists alike flock to the parks and reserves, and city families return to traditional homes. During extreme shortages, emergency allocations might be understandable but they tend to create panic situations that make it more difficult for firms or individuals to make thoughtful decisions about energy conservation.

Training and Education. Throughout this study we found evidence of the need for training of Kenyan production managers in the techniques of saving energy. The relative ease with which the multinational companies in Kenya obtain information and expertise on conservation argues for increased efforts to train energy managers. At present, too few managers are equipped to make straightforward calculations on the payback of investments in conservation options. Few engineers with whom we spoke were aware of the similarity of their energy management problems with those of the other firms. A basic problem that Kenya shares with many developing countries is

that there are too few large firms of a given type to produce a sufficient pool of experience that can be exchanged through trade associations. Fortunately, interest in energy efficiency is growing rapidly. Employees of several large firms who attended a seminar given in Nairobi by one of the authors (LS) indicated that training and improved factory awareness and organization were seen by them as extremely important in improving energy efficiency.

It would be desirable for the Kenyan Association of Manufacturers to organize energy management training programs. Training could be organized along several lines. In the near term, energy assistance from Western countries could support seminars and audit and retrofit demonstrations involving both foreign and resident experts. It is important that seminars by visitors be coupled to actual retrofit installations so that evidence of the effectiveness of conservation be left in place. To provide a domestic capability, Kenyan energy-conservation engineers and auditors also need to be trained. There will be a growing market for such expertise to assist individual companies in their efforts to conserve energy.

Role of Donor Countries and International Organizations. In the development of energy conservation, there may be a key role for countries and organizations that have in the past taken an interest in helping developing countries solve their energy problems. Unfortunately, few of these have shown the necessary level of interest in conservation, probably because of insufficient understanding of the economic benefits that could accrue to developing countries from conservation.

International energy meetings should call greater attention to the promise of conservation. Unfortunately, the program of the August 1981 United Nations Conference on Renewable Energy Sources did not include discussion of end-use patterns and conservation. Yet the characteristics of the uses for energy usually determine the actual cost and desirability of using a given energy source, whether renewable or not. And the rate of growth in energy use will be one of the most important factors in determining whether renewables can catch up with demands for imported oil. The large size of the transportation sector in Kenya, for example, means that direct use of unprocessed biomass would not affect the largest energy user there; processes to convert biomass to liquid fuels with high fuel densities, such as alcohol, would be required if a large portion of even today's

commercial energy use in Kenya were to be converted to renewable fuels. Certainly the topic of end-use patterns should occupy a prominent place in meetings on renewable energy sources.

More generally, conferences and planning exercises sponsored by the United Nations and other groups should also consider the importance of understanding energy end use at the level of industries or individual factories, buildings, and homes. Because of the present neglect of this subject, little appreciation of the economic potential for conservation is gained by officials and experts from developing countries who attend such conferences.

We recommend strongly that a series of international meetings be devoted to assessing and exchanging information on conservation in developing countries. As of the present there has not been a sufficiently detailed comparison of energy end uses and conservation in developing countries that would allow intercomparison and validation of the findings of this and similar studies done in a variety of countries. By such an exchange, valuable information from one country may be generalized to other countries.

Bilateral organizations, such as the U.S. Agency for International Development or the Swedish International Development Agency should consider conservation training, retrofit demonstrations, and similar activities high on the list of their portfolio of activities. Such programs could have benefits of energy supply expansion or renewable energy sources can be realized. Such bilateral assistance programs should also be extended to include research on conservation problems in the developing countries themselves, with work extending to the level of surveys such as those performed or recommended herein. It is imperative that assistance programs have the advantage of a framework of information that will permit realistic judging of potentials for and progress in energy conservation.

Appendix A

DEFINITIONS AND CONVERSION FACTORS

Definitions

All weights are given in metric tons (2204.6 pounds). All heat is measured in joules (J) and their multiples: kilo (KJ = 10^3J), mega (MJ = 10^6J), giga (GJ = 10^9J), tera (TJ = 10^{12}J), and peta (PJ = 10^{15}J). Occasionally, heat is given in British thermal units (Btu) where 1 Btu = 1055 J. 3413 Btus = 1 kilowatt hour (kWh).

Conversion Factors

Because of variations in the calorific content of fuels there are no unambiguous factors that relate their calorific content to their volumes or weights. We therefore adopt certain standards culled from the literature and from material provided by oil companies' specifications in Kenya. In interviews we were often given in non-standard terms a heating value for a fuel that applied to a company; that value is used for comparison of that company's performance, but the standard values are used for compilation of sectoral energy flows. In order to compare our work to that of others we give the values we have adopted (table A-1). They may differ by as much as 10 percent from those commonly used in other countries, but the table below allows the reader to recover fuel quantities in liters and convert those values to other thermal values.

Table A-1. Energy Content of Oil Products

Product	liters/KG	MJ/liters	Other names
LPG	1.85	45.2[a]	
Kerosine	1.27	35.1	Power kero., illuminating kero.
Jet turbo	1.34	35.1	
Aviation gas	1.40	35.1	"AvGas"
Regular gasoline	1.40	35.1	RMS, regular mogas
Premium gasoline	1.36	35.1	RMS, premium mogas
Average of gasoline	1.384	34.4	
Auto diesel	1.19	38.7	"gasoil", "light diesel"
Heavy diesel	1.177	39.2	Industrial diesel oil
Fuel oil	1.06	41.2[b]	"Residual oil," "boiler fuel"

Source: Data from Kenyan oil companies and Statistics on Energy and Power which present oil data in tonnage, not joules.

[a]Actually, MJ/KG and is usually sold by KG.

[b]Varies from 40.6 - 42.0 MJ/liter.

Appendix B

TRANSPORTATION METHODOLOGY AND TOURISM DATA

Introduction

While supplier and end-use data give a fairly reliable picture of energy use in the stationary sectors (see Appendices C and D), transportation energy use is very difficult to estimate. This is because automotive diesel fuel has many uses in construction and agricultural equipment as well as being a convenient and clean boiler fuel. Worse, there is little accurate data on activity levels of the various transportation modes, particularly automobiles. There are some car counts but no published surveys of transportation and energy use. While a good deal of transportation energy use is concentrated into several parastatal firms, much of the remaining transportation fuels are used in a variety of ways, including private, business, and for-hire transportation. Therefore, a variety of approaches were taken, which we review.

Interviews

We met with representatives of major transportation firms: Kenatco (parastatal trucking and taxi company); Kenyan Bus Services (Nairobi and Mombasa domestic routes); East African Road Services (intercity company). From these interviews we gathered information on both fuel consumption and activity levels. Unfortunately, it is difficult to extrapolate Kenatco data to private or company fleet trucking, and it is very difficult to use data on the well-maintained busses from the large companies to represent the hundreds of private busses or small bus companies in Kenya. The share of freight or bus traffic carried by these parastatals was very small. Some of the data provided by these firms are shown in the text in table 4-2 on fuel consumption per unit output.

We met automobile experts at the Automobile Association (AA) and a major insurance company. These individuals provided some hard data and many valuable anecdotes but not enough information to allow a careful analysis of the use of private automobiles or matatu. The limited data provided are given in table B-1.

Table B-1. Distance Traveled by Vehicle Type
(10^6 vehicle kilometers)

	1975	1976	1977	1978
Truck freight[a]	1167.2	1019.0	1231.0	1595.0
Busses	156.3	125.5	138.5	143.4
Automobiles	751.2	582.5	654.4	822.4

Source: Automobile Association, Kenya, Road Safety Report, 1980.

[a]Includes heavy trucks, light trucks and vans.

Vehicle Stock

Based upon data collected in official sources, we attempted to extrapolate from 1967-76 data, the growth in the vehicle stock. For this period the Statistical Abstract gives the numbers of vehicles of each type registered in each year, as well as the number of new vehicles in each class. From the changes each year, we calculate the effective scrappage rate. It should be noted that the actual scrappage rate is unknown; the figure we calculate is merely the difference between the number of new registered vehicles and the total number of registered vehicles. We estimate both the average number of scrapped vehicles of each kind as a fraction of the number of new vehicles, postulating that fewer vehicles are scrapped when fewer new vehicles enter the stock. These two methods allow us to project the increase in stock beyond 1976 from the known number of registrations each year. For automobiles the methods agree within 1.5 percent. The results for four vehicle types are shown in table B-2; the data for 1972 and 1975 are official. Excluded from the calculation were

Table B-2. Vehicles in Kenya
(1000s)

	1972	1975	1976	1977	1978	1979
Trucks	17.4	20.8	21.3	22.2	23.9	25.4
Small trucks	44.2	58.3	61.4	70.0	74.0	78.4
Automobiles	67.5	83.7	86.7	92.5	98.4	100.8
Busses	3.4	4.6	4.8	5.0	5.1	5.3

Source: 1972 and 1975 data from Central Bureau of Statistics, Statistical Abstract, Table 188, and Automobile Association Kenya. 1976-1979 data derived from new registrations and estimated scrappage (see text).

rental trucks and automobiles, including minibusses often used for safaris. Their numbers totalled 6,352 in 1975. "Other motor vehicles" (12,300), motorcycles and trailers were also excluded. We emphasize that the classifictions of vehicles in table B-2 are uncertain, because of the use of all vehicles as matatu and the multiple use of other vehicles.

Additional transportation and tourism data which were used in the text for figures 2-1 and 2-2 are all presented in tables B-3 and B-4.

Table B-3. Air and Rail Transportation Data

	1972	1975	1976	1977	1978	1979
Air						
Passengers (1000)[a]	840	1082	1176	1098	1089	982
Embarcations (1000)	516	613	608	557	587	637
Flights (1000)[b]	10.1	13.7	--	11.1	11.0	--
Rail[c]						
Freight (million ton-km)		2179	2211	2057	2067	
Passenger (million train-km)		1039	1174	1445	1219	
Passengers (1000)		1359	1373	1575	1916	

Source: Central Bureau of Statistics, Statistical Abstract (1980), tables 174 and 180. Air flight data from Shell.

[a]Includes embarcations plus transit in Nairobi and Mombasa.

[b]For Nairobi only, and are predominantly international flights. 1972 datum actually for 1973.

[c]Kenya Railways operated as the East African railroad before 1976.

Table B-4. Tourism Bed Nights
(Million bed nights)

	1972	1975	1976	1977	1978	1979
Total[a]	2.48	3.21	3.57	3.84	3.98	4.34
Nairobi	1.11	1.33	1.43	1.41	1.41	1.50
Coast	0.93	1.37	1.58	1.78	1.91	2.12
Occupancy Rate (%)	49.7	48.8	51.2	54.6	54.1	53.9

Source: Central Bureau of Statistics, Economic Survey 1976 (table 13.7) and 1980 (table 13.5).

[a]Includes coastal, hinterland, Masailand, central and other regions of Kenya.

