# Energy Conservation in Kenya

EXPERIENCES OF THE KENYA RENEWABLE ENERGY DEVELOPMENT PROJECT

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# Foreword

In late 1981, Energy/Development International (E/DI), now a division of the International Resources Group, Ltd. (IRG), was awarded a technical services contract by the Government of Kenya to implement the Kenya Renewable Energy Development Project (KREDP), a bilateral program of the United States Agency for International Development (USAID) and the then Ministry of Energy of the Government of Kenya.

The KREDP is designed to promote tree-planting and introduce conservation measures in order to reduce the consumption of woodfuels and imported oil and thereby help alleviate Kenya's woodfuel and foreign exchange problems. The project has three main programs:

CONSERVATION AND FUEL SUBSTITUTION: This program provides technical assistance in energy planning and conservation, provides training in energy management, and assists in implementing national energy conservation and fuel substitution measures.

AGROFORESTRY: The goal of this program is to promote farm tree planting efforts, especially agroforestry practices, in order to increase woodfuel sources and thus help conserve Kenya's dwindling forests and arrest environmental degradation. The agroforestry program also contributes to increased food production.

COOKSTOVES AND KILNS: The goal of this program is to design, test, develop and mass disseminate more fuel-efficient wood and charcoal stoves and charcoal making techniques.

This booklet, *Energy Conservation in Kenya*, is a brief account of KREDP's industrial conservation and fuel substitution program. E/DI, working with and under the guidance of the Ministry of Energy and Regional Development was able to carry out the activities described in this publication. The Ministry now has the necessary audit equipment and experienced technical staff to continue this program. E/DI is pleased that it was given the opportunity to serve as the Ministry's technical contractor during these formative years.

Samuel Hale, Jr.

PRESIDENT,
International Resources Group, (IRG)

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# Introduction

Kenya had an estimated population of 20.2 million in 1985. The country's land area is about 221,000 square miles, of which only 17% is considered medium to high potential agricultural land. Agriculture is the backbone of the economy accounting for over 30% of Gross Domestic Product Major products include coffee, tea, maize, wheat, sugarcane, cattle and dairy products. Manufacturing is second only to agriculture in economic importance, accounting for about 13% of GDP. Kenya has no known deposits of fossil fuels and therefore must import all the petroleum required for transport, manufacturing and power generation. Fortunately, substantial hydroelectric and geothermal potential exists and has been partially developed.

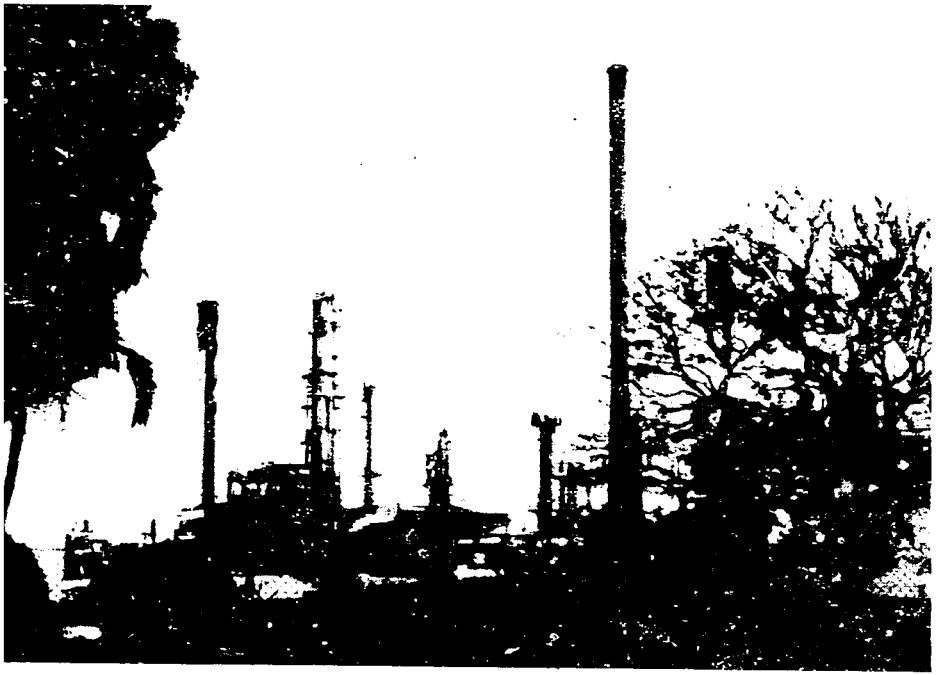

FIGURE 1. *Kenya Petroleum Refinery at Mombasa. The refinery is the sole source of domestically refined products for Kenya, and as well supplies several neighbouring inland countries.*

Since independence in 1963, Kenya has continued to operate a mixed economy where the private sector has played an essential and major role in productive activities. Government is striving hard to provide the necessary jobs and housing, food and essential services required for the country's growing population. Population growth is one of the nation's most difficult problems, as Kenya has one of the world's highest growth rates, averaging about 3.8% during the 1970's. Another serious impediment to realizing Kenya's development goals is insufficient foreign exchange. While the volume of merchandise exports has grown by 1.5% per year since the late 1960's, overall purchasing power has dropped by 27% since the early 1970's. Petroleum imports constitute a major part of this problem, growing from a net cost of only K£ 1 million in 1973 and reaching a maximum of K£200 million or 63% of net export earnings in 1981, before dropping to K£ 193 million or 32% of export earnings in 1984. A major portion of that drop was due to a 12.5% decrease in oil consumption.