Transportation Fuels

The uses of transportation fuels are no less ambiguous. First, there are no aggregate data on the relative use of light diesel fuel in stationary versus mobile engines. While a good deal of transportation energy use is concentrated within several parastatal firms, much of the remaining use of transportation fuels is unrecorded. Even if the characteristics of the auto fleet were well known, it would be difficult to characterize energy use for transportation because the definitions of automobile, truck, or bus overlap. Light trucks are used for personal transportation, while automobiles are used for freight or as matatu, (jitneys).[1] Thus it is somewhat misleading to identify transportation function (private passenger, bus, freight) with vehicle type. Additionally, gasoline and diesel fuel use cannot be allocated directly to automobile or bus and truck use, as there are many autos using diesel fuel, as well as some busses and trucks running on gasoline.

We found no data in Kenya on the weight distribution of the automobile stock, nor any estimate of miles-per-gallon based upon tests or make-up of the stock. We found only some rough estimates of the weight distribution of new autos. Important restrictions on the import of autos, as well as changes in the duty on autos as a function of weight, suggest that the pattern of new car ownership will change radically from 1980 onwards. We were forced to ask suppliers and users to make informed guesses by sector as to how this fuel is used. The specifics of our breakdown are presented in Appendix C on oil use calculations.

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1. The matatu perform a vital service, by extending the bus network to virtually every town and to every part of the larger cities. Matatu were illegal (although tolerated) for many years, but recently the government has moved to give them quasi-legal status.

Appendix C

OIL USE METHODOLOGY AND INDUSTRIAL DISAGGREGATION

Summary of Approach

We examined the sales records of the six private oil-marketing firms in Kenya. Where possible, we obtained sales records by broad consumer classes: road transport; manufacturing; hotels, schools and other institutions; resale LPG and kerosine (primarily for residential use); rail, aircraft, and boat transportation; and agriculture. Knowing the market shares of each product sold by the largest company, we extrapolated product use by sector to the entire economy for 1977 and 1979. This process allowed a first-order tabulation of oil product allocation over end use sectors.

Product sales were then examined more closely by looking at sales to individual customers or groups. Firms were chosen by their consumption level and/or listing in the Census of Manufacturers as having over 100 employees. The definition coincides with that of "large firms" in the Statistical Abstract. Where possible, transport fuels sold to industries were treated separately from those used to generate process heat or stationary source horsepower. Some aggregation of industrial production and oil supplier data was necessary to preserve requested confidentiality.

Data from oil suppliers were supplemented with information obtained in interviews with users (described below). In this way, we often had two sources of energy use data that could be checked against each other. Because our goal was to produce a complete energy balance, it was necessary to estimate the consumption of fuel by all firms in each major economic sector or industry, where actual data were not available. The data on electric power were substantially complete for all large firms, which permitted use of the following technique to estimate total oil consumption. For a given industry, we took the ratio of electricity use for firms

interviewed to all firms in the EAPL listings, then extrapolated the fuels use data from the interviewed firms to the entire industry, in the same proportion. This permitted a first-order estimate of energy by manufacturing sector. For some industries (cement, oil refining, paper, textiles, and hotels) our surveys reached firms accounting for more than half the fuel consumed in their respective industries.

Oil Use Calculations

Calculating the details of the flow of oil in Kenya is difficult. Official publications, such as the Statistics of Energy and Power, which appeared in 1979 from the then Ministry of Transport and Communications and the Central Bureau of Statistics, gives only the consumption of fuels, not their end users. We found that each oil company kept rather detailed records on the type of consumer for each oil product. While smaller companies identified major consumer classifications like "hotels," "industry," the larger companies kept computer records by the equivalent of two- or even three-digit classifications. We therefore followed a variety of approaches. The most aggregate approach takes the sales of oil from Shell/BP, broken down by sectors by T. Wainaina, J. Nganga, and F. Kiura of the marketing department. Knowing the quantity of the i-th fuel in the j-th sector as sold by Shell, Shell's total sales of the fuel, and the overall market share for that fuel across all sectors for Shell,

$$S_{ij},\ TS_i,\ SH_i, \text{ respectively,}$$

we can estimate total sales of each fuel for the country

$$(TS_i) \text{ as } TS_i = TS_i/SH_i.$$

Since there is no published data for 1979 use of fuels this method was used to get totals for the country.

We then approximate the sectoral breakdown of fuel use by assuming only that the distribution of sales of a particular fuel by Shell over sectors is approximately the same for the sum of all other oil companies. Since the overall market share for Shell is greater than 50 percent by volume of all products, the approximation is reasonable. We treat the

largest single customers (the railroad, cement mills, paper mill, and EAPL) carefully, when they are included in Shell totals and when not.

Shell provided data broken down into the following sectors: resale, road transport (contract sales), hospitals, schools, hotels, other institutions, industry, government, agriculture, marine. We have assumed the following fuels in assigning fuels:

1. Gasoline (regular and premium): All assigned to transportation, we note the share sold by retail pumps and that sold by contract. Where sales to agricultural institutions are noted, we keep the share separate. We assume a heat content of 34.8 MJ/liter for both grades.

2. Diesel Fuel (automotive): We assume that resale is 80 percent transport, 20 percent agriculture equipment; marine is all boats; industry, buildings/institutions are 80 percent stationary source, 20 percent vehicles; government is 80 percent vehicles, 20 percent stationary source; in the agricultural and construction sectors, we assume that 50 percent of this fuel powers transport equipment, 50 percent powers stationary sources. We assume a heat content of 38.7 MJ/liter.

3. Kerosine: This is mostly composed of illuminating kerosine (IK), with some "power kerosine" still sold to tractors. In accordance with advice of every oil company, we count all "resale" IK as residential, and allocate the rest according to Shell. A small amount is used for transportation or agricultural equipment. We assume a heat content of 35.1 MJ/liter.

4. Aviation Fuels: Avgas is collected under domestic air transportation along with 10 percent of the jet turbo fuel. The remaining turbo fuel is classified as international transport. We use sale of fuels at Kenyatta and Mombasa airports since the official data is somewhat confused between sales and exports. We use a heat content of 35.1 MJ/liter. There is some confusion in official statistics between sales (including bulk exports) and use in aircraft leaving Kenyan airports.

5. Industrial Diesel Oil: After marine and road transport are subtracted, the remainder is assumed to be used in stationary applications, primarily as boiler fuel. There is some use for construction and agricultural equipment that is noted separately by Shell. We also found a few firms producing their own electricity with IDO. Additionally EAPL and the Kenya RR use IDO. We distribute resale industrial diesel oil among the

other sectors according to their proportional shares of allocated fuel sales for IDO. We assume a heat content of 39.1 MJ/liter.

6. Fuel Oil: This is also known as boiler fuel, residual fuel oil, or heavy boiler fuel. We use a heat content of 41.2 MJ/liter unless given other values by users. We distribute resale fuel oil among the other sectors according to their proportional shares of allocated fuel sales for IDO. Adjustments are made from national totals for the railroad and EAPL.

7. LPG: LPG is sold in small cylinders, large commercial cylinders, and large truck-loads. Following the oil companies, we count all small cylinders sold on the resale market in the residential sector, though some small shops may make resale purchases. The heating value of LPG varies considerably depending on the mixture of propane and butane; we assume 45.2 MJ/KG, the physical unit that LPG sales are reported in.

The results of this attempt to allocate fuel use are shown in table 4-1 in the main text. Using the same method applied to 1977 data from Shell we produced a similar balance for that year (table C-1). In both cases the fuel totals agreed rather closely with data published in the Economic Survey or the Statistics of Fuels and Power. Because of uncertainties in the identity of many electric power users (representing at least 15 percent of consumption in 1977) we do not break these data down as carefully as we did for 1979.

In the case of certain fuels, notably resale illuminating kerosine and LPG, each oil company provided us with their sales. As a first-order estimation this method tends to approximate well the total sales of fuels between industry, transportation, and building; but the division among building customers--hospitals, schools, government, hotels--is uncertain because the market share approach using Shell data may not hold at this level of detail. On the other hand, the use of Shell's market shares to represent the use of boiler fuels is probably accurate.

Industrial Disaggregation

Where the data we have collected by user, or from oil suppliers by customer, appear to dominate the sector, we break down oil use into two- and three-digit industrial classifications. Using data on the dominant customers in sectors like textiles, steel, plastics, or food, we define the ratio between the known consumption of fuel (from oil companies or users)

Table C-1. Composition of Energy Use in Kenya, 1977.
(Terajoules)

Sector \ Fuel	LPG	Gasoline	Jet Fuel	Autodiesel	Kerosine	Heavy Oils[a]	Aviation Gas	Crude Oil Losses[c]	Coal	Total Fuel	Electricity[b]	Total Energy
Residential	384				2012					2396	878	3274
Commercial	225			110	110	307				752	1069	1821
Schools & Hospitals	100			52	32	106				290		
Other	125			58	78	201				462		
Industrial	162			1178	620	11406			1834	15200	2236	17436
Energy						5212		4313		9525	144	9669
Refinery								4313		4313		
Electric Power Plants						5212				5212		
Construction[d,e]										675		675[f]
Agriculture[e]	1	474		3289	54	1033				4850		4850[f]
Transportation		12418	13833	9814	15	6302	290			42672		42672
Road		12409		8603	15					21027		
Int'l Aviation			13833				290			14123		
Rail				1050		5090				6140		
Marine		9		161		1212				1382		
Total	772	12892	13833	14391	2811	24260	290	4313	1834	76070	4327[f]	80397[f]

[a] Includes industrial diesel oils and fuel oils.

[b] Electricity counted at 3.6 MJ = KWh and therefore reflects end use consumption.

[c] Includes only losses incurred in electric powerplant production and in oil refineries.

[d] Fuel disaggregation unknown

[e] Unknown electricity consumption

[f] Partial estimate, see footnote e.

and electricity (from EAPL or users) and form the ratio of the two. We use EAPL data to find the remaining firms in this sector, and, using their electricity consumption as given by EAPL, approximate fuel consumption using the ratio derived from surveyed companies. Letting total electricity and fuel sales to surveyed k firms in sector j be represented by

$$E_k^j \text{ and } F_k^j, \text{ respectively, } R_k^j = F_k^j/E_k^j$$

and calling total electricity consumption for all large firms in that sector (as defined by EAPL lists)

$$E_t^j$$

we derive total fuel consumption

$$F_t^j = E_t^j * (R_k^j).$$

Since the ratio of fuel to electricity consumed in an industry can be expected to vary from company to company, this method of estimating sectoral fuel use has risks. In particular, use of consumption figures for the very largest firms in a sector may be misleading for the next-largest, because fuel consumption per unit of product always tends to be lower as companies get larger. On the other hand this method does allow us some allocation of oil among three-digit industrial sectors. To reduce uncertainty we aggregate all heating fuels and use their thermal content for this derivation. In extrapolating we exclude from the list of surveyed companies the fuel consumption of companies that self- or co-generated electricity. We also excluded the consumption of Pan African Paper Mills from the extrapolation base as they make pulp and pulping chemicals, in contrast to the other firms listed under Paper. These firms' consumption are included under the total sectoral consumption.

Using interviews and data from oil suppliers available through mid-April 1981, we present the results of the survey over the sectors shown in table C-2. We give the total electricity and fuel consumption of the firms whose data were obtained directly or from oil suppliers, and the total

Table C-2. Energy Consumption of Manufacturing and Commercial Firms, 1979

	Firms in Present Survey				All Firms in EAPL List		
					Recorded		Extrapolated
	Number in Oil Company Data	Number in Direct Survey	Fuel (TJ)	Electricity (GWh)	Total Number	Electricity (GWh)	Fuel (TJ)
Manufacturing	37	22	8102.1	395.1	286	598.8	15730.6[a]
Food & Kindred	10	6	1090.2	87.2	121	148.5	3217.6
Textiles	12	2	1131.8	67.4	47	80.7	1353.8
Paper	4	[illegible]	88.0	6.5	12	23.8[a]	1684.5
Cement	-	2	4215.1	123.5	6	124.0	5570.0[b]
Rubber	2	1	234.4	13.1	11	15.7	281.2
Glass	2	2	700.3	8.5	5	9.6	793.8
Chemicals	2	3	390.0	9.6	22	19.6	837.4[a]
Metals, Machinery	2	3	192.0	32.7	52	56.2	329.4
Transport Equip.	3	1	60.0	3.5	10	5.7	95.8
Other	-	-	-	-	-	115.0[c]	1567.1
Commercial[d]	17	5	394.2	24.5	115	363.1	1442.0
Hotels	14	5	206.5	17.8	70	43.8	509.8
Hospitals[e]	3	-	187.8	6.7	45	18.4	512.0
Other	-	-	-	-	-	300.9	420.2

[a] Includes self or cogenerating firms. Totals of firms surveyed exclude these firms for extrapolation purposes.

[b] Includes 1310TJ coal.

[c] Includes remainder of EAPL industrial tariff excluding energy sector. Sectoral total includes small industry classification.

[d] Commercial "total" and "other" include hospital electricity, but exclude extrapolated fuel use. Sectoral total includes shops.

[e] Data uncertain due to small sample. Not included in energy balance.

electricity consumption of all firms in the sector. The numbers of firms in each sample are given, and the final column gives the extrapolation we arrive at. Under "other" we list the residual consumption of fuels and electricity based upon EAPL's lists and our own manufacturing/industry and commercial sector fuel consumption totals derived from Shell data.

Time constraints limited the number of firms we were able to question directly, as well as the amount of data we could request from oil companies, several of which merely allowed us to copy any desired information by hand. Nevertheless, we feel certain that it is entirely possible and practical to obtain a detailed picture of oil use based upon supplier data with user information serving as a check.

Certain problems arise in either case. Some firms report to us actual energy consumption during a period, while others report purchases. Since we did not note storage capacity we might over- or underestimate fuel use because of stock changes. A few firms reported accurate consumption figures for key processes but did not necessarily give us plant-wide consumption. The breakdown of auto diesel fuel use among transportation and stationary uses was usually available but not always submitted to us.

Based upon our interviews and reconstruction of country-wide data using information from Shell and other companies, we present in the text (tables 3-1 and 3-3) our best estimate of oil use among industrial and commercial firms. Note that we surveyed industrial firms consuming 9,730TJ of oil and 1,310TJ of coal, out of a total manufacturing fuel consumption of 14,420TJ of oil and 1,640TJ of coal. Thus our survey covers about 60 percent of all industrial fuel use. Corresponding figures for industrial electric power use are a surveyed 395 GWh out of a sector-wide total of 599 GWh, yielding a coverage of 66 percent. The coverage of firms in the subsectors we surveyed is much higher.

Excluded from the survey are several subsectors, many of which are not energy intensive (such as printing), or those that do not purchase their own electricity, such as sawmills. These companies, as well as small electric power consumers are hidden in the "other" classification. While we could disaggregate their electricity consumption, and in fact do so in table 3-2, we could not find enough information on their fuel use. The data from hospitals and schools were too poor to permit reliable extrapolation. The only other major <u>fuel</u> consumer in this sector is the

laundry industry, for which we have little data. However, most of the electric power consumers in this sector are office buildings, government offices, and other institutions whose fuel consumption is very low. Hence we are not surprised to find that hotels consume a large fraction of all fuel in the commercial sector.

Appendix D

ELECTRICITY CALCULATIONS

Introduction

The East African Power and Light Company (EAPL) is the only supplier of electricity to final consumers in Kenya (though some firms self- or cogenerate electricity). We examined EAPL's regional breakdowns of electricity use by tariff and consumer class. We then examined the consumption of each heavy user (normally classified as industrial/commercial) by customer and by economic sector, using the EAPL trade classifications. We also separated domestic hot water off-peak electricity users and very low electricity consuming households from the residential tariff. We sorted industrial and commercial data for several years prior to 1979 but were not able to identify all customers for these earlier years. We believe that this is possible, however, and that a complete analysis of electricity use in these sectors could be made from 1974.

Electricity Use Calculations

Electricity consumers are divided by tariff classifications into several groups. These were numbered 1-9 until January 1979, thence A-F. The heaviest users (4 and 5, later B1-3 and C1-3) are presently broken down by demand as well as monthly use. The classifications are shown in table D-1, along with consumption, number of consumers, use/customer, and average price. Data through 1978 were supplied by EAPL. We were provided with detailed lists of customers and consumption on a confidential basis by EAPL. These lists reach back to March 1977 for the entire country and back to March 1974 for the Nairobi region.

Under the old Tariff system Tariff 4 (T4) covered "commercial" establishments, while T5 covered "Industrial Firms." Both of these tariffs cover consumers using more than 7000 kWh/month. T3 covered firms whose monthly consumption was less than 7000 kWh/month; those whose consumption occasionally surpassed this figure were printed out with T4 and T5. In 1979 the system was changed, with B1-3 replacing T4 and C1-3 replacing T5 approximately. The latter class (3) corresponds to consumers with two meters, one for peak consumption. The division among customers depends on the total demand in kVA (kilovolt-amperes).

Each firm is given one or more account numbers, depending on its service and the number of meters or transformers it has. In all cases the account number is keyed to the region where the customer is located; 1 for Nairobi, Thika, Athi River and so forth; 2 for the Coastal Region; 3 for the Rift Valley; 4 for the North; and 5 for the West. With the exception of some 3-accounts, these numbers have been unchanged for many years. Unfortunately the number of accounts exceeds the number of customers. If we count a "customer" as an enterprise in a single location that may have more than one premise, such as the University or several factories with neighboring plants who report their output over all co-located plants, the identification of "customer" with account becomes even more strained. Therefore the entry "number of customers" in table D-1 should not be taken literally when read with these qualifications in mind.

Data received from EAPL contained the account number, average consumption per month over the previous "n" months (variable with each account), customer type (according to a three digit ISIC scheme), average price paid for electricity taking into account both kWh and demand charges, demand over the previous month, and load factor. We preserved all but the last two entries in our own files. In January 1979 the name of each consumer was added to the EAPL print-out, though the consumer name might be that of the legal owner of the building or installation, not necessarily its popular name. Some hotels and buildings were referred to by their owners' names. We sorted these data by name (alphabetically), by account number, and by type.

Unfortunately the EAPL classifications for type were somewhat in error. In most cases the errors appeared systematic, perhaps due to a programming error in the billing computer made many years ago. Several

hotels were classified as fisheries, for example. We corrected the January 1980 list as best we could, using the Census of Manufacturers and the Kenyan telephone directory. Several firms' classifications remain uncertain. This master file of firms was then used to correct the type of entries in older billing lists, as well as to add customer names to those lists.

To accomplish this task a computer program was written that matched account numbers between the January 1980 billing list and any other list. It was presumed that most firms in business in 1977 or before survived to 1980, though there were some nonmatches in the 1977 data because of account number changes.

Once the billing list was corrected so that names and classification types were deemed correct, the entire year's consumption was sorted into 34 small customer classes and then nine large classes. When accounts in earlier years are correlated, then a careful comparison of consumption over time can be made; for now only the 1980 data were used. These data were manipulated using the monthly average consumption over the previous "n" months (n = 12 in most cases) to arrive at the previous year's consumption. It was assumed that accounts with an "n" figure less than 12 represented new meters, new accounts, or even new customers. Thus the January 1980 list was used to represent calendar 1979, March 1977 for calendar 1976, and so forth. Totals were then found for each industry and large sector; these are presented in the text (table 3-2).

We present the full breakdown of electricity use in table D-1. 1979 data were taken from the complete printout of January 1980, while other years' information was supplied in the aggregate from EAPL records. The 1979 data are not completely consistent with those of other years for the several reasons discussed in this report.

Comparison of the totals for B and C Tariffs in 1979, 835 GWh, show consistency with the calendar 1978 consumption of 806 GWh according to EAPL records. The small growth over the two years may appear because of improper accounting, since T4 and T5 do not correlate perfectly with B and C, but may also reflect the 1979 slowdown in economic growth. However, preliminary comparisons of 1977 data show larger inconsistencies, while data for Nairobi alone from calendar 1975 appear consistent with EAPL published statistics. Therefore, we conclude that our analysis of EAPL

Table D-1. Electricity Use in Kenya: Provisional Breakdown by Customer Class

Year	Class	Customers[a] (1,000)	Consumption (GWh)	Use/Customer (MWh)	Average price (Kenyan cents)
1972	Residential	39.60	120.495	3.042	25.74
	Small residential	41.38	9.947	0.240	113.47
	Small commercial	15.25	100.492	6.590	41.81
	Commercial	0.299	103.805	347.174	23.59
	Industrial	0.287	261.504	911.163	17.89
	Res. hot water	22.58	117.942	5.223	12.40
	Other off-peak				
	Street light	0.065	9.388	144.431	27.23
	Staff housing	1.05	2.498	2.379	10.60
	Other	0.006	68.776	c	12.28
	Total	--	794.847	--	28.80
1975	Residential	44.623	148.522	3.320	26.07
	Small residential	51.771	15.052	0.291	108.74
	Small commercial	18.228	127.326	6.985	44.71
	Commercial	0.368	136.007	369.584	26.59
	Industrial	0.373	311.854	836.070	22.00
	Res. hot water	25.600	134.551	5.240	14.93
	Other off-peak				
	Street light	0.095	10.670	112.316	31.39
	Staff housing	1.043	2.735	2.622	10.45
	Other	0.007	114.714	c	15.54
	Total	--	1001.431	--	25.90
1977	Residential	51.115	172.350	3.372	36.75
	Small residential	58.199	17.257	0.297	133.92
	Small commercial	20.566	146.412	7.119	65.88
	Commercial	0.413	154.741	374.676	40.49
	Industrial	0.534	542.945	1016.751	31.01
	Res. hot water	26.373	111.038	4.210	21.13
	Other off-peak				
	Street light	0.099	10.808	109.172	46.77
	Staff housing	1.221	3.182	2.606	22.88
	Other	0.002	44.897	c	25.82
	Total	--	1203.630	--	37.80

Table D-1. (continued)

Year	Class	Customers[a] (1,000)	Consumption (GWh)	Use/Customer (MWh)	Average price (Kenyan cents)
1978	Residential	55.934	190.632	3.408	35.95
	Small residential	62.238	18.498	0.297	134.88
	Small commercial	22.320	147.626	6.614	67.64
	Commercial	0.461	173.538	376.438	40.51
	Industrial	0.681	633.779	930.659	31.49
	Res. hot water	27.369	116.537	4.258	21.23
	Other off-peak				
	Street light	0.092	10.426	113.330	46.67
	Staff housing	1.245	3.114	2.501	22.43
	Other	0.002	6.418	c	28.27
	Total	--	1300.568	--	38.10
1979 (Actual)					
	Residential)	144.8	340.0	2.348	c
	Commercial and Industrial (B/C)	1.20	989.0	824.167	c
	Off-peak	27.8	c	c	c
	Street light	0.08	10.0	125.000	c
	Other	--	--	--	c
(Re-classified)					
	Residential[b]	77.6	214.3	2.762	c
	Small residential[b]	48.9	11.7	.239	c
	Small commercial	c	132.7	c	c
	Commercial and Industrial	1.2	--	708.583	c
	Commercial	--	226.8	--	c
	Industrial	--	623.5	--	c
	Res. hot water	21.8	54.0	2.477	c
	Commercial off-peak	6.0	60.0	10.000	c
	Street light	0.08	10.0	125.000	c
	Staff housing	1.5	3.2	2.133	c
	Bulk housing	c	2.8	c	c
	Total	--	1339.0	--	--

Source: Data for 1972-78 provided by Mr. P. Okwany of EAPL. "Actual" data for 1979 published in Central Bureau of Statistics Economic Survey 1980, table 10.6 (Nairobi). "Reclassified" explained in text.

[a]Number of customers equal to number of meters.

[b]Split between residential and small residential in 1979 based upon number of consumers in the 30-150 kWh/month and 1-30 kWh/month interval of Tariff A, respectively.

[c]Not estimated.

large customer statistics is basically sound and can be used to represent the major electricity users in Kenya. In 1979 total electricity consumption on the large customer tariffs was 835 GWh, out of a total of 1339 GWh sold. Of this, approximately 6 GWh represented bulk sales to residential estates built for employees of various large firms.

EAPL provided a breakdown of consumption in the new Tariff A by consumption interval and region. Unfortunately the total consumption within each interval was not provided, so we were forced to make a rough average for each interval and the older tariff classification that it represented. EAPL did provide totals by tariff for Tariffs A, D (offpeak), and E (Street Lighting) communicated to us, by the Energy Systems Research Group. When these figures were added to our own for Tariffs B (T-B) and C (T-C), however, the grant totals were over 1700 GWh, far higher than sales recorded in 1978. Most of the growth appeared in Tariff A (T-A)--a 250 percent increase in consumption per customer in the nonresidential consumers compared with the old T-3 consumers in 1978--and in the off-peak Tariff D.

Additionally, the detailed lists provided by EAPL did not cover the small commercial customers that consumed 147 GWh on T3 in 1978, of which perhaps 10 percent was concentrated into a few large firms that would have qualified for T4 and T5 in 1979. Unfortunately these T3 customers disappeared into T-A (the residential sector) in 1979, and were therefore lost into the residential sector. The consumption in this sector was nonnegligible, of the same order as the "commercial" sector (T4), and represents an important part of the Kenyan economy. Unfortunately EAPL was not able to list the names or principal products of these customers. Its omission from our analysis constitutes a potential problem for study of the "informal sector" or cottage industries.

Cross Check on 1979 Data

The Economic Survey 1980 published sales totals for EAPL that included self generation for the years 1975-1979. Figures for the 1975-1978 period checked against those provided directly by EAPL. For 1979 the Economic Survey gave as "Residential," 340 GWh, as "Commercial" 335 GWh, as "Industrial" 724 GWh (including 70 GWh of industrial self-generation), and 10 GWh of "Street Lighting." The total, 1,409 GWh, is consistent with our

own figures provided that the subtotals are interpreted in the following way:

Residential (340 GWh) includes 226 GWh corresponding to T-1 and T-2 in 1978, assuming constant consumption per customer and the increase in customers as provided by EAPL. The 54 GWh of off-peak consumption that is used for residential hot water heating is included herein, as well as 60 GWh of nonresidential off-peak electricity (now T-D, formerly T-6) use that according to EAPL is not strictly residential. EAPL staff housing consumption is included in this total, but purchases in bulk by other companies for their employees are not. These are added later and subtracted from the T-B and T-C listings.

Commercial (335 GWh) includes 226.8 GWh founded in our analysis of T-B and T-C that is assigned to the commercial sector, and 108.2 GWh of consumption by the largest T-A consumers, formerly classified under T-3. To the extent that some of the "commercial" customers included in the 226.8 GWh subtracted already reside in the EAPL "industrial" class. This means that the T-B and T-C subtraction performed above removes too much power from this class and leaves too little in the old T-3 category. However, the residual shows up in the EAPL "industry" classification. Examples of uncertain users include street lighting districts and water pumping, counted as commercial in our classification scheme, and EAPL staff housing, counted as residential by use. If these houses are counted in EAPL as residential, the 60 GWh of off-peak nonresidential (T-D) must be reduced by the same amount.

Industrial (724 GWh) includes the remaining consumers in T-B and T-C not accounted for in "commercial." It appears that the present breakdown of the "industrial" sector is made by looking at the consumer type given in the EAPL tariff. We believe our refinements and corrections to these classifications make our breakdown somewhat more accurate. There also appears to be some residual T-3 consumption herein. Our industrial classification, when agriculture, construction, mining, and energy are included, gives 623.5 GWh. The residual accrues to old T-3 customers, and 70 GWh of self-generated electricity not counted by EAPL.

Appendix E

SOLAR WATER HEATING CALCULATIONS

Based on data provided by three solar equipment distributors in Kenya, we have made estimates of the total installed square footage of solar hot water collectors between 1975 and 1980 and the annual energy savings attributable to those installations. The accuracy of the estimates provided cannot be guaranteed because of uncertainty as to the number of installed systems, the split between active and thermosyphon systems, seasonal fluctuations in performance due to cloud cover, variations in energy output caused by different installation techniques, and geographic locations. In spite of these factors, however, we feel that the numbers presented represent a good approximation of the current energy contribution attributable to solar domestic hot water heating in Kenya.

Table E-1 shows the square footage of collectors installed between 1975 and 1980. Together, the three reporting companies roughly represent a minimum combined market share of 90 percent so the survey coverage is fairly complete.

Table E-1. Solar Hot Water Heaters Installed Collector Area in Kenya by Year (square meters)

	Firm 1	Firm 2	Firm 3	Annual total	Cumulative total
1975		45		45	45
1976	30	125		155	200
1977	145	134	6	285	485
1978	9	100	702	811	1296
1979	64	42	577	683	1979
1980	188	12	768	968	2947
Totals	436	458	2053		

Based on reported performance data from thermosyphon DHW designs, estimates for average daily energy yield are shown in table E-2. For the purposes of determining energy contribution from solar DHW, we use a performance figure weighted by square footage sales or 739 Btu/ft^2-day (8.380 MJ/m^2-day).

Table E-2. Calculation of Performance Factors for Solar Hot Water Heaters

Company	Gal/Day	x Δ ^oF	x 1 Btu/lb	- Δ ^oF	x 8.33 lbs/gal	+ ft^2	=Btu/ft^2-day
Firm 1	19.8	80	1		8.33	16.14 =	817.5
Firm 2	27.0	85	1		8.33	24.00 =	796.6
Firm 3	9.5	76	1		8.33	8.48 =	709.2

Note: Weighted Average Performance = 739.0 Btu/ft^2-day = 8.380 mj/m^2-day.

Delivered solar energy is then estimated by multiplying the cumulative square meters of installed collectors in 1979 and 1980 by the average annual yield per square meter. These results are shown in table E-3.

Table E-3. Annual Delivered Energy for Solar Hot Water Installations, 1979 and 1980

	Daily yield mj/m^2-day	x	365 days/yr	x	square meters + 10_6	=	TJ/yr
1979	8.380	x	365	x	1979 ÷ 10^6	=	6.053
1980	8.380	x	365	x	2947 + 10^6	=	9.014

The types of energy saved by solar hot water heating could be estimated by apportioning on a Btu equivalency basis the delivered solar energy to the fuels that otherwise would have been used to heat water in houses, flats, hotels, lodges, farms, schools, etc. Fuel oil burned in hot water boilers primarily is used to provide hot water in hotels and schools while LPG or wood is used in remote lodges and electricity is used in residential homes. Because of the small absolute contribution to the Kenyan energy balance we do not calculate fuel specific solar energy savings.

Appendix F

KENYA OIL PIPELINE

Kenya Oil Pipeline

We studied the Kenya Oil Pipeline, which supplies the Nairobi area from Mombasa with around 1.2 million tons of oil each year. The pipeline company provided data on pumping energy consumed per cubic meter of oil pumped. Additionally, we estimated the amount of fuel required to haul a ton of oil uphill from Mombasa to Nairobi, and return the empty lorry. Using data from a report from the Oak Ridge National Laboratory we estimate the energy intensity of tanker transport from U.S. data to be around 2 MJ/ton mile. This is certainly a lower limit for Kenya. Other estimates compiled by O. Mbeche using information from transportation companies in Kenya put the cost much higher. Assuming a round trip of 500 miles, we found that the consumption of oil for tanker transport was around 20 times greater than the consumption of electricity for pumping a given quantity of oil. We counted the electricity consumption of the pipeline in the energy sector.

From the Economic Survey 1980 we learned that 1.02 million cubic meters (m^3) of oil were pumped in 1978. In 1979, the first full year of pipeline operation, the comparable figure was 1.37 million m^3 pumped, requiring an estimated 4.2 petajoules of petroleum products (see text, table 3-1).

Appendix G

CASE STUDIES: ENERGY CONSERVATION IN THE INDUSTRIAL AND COMMERCIAL SECTORS

Introduction

During the course of our preliminary investigation in 1979 it became clear that the best sources of information on conservation in Kenya would be engineers and managers in the major factories and buildings in Kenya. We interviewed several dozen firms to collect data on both energy use and economic activity levels. We selected firms on the basis of their size (as listed in the Census of Manufacturers) or the recommendation of marketing managers at oil companies and commercial engineers at EAPL. Each visit with an engineer and managerial staff lasted from 30 minutes to several hours. Our party was usually joined by people from management, accounting, and engineering. We were often given a tour of the factory and photographed evidence of conservation actions, such as added insulation. We also looked for escaping steam or hot water, loose insulation or pipe fittings, or other evidence of energy loss. To accompany our write-up, we requested data on energy use, physical output, conservation experiences or other qualitative information that should accompany figures on energy use. Initially we were accompanied by a representative of EAPL, or were introduced by a representative of an oil company. In order to increase our flexibility, we began making our own inquiries, and we were usually successful in setting up appointments. The Ministry of Energy supplied an official letter of introduction, which was supplemented by our own letter explaining the nature of our study and the information we required.

In our work we encountered some difficulties. First, we found that firms were willing to talk but were somewhat hesitant about putting information in writing because of the difficulty of collecting even basic information on energy use and output. We found that about one firm in

three provided us with the promised data very promptly, a third came forth with adequate information after a few follow-up phone calls, and the remaining firms either required considerable prodding or never produced the promised data. It was felt that the main reason for the delays was the difficulty that management encountered in finding the time to prepare energy and output accounts, not unwillingness to cooperate. The primary data from, and descriptions of interviews for which no data were provided, are given below. As a result of these difficulties, we are not able to present quantitative data for some companies that had presented interesting qualitative descriptions of their conservation actions.

Moreover, we often found that engineering staff and accounting or management staff kept records in different ways; the engineers recorded physical quantities of fuels ordered and consumed but left the calculation of energy costs to management. Energy costs were then combined with other costs, such as those for water. In this situation it was difficult to get some firms to uncover the original orders for fuel containing physical quantities. Often recorded purchases did not correspond to consumption because of changes in stocks. Fortunately a number of firms monitored their tanks regularly and recorded actual consumption, rather than estimating it on the basis of some design calculation of energy use per day.

Confidentiality is a problem that hinders somewhat our description of firms' actions. Because of our pledge of confidentiality we are not permitted in every case to name the firm we interviewed. We refer instead to the type of firm.

A comment made by an anonymous industrial consultant in Kenya, while somewhat speculative, bears mention. He pointed out that growth rates and profit margins among many firms in Kenya have been so high in recent years that many were simply uninterested in pausing to consider the benefits of energy conservation strategies, even those with payback rates comparable to those of the whole operation. This situation is consistent with experience in other countries; when the gains from investments in conservation are small relative to the overall flow of resources in a firm, conservation is usually accorded a minor role in planning. Firms that had not looked carefully at their energy use would not have the data we requested on hand; it is understandable why some firms could not respond to our request for data.

A local consulting firm, Bikro Consult, was enlisted to help with data collection in the commercial sector. Bikro Consult sent out survey forms to a number of hotels, schools, and hospitals, requesting information on activity and energy use (for example, hotel bed-days, school pupil numbers, hospital bed-days). We supplemented their efforts by interviewing personnel of several hotels in various parts of the country. Unfortunately, many of the survey forms Bikro sent out were not returned, and most of those that were returned were incomplete. Such information was useful neither for measuring changes in energy use related to conservation nor even for gaining information on total energy use in these respective activities. We therefore turned to Shell data for information on fuels used, which did give an indication of consumption levels in hospitals and schools. Since we covered the majority of hotels separately, the only remaining important fuel consumers in the commercial sector were laundries, which we did not study. We believe that we have accounted for most of the fuel use in this sector. Information on electricity use in the commercial sector was found readily from the large-consumer tariff data provided by East Africa Power and Light Company (EAPL).

Case Studies: Hotels

We visited a variety of hotels and lodges in all parts of Kenya. They can be divided into several classes: Nairobi city, coastal, other cities, and remote lodges. Hotels in cities other than Nairobi tend to be smaller and less modern, but the largest hotels in Nairobi appeared to have low energy intensities because of economies of scale.

The measure of output in the hotel is the guest-day. Guest days are also recorded in the Economic Survey and Statistical Abstract, so it is possible to construct an overall country index of energy and tourism. Most hotels use LPG in bulk for cooking, and fuel oil or industrial diesel fuel for heating water for bathing, laundry, and dishwashing.

The energy situation in hotels was particularly interesting. A Lawrence Berkeley Laboratory investigation revealed that hotels in Hawaii spend around $60-70/month for energy per room based upon 80 percent occupancy. These costs become important in boosting--or wiping out--profits. All the hotels we visited, or the managers with whom we spoke, indicated concern over energy. African Tours and Hotels and Serena Hotels, as well

as the Kitchwa Tembo (KT) tent camp in Masai Mara we visited, expressed dissatisfaction over costs and operating experience with diesel generators. At KT the manager told us that his wood supply, previously taken for granted, would be exhausted soon, in the sense that his trucks had to go farther and farther to gather wood! Presently KT uses wood fires under oil drums to make hot water for its guests. But even the modern hotels are finding it difficult to meet the rising cost of energy. The Intercontinental found that its water heating system could not keep up with morning hot water demands, prompting interest in adjusting the flow in showers.

Nairobi: Two Major Hotels. The first hotel studied in Nairobi is fully air conditioned and uses fuel oil for heating water and gas for its kitchen. The data presented below illustrate that a concerted effort to reduce energy costs gives higher returns.

When the present engineer arrived the electricity usage was very high, due largely to a sizeable air conditioning load. He has been able to cut this load markedly, by about 35 percent on a per guest-day basis and nearly as much on a yearly basis, through better maintenance. When we first visited the hotel in October 1978 we found it uncomfortably cold inside in the evenings. The temperature in 1981 in the same rooms was much more mild. The hotel has a heated pool but the temperature has been turned back. Though few attempts were made to save oil and gas, the data show declines in unit consumption of both.

The engineer has not installed sun screens or other sunshading devices on the windows. We judge that careful fitting of sunshades to the windows of this hotel could cut the air conditioning load even further, perhaps reducing the overall electricity bill by 15 percent. Since the system is

Major Hotel #1

Year	Oil TJ	Gas TJ	Electricity GWh	Oil (MJ)/ Guest-Day	Electricity (kWh)/Guest-Day	Gas (MJ)/Meal
1976	38.7	--	4.61	315	37.5	--
1977	35.5	21.8	4.11	307	35.5	3.87
1978	39.8	20.1	3.25	306	29.4	3.52
1979	33.6	18.2	3.07	260	23.7	2.96

. . .

central it might be feasible to install heat recuperators to maximize the use of outside air in the make-up of circulated air and reduce the amount of cooled air being exhausted. Shower-head flow restrictors--a must for every hotel in Kenya--could be installed provided they were checked periodically for scaling. This would reduce unit energy consumption even further.

The second hotel, which belongs to an international chain, was very forthcoming with data. It required its engineering staff to submit monthly energy records to the home office. These records showed oil consumption, cooking gas consumption, electricity and water consumption, number of single and double occupancies, and number of meals served in the restaurants. The quality of the information was very good; we were only had to total all of the monthly figures to obtain a yearly average.

The engineer we met expressed a great interest in conservation. He noted that because of a significant expansion in the number of rooms without a corresponding increase in boiler capacity, certain economies have been realized. However, the new rooms faced directly into the morning or evening sun, increasing the air conditioning loads. The engineer had not been able to deal with this problem or with that of low flow shower heads, though he had investigated cutting the actual flow of water to rooms before. This experiment produced poor results, as guests complained. It appears that hot water flow in hotels can only be cut by using low-flow shower heads such as those now commonly available in the United States. We suggested that shower flow restrictors be installed in several rooms and that these rooms be observed over several months to see if the guests complained or if undue amounts of scaling from hard water built up in the shower heads. We estimated that a full-scale program applied to this hotel might reduce the hot water bill from the rooms by 40 percent or more; assuming that hot water for showers is the predominant use of hot water for the entire hotel, we foresaw at least a 20 percent reduction in overall fuel oil use. Use of heat recovery from higher temperature uses (laundry, steam for cleaning, dishwashing) to the hot water storage tanks could save additional oil.

The figures in the table below suggest some efforts at conservation. However, the biggest drop in unit consumption occurred when the hotel was enlarged. Since economies of scale appear to be typical of many applications of energy, it would be difficult to ascertain how much conservation

per se has occurred in this hotel. We show the relative rise in the number of guest-days since 1975. The increase in energy intensity appears correlated with the small drop in load factor in 1976, while the big decrease in intensity in 1978 and 1979 appears due to the expansion. In 1979 guest-days increased over 1978 and intensity fell. We consider a steady drop in intensity even as load factors fluctuated as a more unambiguous sign of conservation.

Major Hotel #2

Year	Guest-Days 1975=100	Oil(MJ)/ Guest-Day	Electricity (kWh)/Guest-Day	Liquified petroleum gas (MJ)/meal
1975	100	134	16.7	8.37
1976	99	142	17.4	--
1978	177	107	14.4	--
1979	184	103	14.2	7.30

. . .

Other Hotels. We visited several hotels and lodges in other parts of the country, but did not obtain accurate data on both guest days and energy consumption from many of them. The first hotel listed here showed higher fuel use/guest-day than the others. This is probably explained by the distance from the hot-water boiler to the main hotel building, and isolation of the storage tank.

Other Major Hotels

Year	Oil(MJ)/ Guest-Day	Electricity (kWh)/G-D	Oil (MJ)/G-D	Electricity (kWh)/G-D	Electricity (kWh)/G-D	Electricity (kWh)/G-D	Electricity (kWh)/G-D
1975			735				
1977		28.7	465	21.5	27.1	22.5	33.2
1979	146	32.1	477	16.9	14.0	18.3	30.1

. . .

The second hotel is somewhat smaller. Its oil intensity appears correspondingly larger; its electricity intensity averages 16.9 kWh/guest-day, remarkably similar to the first hotel. It appears that economies of scale are crucial to determining energy intensities. Additionally, 1977 showed a 35 percent increase in total guest-days and a 15 percent drop in

total oil consumption, indicating that both load factors and conservation contributed to the drop in consumption in 1977. The 1979 capacity was down somewhat, and oil intensity increased by a similar amount. Hotels #3-5 provided data on guest-days, and electric power usage was found in EAPL listings for nearly the same periods. The drops in intensity suggest conservation, but all hotels had higher occupancy in 1979 than in 1977.

Coastal Hotels: A Mini-Energy Audit. The beach hotels have experienced difficulties with their air conditioning systems, in part because the rooms were not designed for space conditioning (that is, they are not insulated). We made an onsite audit of the Nyali Beach Hotel, in part because the assistant manager expressed great interest in reducing his costs but confessed he had done little to audit the uses of energy in the hotels. Among the things we pointed out were:

1. The cottages shared immersion electric water heaters in groups of three that were run 24 hours a day. No estimate was made of the amount of hot water used by time of day, but we suspected that these devices produce far more hot water, at enormous energy cost, than is really demanded.

2. All rooms are outfitted with individual air conditioners. No one has evaluated the thermostat setting. Rooms have louvre windows with little or no shading. Infiltration therefore constantly offsets the effect of the air conditioner, and solar gain heats the rooms even more. The windows have no screens, so that opening them at night to increase natural cooling lets in swarms of mosquitoes!

3. The central hot water system in the main building runs on oil. No evaluation of the benefits of reduced water use or solar hot water heating, now gaining wide acceptance in Kenya, had been made.

4. Still, some measures of a general housekeeping nature have been undertaken. This is not clear from the table, because data on guest-days were unavailable. The drop in energy use in 1979 appears to be a result of interest in conservation. The managing director pointed out that the hotel was more carefully managed from an energy standpoint in 1979 than earlier. This attention appears to be returning some benefits. But there are many new realistic conservation possibilities. It appears that the main barrier is lack of information.

Major Coastal Hotel

Year	Oil TJ	Gas TJ	Electricity GWh	Oil(MJ)/ Guest-Day	Electricity (MJ)/Guest-Day	LPG/(MJ)/ Meal
1975	9.37	1.71	1.33	--	--	--
1977	11.25	1.87	1.77	--	--	--
1979	7.68	1.17	1.75	--	--	--

. . .

We surveyed several other coastal hotels. At one a solar hot water heating unit had been tried and abandoned. At several others new solar units were being installed. At one coastal hotel, electricity use was 30.1 kWh/guest-day in 1979 (see table 4-2), a high figure reflecting air conditioning, but fuel use was low, in part because of solar hot water heating.

Industry

Industry use is dominated by heavy oils for process industries like cement and rubber, and electricity in the assembly industries such as vehicles or textiles. We interviewed a dozen firms as part of a preliminary investigation in 1979 and well over three dozen in 1980 and 1981. We present herein the results of some of these interviews. Not all firms providing data were visited, and not all firms we visited provided data.

Steel Mill 1. This steel rolling mill produces bars and drawn steel. The equipment was relatively old. Electricity was used for scrap melt, oil for reheating. We did not receive any precise data or time series but were given approximate information on oil consumption for heating and electricity consumption for scrap melting. In 1978 melting scrap required 0.675 GJ/ton of oil and 66 kWh/ton electricity (2.4GJ), while reheating and drawing required 4.11 GJ/ton oil and 200 kWh/ton (0.72GJ). These figures are consistent with those provided by the second steel mill studied.

The engineer indicated that, given the age of his equipment, his main concern was starting the mill in the morning.

Steel Mill 2. This steel mill is relatively modern. Heating takes place in a milling furnace; there is also an electric arc furnace and much heavy electric rolling equipment. The managing director cordially received us and our escort, an engineer from EAPL, and expressed great interest in conservation. He was thoroughly conversant and was able to provide many

written details of his operations and plans and could relate these to the changes in energy use that had been observed in the factory.

Energy Use in Large Steel Mill #2

	TOTAL PLANT		PROCESSES		
			Rolling		Arc furnace
Year	Oil GJ/MT	Electricity kWh/MT	Oil GJ/MT	Electricity kWh/MT	Electricity kWh/MT
1975	2.81	210	67.94	171.24	1286
1977	4.07	590	82.9	221.45	797
1979	3.84	670	79.3	223.10	676

Source: Steel Mill #2, Private communication. The intensities cannot be added. In 1975 very little steel was melted in the arc furnace; in 1977 about 45 percent of rolled steel was melted first, in 1979 somewhat less.

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While the company failed to provide data on total output, it provided details of energy use/ton milled steel and melted steel. Specific fuel consumption increased over time as a greater share of inputs were scrap produced from locally made ingots, rather than imported billets. Given this change in input material required, the management found it necessary to refine the technology of steelmaking (in Kenya) in order to achieve optimal rates of production.

This illustrates the effect of accounting on energy use data. What was formerly an energy flow hidden as an import of a raw material became an overt energy flow when that material was processed to a greater degree in this plant. The manager pointed out that domestically made scrap requires less overall foreign exchange than imported scrap, since the energy cost of scrap is not the full cost.

The manager pointed out the areas in which steps were taken to conserve energy:

1. Automatic temperature control in the reheating furnace should reduce specific fuel needs by 15 percent. An additional recuperator is being studied to achieve further savings.

2. Fuel changes are planned for several smaller operations, including replacement of kerosine and diesel oil burning in heating ladles with fuel oil.

3. Direct passage of hot billets from the casting machine to the reheat machine is planned. By eliminating the cooling down and heating this modification saves considerable heat energy, both fuel and electricity.

4. More efficient burners and automatic control processes are being installed at the wire galvanizing plant.

5. Scrap is preheated before passage to the arc furnace.

6. Other measures include keeping the better insulated molds warm, improving process controls, improving the furnace lining (better insulated, longer lasting as well), improved power factor with better process controls, more coordinated flow of materials. Even an alarm has been installed in the load-leveling system!

As a result of these steps, fuel and electricity use in the plant have been controlled somewhat. Offsetting these measures are an increase in the use of power for milling and rolling machines and the increase in heating because of the change in material inputs. Overall, the two increases specified have been small, 15 percent in the rolling mill heating and 25 percent in the rolling mill and other machine power, compared with a much larger reduction in electricity use in the arc furnace.

The manager showed a keen awareness of the concept of "total plant efficiency" (c.f. our comments about hotels). He was aware of the need to integrate energy management into the overall drive for increased productivity in the plant. This is consistent with decades of energy improvements in industrialized countries that have accompanied higher labor productivity. The manager was aware of the need for employee incentives to improve productivity and output, suggesting that he would continue to call for improved energy use as well. He stressed the importance of factory organization.

In many ways this factory showed many of the textbook characteristics of one run by energy conscious staff. While we share with the manager the feeling that more can be done--new furnaces being added will use continuous casting in an integrated facility that will cut unit energy costs even more--we were impressed by his overall comprehension of the energy problem, his ability to describe everything on short notice, and his ability to produce accurate data on consumption in various processes.

Bottle Factory. We chose to visit an important bottle factory in Kenya. Glass bottles are produced in large quantities here, and the vintage of the equipment varies from the first machines, still in use, that were installed in the 1950s, to those put in service in 1980.

The factory uses some scrap cullet and was aware of the energy savings inherent in scrap recycle. The manager and engineer expressed an important concern about energy. However, they also expressed some reservations about the prospects for more efficient energy use. They felt that existing equipment promised little scope for improvement. In particular they noted that their furnaces were imported. Expertise to radically change the process was not available, nor was the best possible maintenance. Design parameters locked them into certain patterns of consumption.

Energy Use in Glass Bottle Factory

	Fuel		Electricity	
Year	TJ	MJ/KG	GWh	kWh/KG
1979	92.46	--	5.466	--

Source: Factory records; supplier records.

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On the other hand, they were optimistic about the energy consumption of their new glass making machine, scheduled to come on line in late 1980. We were shown computers for better timing and process control, and heat recycling equipment. Yet the improvements in energy use that result from use of this new equipment are not interpreted as "energy conservation," and the staff did not immediately include these improvements in our discussion of conservation measures they had considered.

We were never provided output data, so it is difficult to make careful comparisons of energy intensity over time. The staff quoted as a rule of thumb the ratio of one ton of oil to four tons of melted glass as a worldwide standard for fuel intensity.

Pyrethreum Plants. Pyrethreum is an insecticide processed from a plant of the same name. We toured the large processing plant in Kakuru and were shown many examples of retrofitted conservation technologies.

The most interesting feature of the boiler room was its dual mode capability. The plant burns sawdust taken from a neighboring sawmill, replacing up to one-third of its oil use. In the plant itself the engineer had added steam traps and meters wherever necessary to monitor steam use and reduce heat loss. He added insulation to many lengths of pipe. Electricity was submetered throughout the plant in an effort to spot inefficient use.

After a tour of the plant, we were provided more information. The senior process superintendent was aware of the need to lower energy use per unit of output. He described his company's efforts:

> Our largest single economy is in regard to steam generation, where we use sawdust, where possible, in lieu of fuel oil. Availability of sawdust and rain occasionally have some cause for constraint. We are at present engaged in other solid fuel possibilities, but it is too early to comment right now, but we are really pushing our priority of using local solid fuel.

Chemical Processing: Pyrethreum Board

	Fuel		Total fuel	Electricity	
Year	Oil (TJ)	Sawdust (TJ)	MJ/KG	GWh	kWh/KG
1972	27.6	--	2.58	4.29	4.01
1975	45.9	0.45	3.08	4.66	0.31
1977	21.9	23.50	3.98	3.89	0.34
1979	37.5	14.80	6.60	3.23	0.41

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The figures shown reflect two interesting phenomena associated with energy demand analysis in Kenya. A comparison between 1975 and 1977 highlights a trend common to many industrial concerns in the country: electrical input per unit rises as fuel input falls. The relatively cheap price of electricity influences the choice of electricity over liquid fuel when electricity is available. The 1979 data point out the problem of industries running well below capacity because of uncontrollable factors. In this case, the company experienced problems with their feedstock deliveries, so that inefficient use of the plant led to significant energy waste. In the superintendent's words, " The Plant was started and stopped to process small quantities, at very frequent intervals, in order

to meet urgent demands. This is most wasteful, particularly in regard to steam and electricity."

The data shown below illustrate an important issue beyond the problem of measuring capacity variations and their effect on unit energy consumption. If we count calorific content of fuels, the energy intensity of production has increased in spite of the firm's efforts at conservation. If we count oil use alone, conservation efforts have paid off. Part of the difficulty of measuring conservation and the effectiveness of fuel substitution is that the replacement fuel, here sawdust, may not burn as efficiently as the oil it replaces. Thus simple addition of the calorific values of the quantities of both fuels consumed in this plant may not reflect the changing amounts of heat delivered to the boilers.

Creamery. We visited one of the Kenya Coop Creamery (KCC) factories. The plant appeared modern and clean. The engineer took us on a quick tour and made several points about energy conservation.

He showed us several measures he had taken. Reinsulating the boiler and steam lines offered a big savings, estimated at 25 percent. Adding thermostat controls to the refrigeration system, so that the refrigerator compressor was off when not needed, saved 60 percent of the electricity used in the function. Pumps were synchronized with the pasteurization machine. The boilers were descaled more often, and are now maintained annually. This last factor, the frequency of maintenance, appears to be important as a variable factor in the level of energy savings achieved. Some firms are discovering that higher energy costs justify more frequent maintenance.

In the summary provided by the firm, measures to "ensure more efficient use of energy" included:

- Regular servicing of machinery;
- Regular cleaning of all heat exchange equipment;
- Heat regeneration in the pasteurizers and thermocompression in the evaporators;
- Insulation of steam and refrigeration pipes;
- Use of condensate on boilers;

- Decreasing the running time of machinery;
- Changing to more energy saving automatic machinery.

Energy Use in Creamery

Year	Fuel MJ/1,000 liters	Firewood MJ/1,000 liters	Electricity kWh/1,000 liters
1972	1940	70	47.8
1975	1600	230	51.1
1977	1460	0	85.6
1979	1480	0	96.8

Notes: Firewood counted separately because of uncertainty over actual thermal content; 6 GJ/cubic meter assumed.

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The summary was signed by the company accountant from the head office, while the visit was conducted by an engineer in a different city. It may be significant that the importance of energy efficiency is appreciated both by line personnel and by management, particularly in the accounting department.

The data from all operations in Kenya show mixed trends. While fuel intensity (fuel oil and industrial diesel oil) has fallen markedly since 1972, electric intensity has increased. We have omitted firewood used in 1972 and 1975 from this balance. In 1972 firewood provided about 5 percent of all thermal energy (assuming 6 GJ/cubic meters), in 1975 about 15 percent. Including this fuel would raise the total fuel intensities in these years somewhat, though the conservation recorded would remain, and the intensities for 1977 and 1979 would be relatively greater. Output for this operation remained relatively constant, so these reductions in intensity must be credited to conservation. On the other hand, the doubling of electric intensity is hard to explain, and might be a factor in bringing about the efforts to conserve electricity that were recounted above.

Large Food Processing Plant. This plant, belonging to an international company, expressed great interest in our project and provided data and descriptions of their conservation achievements. Their energy use/output, excluding transportation fuel, has dropped about 5 percent between 1976/77 and 1978/79 but rose somewhat in late 1979. The increase

may be caused by seasonal effects, since the data covered the second half of the calendar year only. Fuel use in 1975/76 was considerably higher.

Energy Use in Food Processing Plant

Year	Fuel/Output MJ/KG	Electricity/Output kWh/KG
1975/76	6.25	0.098
1976/77	4.56	0.073
1977/78	4.48	0.054
1978/79	4.37	0.050
1979/80	(4.98)	0.049

Notes: We have assumed that "fuel" for this operation consists of the sum of autodiesel and heavy fuel oil used in operations. Data for the last part of 1979 are uncertain.

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This plant undertook a series of conservation projects. They estimate that between 5,000 and 10,000 Kenyan Shillings (KSh) are devoted yearly to scheduled maintenance of steam traps, air vents, valves, and pipe fittings. Other firms noted these leaky components but few reported regular surveys and maintenance for the purpose of saving energy. An additional inexpensive procedure involves burning lubrication oil when it is dirty rather than throwing it away; the procedure costs 100-200 KSh/month but saves 800-1000 liters/month. This is the equivalent of saving energy at a cost of less than 7 KSh/GJ.

Major investments have been made in the water cooling system (using cooling capacity to preheat some boiler feedwater), and insulating the steam piping system as well. The firm estimates that the savings will run to about 2.4GJ/hour on the pipe insulating project. Assuming the plant runs 6,000 hours/year, with a capital recovery factor of 20 percent, this yields a cost of saved energy of roughly 5 KSh/GJ, a bargain at any oil price. An additional insulation project planned for 1981 would cost about 9 KSh/GJ saved, still a very good bargain. An additional project involving heat recovery from a condensation stage would cost about 5 KSh/GJ. This indicates that major savings are possible at very little expense, that is, at low energy costs compared to the cost of supplies.

Tire Factory. This factory produces recapped tires by two processes as well as some other rubber products, notably Wellington boots. The general manager was prepared for our visit with much information on his equipment. A new process was added that allows tires to be recapped using far less heat. Equally important, installation of new capacity in a new part of the factory resulted in a significant savings of oil. The manager believes this is due to the newer boilers and increased insulation on the steam pipes, which we were shown.

Significantly, our visit appears to have provoked an internal investigation that caused this discovery. We asked for fuel consumption in physical units as well as the physical quantity of rubber milled. Initially the factory provided their fuel and electricity costs, but at our behest called their supplier and procured physical quantities of oil used. While their output and energy inputs were measured over slightly different periods, it appears that a great savings has been achieved due to the modernization. The new cold recapping process is still under consideration.

This interview illustrated two important points. First, a great deal of energy savings is possible with modernization, keeping the process the same but upgrading the product. We estimated a three year payback for the change of boilers. Second, additional savings are possible when a new process is introduced. The manager expects to save additional energy using the cold recapping process. Finally we found that the procedure of formulating energy accounts led in fact to a discovery that energy was being saved! Comparison of their records with those of both their fuel suppliers confirmed that fuel use had dropped dramatically, as indicated in the table below.

Energy Use: Tire Recapping and Rubber Molding

Year	Oil MJ/KG	Electricity kWh/KG
1977	21.7	0.86
1978	18.4	0.64
1979	13.7	0.96

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Vehicle Assembly #1. Vehicle assemblers are rather new in Kenya, three factories appearing during the past five years. This plant produces finished vehicles from parts. Electricity is used for welding, lighting, and mechanical drive, heat for molding and paint drying.

Fuel use in this factory shows interesting patterns. The company has switched fuels regularly to take advantage of lower cost fuels and to avoid in some cases lower grades of fuels fouling their boilers and dryers. They intend to return to heavy diesel oil (industrial diesel oil) because of its relatively low cost and oversupply in Kenya. Automotive diesel and kerosine, while cleaner, are harder to get. This change will require cleaning the fuel with a centrifuge. Their awareness of the problem was clear. Their fuel use records indicate a constant awareness of the cost and availability of fuel, a fact not always noted by engineers and accountants in other companies.

The company found that the crates in which the automobile parts arrived might provide a significant source of fuel, and they are investigating whether this wood could be converted to gas and burned in their paint shop. They now employ a man full-time to look after the use of lights (the lighting levels in the factory were quite high), air conditioning, and other power. They have power factor compensation, which raises their power factor to between 0.90 and 0.95. This reduces their unit electricity costs and the EAPL peak. They time the use of the paint shop so that the drying ovens reach the correct temperature just as the first vehicle is ready for baking. However, they have not found a use for the waste heat in the paint drying unit, except for some preheating of the incoming air.

The managers we met with pointed out an additional problem that makes analysis of this factory's operations difficult. The data we present below

Vehicle Assembler #1

Year	Fuel/Output MJ/Vehicle	Electricity/ Output kWh/Vehicle
1977	5000	561
1978	5240	597
1979	3550	481

Notes: Fuels vary widely; process fuels have been combined; some gas is used to operate forklifts and the kitchen.

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represent the start-up of the plant, when output is expanding rapidly. It is difficult to separate the effects of underscale operation, learning, and experimentation with new fuels from the measure of fuel effectiveness, fuel use per unit of output. The managers noted that it was hard for them to read their own record because of this difficulty. While many firms in Kenya commonly experience steady growth in output, the output of a new firm such as this one, though growing, is very irregular.

Vehicle Assembler #2. This assembler also produces a variety of vehicles, predominately trucks. The engineer with whom we spoke in 1979 was discouraged by the difficulty of training staff to look after energy matters. However, the data presented to us show a marked decline in oil use per vehicle assembled. While size and nature of vehicles vary somewhat from year to year it is safe to assume that the lower oil use in 1979 reflects some success with efforts to conserve energy.

Vehicle Assembler #2

Year	Fuel MJ/Vehicle	Electricity kWh/Vehicle
1978	1950	173
1979	1780	610

Notes: The electric power data for 1978 may be spurious, according to EAPL, because of a problem with the meter.

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Paper and Pulping Mill. This fully integrated paper and pulping mill has been in operation since the mid 1970s. The staff in Nairobi was very cordial and provided us with a tour of the plant facilities. The staff there had undertaken a substantial conservation program since our first visit to Kenya, and the plant was expanded. Data on the papermill are published in their annual report.

Unfortunately the cogeneration of heat and power in the original plant could not be expanded. It was proposed that a unit of roughly 4MW electrical capacity be built to provide more than enough electric power to the factory. At the time, however, it was not permitted to sell this excess power. This meant that the factory had to consider only a 1MW capacity cogenerator, whose size and unit costs were considered too high to justify

Pulp and Paper Mill

Year	Fuel TJ	Electricity MWh	Output MT	Fuel/Output GJ/MT	Electricity/ Output GJ/MT
1977/78	2340	--	49800	47.5	--
1978/79	2210	5270	50200	44.0	0.38
1979/80	2070	10440	53300	38.8	0.71

Notes: According to the factory the heat value of the heavy oil is 41.7MJ/l, that of heavy residual oil. Electricity converted to thermal value at 3.6MJ/kWh. The expansion and addition of purchased power was only partly complete in FY78/79, hence the low value of purchased power. FY79/80 data reflect full use of purchased power.

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the added expense. While changes in regulations now permit selling of excess self-generated electric power, the changes came too late to influence the decision to expand the plant based upon purchased power from EAPL. Consequently the data on energy use contain purchases of electric power starting in 1978/79. However, the quantities of purchased power appear far less than the reduction in oil use, when both are expressed on a per unit of output basis. That is, the reduced demand for oil because of the purchase of electric power accounts for only a part of the observed savings in oil use.

The data appear to show a significant savings in oil use in the past two years, particularly the past year. These savings, according to the chief accountant, were the result of a concerted effort in 1979 to reduce fuel costs.

Soap & Household Products Manufacturer. This affiliate of a worldwide company was quite concerned with energy-related issues. The resource engineer was most helpful in providing us with information, as well as taking us around the plant and allowing us to take photos of improved insulation, etc.

The major demand for energy is that of process heat, which is supplied in the form of steam, raised in a series of boilers and transported throughout the plant by an extended system of steam pipes. The fuel for the boilers have varied, with the company switching from mainly wood-burning to more efficient oil-burning boilers, in stages, in 1975 and 1978.

Soap and Household Products

Year	Oil TJ	Wood husks TJ	Total fuel MJ/KG	Electricity GWh	Electricity kWh/KG
1977	185	606	12.76	8.5	0.137
1978	245	573	12.56	9.0	0.139
1979	346	444	11.61	10.0	0.147
1980	342	429	10.70	11.0	0.151

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Presently, with the continuing increase in oil prices, the engineer indicated that they would like to switch back to firewood, and are actively considering the installation of burners capable of burning any type of "waste" fuel. Due to the heavy pressure being placed on the country's forest reserves, a complete return to burning firewood is not feasible without an assured supply of wood. He was therefore very interested in the firewood problem, hoping the government was going to take active steps to increase wood production. He also mentioned the need to have government policy clearly outlined, so that individual companies could make their long-range decisions on capital investment with some assurance of what type of energy options will be encouraged by the government.

The company's own projections forecast their output rising some 20 to 30 percent over the next five years, while they assume energy costs will climb 200-300 percent in the same period, so they are quite aware of the need for and value of conservation. They have therefore begun a conservation program which they conservatively predict will result in a 10 to 15 percent savings in the next two years. This program consists of:

- Recovering process heat to preheat input feedstocks;

- Investigating changing process times and the size of batches, which were overly conservative (that is, provided more reaction time and reaction area than actually needed) in the past;

- Increasing insulation on all steam pipes up to latest European standards;

- Altering the storage tanks for the feedstock oils used, to provide for less heat loss during storage;

- Switching from the traditional used of steam to raise a vacuum (which drives barometric steam vacuum pumps) to mechanical pumps (run on cheaper electricity);

- Insulating the smokestack on their boilers to prevent heat loss.

A look at the energy intensity calculated for their product shows a steady decline in fuel energy per ton. The rise in electricity use reflects the relative pricing scales which have influenced energy choice.

The appreciation of the need for comprehensive conservation that this company displayed is in part due to a constant influx of directives from the engineering department of the multinational corporation's main headquarters. It is just this type of information that local Kenyan firms lack access to; our survey clearly differentiated the local from the multinational corporations in terms of their awareness of conservation.

Cigarette Manufacturer. This subsidiary of a multinational corporation had perhaps the best developed energy bookkeeping system of any firm we visited. We were shown internal company forms on which were tallied monthly totals of electricity and liquid fuel use, along with cigarette production and a resultant energy index of "energy per 1000 cigarettes." The final index was questionable, because the heat value of the liquid fuels was directly converted from joules to kilowatt-hours (by a simple division of 3600), then added to electricity consumption, but the basic concept was laudable. The system had been in effect for only a year, so trends towards energy efficiency were not yet readily apparent.

Cigarettes

Year	Fuel MJ/1,000	Electricity kWh/1,000
1979	4.34	0.41
1980	3.71	0.41

. . .

The company was making an effort to reduce unnecessary energy use. Posters were placed throughout the factory complex reminding workers to turn off unused lighting and to avoid wasting fuels. The company canteen, where several hundred workers take their lunch, was being fitted with a solar system to supply hot water needs. The factory engineer indicated to

us that this solar hot water system was being used on a trial basis, and should it prove effective, was to be enlarged to meet a greater share of the plant's hot water needs.

Textile Mill #1. This new mill is continually expanding. The management told us that although they are now in the process of a three-fold expansion, they estimate that energy use will only double, through careful design of new facilities. Unfortunately, the data we received were not detailed enough to allow us to perform any useful calculations.

The expansion will call for the installation of a second boiler, which will run on fuel oil rather that industrial diesel oil. The fuel will be preheated with steam coils to improve combustion. The original electrical system was retrofitted with capacitor banks in October 1980 to improve the power factor, bringing down electricity demand from 315 kVA to 215 kVA. As the expansion proceeds, two more increments of demand, also of 215 kVA, will be added.

Textile Mill #2. The management of this mill was quite proud of the steps they had taken to conserve energy. We quote from their letter:

> Almost all the steam condensate is being collected through a network and pumped back to the boilers....By this implementation, we have so far been able to save up to about 8% of fuel oil fed to the boilers. Shortly, we are arranging for 100% of the condensate to be taken to the boilers....
>
> The power factor, which was in the order of about 0.90 has been brought up to about 0.98 to 0.99 by suitable addition of capacitors and maintenance of equipment....
>
> Almost every steampipe throughout the mills has been lagged (insulated) properly.
>
> Even some of the equipment, like reaction chambers, have been lagged.
>
> Some of the steampipes have been relined and rerouted.

Curiously, our calculations show a steady rise in energy per unit of output for the last five years. We must note that the indices we calculated are only for chronological comparison. Because the output of cloth and yarn was given to us in disparate units, we could only calculate an index which assumed all the energy used went toward the production of each type of product, an obvious impossibility, yet the method does allow a year

to year comparison. It is conceivable that if product mix were to vary widely, and if the energy inputs for the two types of product were significantly dissimilar, this method would be pointless. The production of cloth to yarn produced was roughly the same from year to year, however, and we feel that as a first order approximation, the results do conflict with the claims made to us.

Cloth Mills #1 and #2

Year	Fuel/M	Fuel/KG	Electricity /M	Electricity /KG	Electricity /KG*
1976	6.5	28.5	0.73	3.17	
1977	10.3	51.7	0.76	3.79	
1978	12.3	61.3	0.84	4.18	2.67
1979	11.9	70.9	0.75	4.47	3.37
1980	13.3	73.1	0.80	4.42	3.22

*Figure from different mill for comparison.

. . .

Chemical Extract Producer. The chemical this company produces is drawn from the bark of the wattle tree, grown on the company's own plantations. This puts the company in an enviable position with regard to energy, as its basic feedstock also serves as fuel. The bark is stripped from the tree, and the remaining wood is used to fire boilers, providing both process heat and cogenerated electricity. There is sufficient excess wood to produce large quantities of charcoal for resale.

The company has 20,000 acres (8500 hectares) planted in wattle, which grows on a ten year cycle, so that 2000 acres are harvested per year. Of this wood, approximately 15,000 to 20,000 tons are used directly as fuel for the plant. The excess is converted into charcoal, with average production about 8 tons per month. The conversion efficiency for this charcoal production is 25 percent, the resulting charcoal considered among the best available in the country (heating value about 13,000 Btu/lb).

Paper Mill. This small paper mill is run by an engineer who was quite anxious to receive some sort of assistance in planning a conservation strategy. As we walked through the plant, we noticed some modest efforts at preheating process water with waste heat from the boilers, but small leaks in water and steam pipes were evident in many areas. The storage tank for

the preheated process water was open to the atmosphere, resulting in the loss of a good deal of the heat gained through preheating. A modest investment of effort and capital could easily save a minimum of 10 percent on fuel here.

Water for the plant is pumped uphill from a nearby stream into settling ponds. We noticed that when these ponds were full, overflow water would be lost, without an automatic cutoff signal being sent to the water pumps. The engineer did point out that more careful recycling of process water was cutting the need for fresh inputs, therefore reducing pumping requirements.

For 1978 and the beginning of 1979 fuel use remained at around 8.0 MJ/KG finished paper, while electricity use dropped from 0.62 kWh/KG to 0.54 kWh/KG.

Glass Manufacturer. The engineer at this plant was quite modest about some major savings which had taken place here. The original furnace, used since the plant opened in 1972, was augmented by a newer furnace in 1979. The new furnace incorporates a heat recovery system which uses waste gas to preheat air being fed to the combustion chamber. The better combustion which results, along with better insulation on the furnace walls, has led to a significant drop in fuel per unit of output, as shown in the figures below. The newer furnace was used for 80 percent of overall production in 1979, with substantial energy savings. At the same time, more conscientious monitoring of electricity use has dropped electricity inputs as well. These savings are shown clearly in the table. Interestingly, the drop in production from the older furnace in 1979 seems to have been responsible for the increase in fuel intensity in that unit, but the electric intensity fell anyway. At the same time the overall savings from modern equipment are revealed dramatically when the two furnaces are compared.

Glass Factory

	Older Furnace		Furnace w/heat recovery	
Year	Fuel MJ/KG	Electricity kWh/KG	Fuel MJ/KG	Electricity kWh/KG
1977	34.6	0.83		
1979	37.9	0.52	17.8	0.30

. . .

Battery Manufacturer. We visited an important battery manufacturing plant. Engineers there indicated that no special conservation measures had been instituted. However, data provided show a meaningful drop in intensities best explained by economies of scale. Factory output increased greatly between 1972 and 1979. The type of output has remained constant.

Battery Manufacturing
Units: 1000 Batteries

Year	Fuel MJ/1000	Electricity kWh/1000
1972	33.0	39.4
1975	29.6	31.1
1977	27.7	24.4
1979	25.7	18.7

. . .

Sawmills. We visited two sawmills and collected data from a third. Here use of industrial diesel oil for self-generation of electricity was important, since mills are often located in forests far from electrified areas. None of the mills reported appreciable sawdust combustion. We show the electricity consumption figures and those for electric generation (mill #3) as a further indication of how intensities fall as production increases. We give indices of production (1977=100) for each mill. Output is measured in cubic meters. If the intensity from the self-generating sawmill are compared with those from the two that purchase electricity, an effective conversion efficiency of about 10 MJ/kWh can be obtained, consistent with those of the best diesel engines though somewhat higher than normal. The actual production of electricity might be less.

Energy Use in Sawmills:
Purchased Electricity and Fuel for Self-Generation

	Mill #1		Mill #2		Mill #3	
Year	Production	Electricity kWh/cu. meter	Production	Electricity kWh/cu. meter	Production	Electricity kWh/cu. meter
1977	100	30.7	100	41.3	100	682
1978	134	28.3	112	37.7	152	392
1979	136	28.4	113	25.9	160	380
1980	130	27.1	111	29.4	148	294

. . .

Sugar Mill. We visited a large sugar mill that used a significant quantity of bagasse as fuel. In addition to many small operations to keep fuel costs down--the mill also consumed fuel and diesel oil--the mill generates its own electricity. Thus the fuel figures, bagasse included, reflect self-generation. This may explain the great increase in intensities in 1979. We assume a value of 9.76 MJ/KG for bagasse, 13.96 MJ/KG for wood.

Energy Use and Production in a Sugar Mill

Year	Production 1975=100	Oil MJ/KG	Wood MJ/KG	Bagasse MJ/KG	Electricity kWh/KG
1975	100	0.45	0.12	24.0	0.22
1977	137	0.20	0.11	24.1	0.20
1979	156	0.81	0.14	30.1	0.34

Non-Respondents:

Beverage Bottler. This bottler of a well known product briefly showed us the factory, where new insulation had been added to oil pipes. He pointed out that restrictions on the importation of one key ingredient forced the factory to refine the ingredient themselves, which will increase factory energy use in the future. Unfortunately the factory had not provided us with end-use data as of April 1, four months after the data was promised.

Bakery. The manager and chief engineer discussed energy with us, and showed keen interest in the use of energy/output ratios as an auditing tool. They indicated that a local consultant had been hired to install some heat saving devices, such as heat traps. Currently they were more concerned with factory expansion. Although the manager promised us data in November, when we called he hung up on us, so no information is available.

Steel Mill. At this steel mill we were introduced to the managing director and chief engineer. They had never looked carefully at energy, but had just installed a series of water conservation measures that reduced their water use by 50 percent. However, they expressed an interest in energy savings as well. Unfortunately they never provided promised data on energy use and output.

Flour Mill. The accountant at the mill noted that a group of foreign engineers had visited the mill to examine energy efficiency. One recommendation was to stop parts of the plant when capacity was low. Load levelers to save electric power and costs were also installed. Unfortunately the head office never provided promised information on energy use and output.

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