# The Role of Energy Conservation

Energy conservation activities have been acknowledged to play an important part in the Government's strategy to deal with foreign exchange constraints and the adverse terms of trade. The Kenya Government and the U.S. Agency for International Development agreed to undertake the Kenya Renewable Energy Development Project (KREDP) in 1981, and recognizing the opportunities for conservation included a significant conservation component. The ultimate objective of this program was to increase the efficiency of energy used and thereby industrial and other processes as a whole, not simply to reduce energy consumption. Conservation activities have been structured to help Government provide policy guidance and training, as well as to augment the private sector's strong economic incentives to save fuel wherever cost effective.

FIGURE 2. *Petroleum Tanker Off-loading at Mombasa. All Kenya's crude oil and refined products come through the Port of Mombasa.*

The specific objectives of the KREDP conservation program are to:

- establish energy information and acquisition systems,
- provide technical assistance in energy conservation, and
- provide economic analysis support.

The project was implemented through the work of one long-term advisor, 9 months of short-term specialized technical services, a Kenyan conservation technician and several Government counterparts.

# Identification of Conservation Potential

One of the first steps of KREDP was to undertake a review of information available with which to design and execute conservation actions, and upon which to base energy policy recommendations. This review identified a need for a more in-depth understanding of the extent and nature of industrial energy use, and a need for first-hand exposure to Kenya industrial firms on the part of Government staff.

The project ultimately focused on the industrial sector as the best candidate for intervention, even though industry was only found to consume about 31% of petroleum fuels, versus

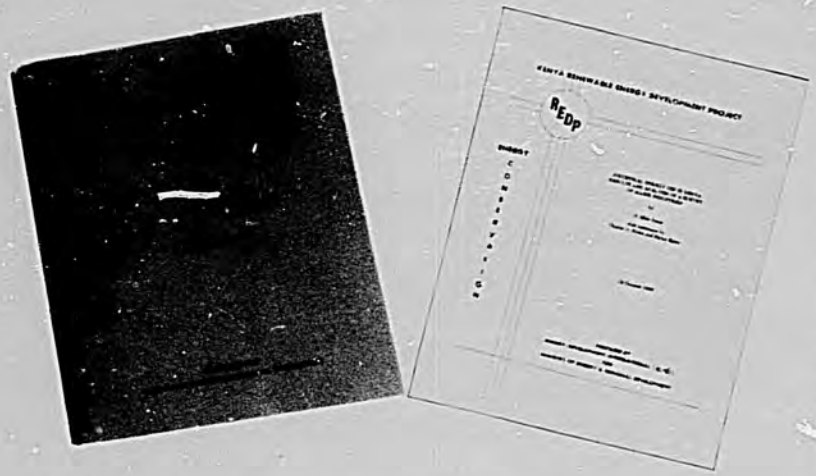


FIGURE 3. *Survey Reports Prepared under KREDP.*

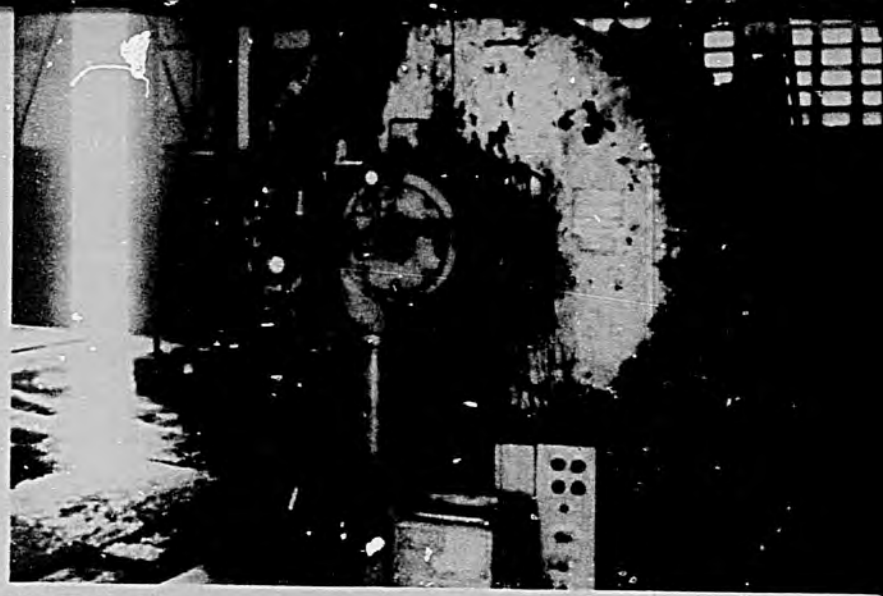

FIGURE 4. *Typical Industrial Boiler in Kenya. Shown is front with oil burner and controls.*

44% for ground transport. This was because industry has a strong commercial incentive to reduce costs, as well as the economic importance of manufacturing to the national economy. Also transport conservation studies were being undertaken elsewhere in Government.

Two industrial surveys were conducted in 1981 and 1983 to provide necessary information for a conservation programme. The results of the surveys and associated plant visits proved to be extremely useful in ascertaining both the nature of local industrial activities and in determining the extent of conservation opportunities. From the surveys the following list was obtained reflecting the major opportunities:

## Common Conservation Opportunities Observed in Kenya

Boilers

- Burner maintenance and adjustment
- Regular cleaning on the water and fire sides
- Improved water treatment
- Improved design and replacement of old boilers

Steam Systems

- Return part or all of steam condensate
- Repair or replace deteriorated insulation
- Repair of steam and water leaks
- Maintenance or replacement of faulty or inappropriate steam traps and pressure reduction valves
- Use of steam condensate for flash steam
- Opportunity to use high pressure steam for cogeneration of electricity.

Furnaces

- Better control of excess air through burners and furnace openings
- Insulation, and insulation and refractory maintenance
- Recovery of waste heat through recuperation or material preheating

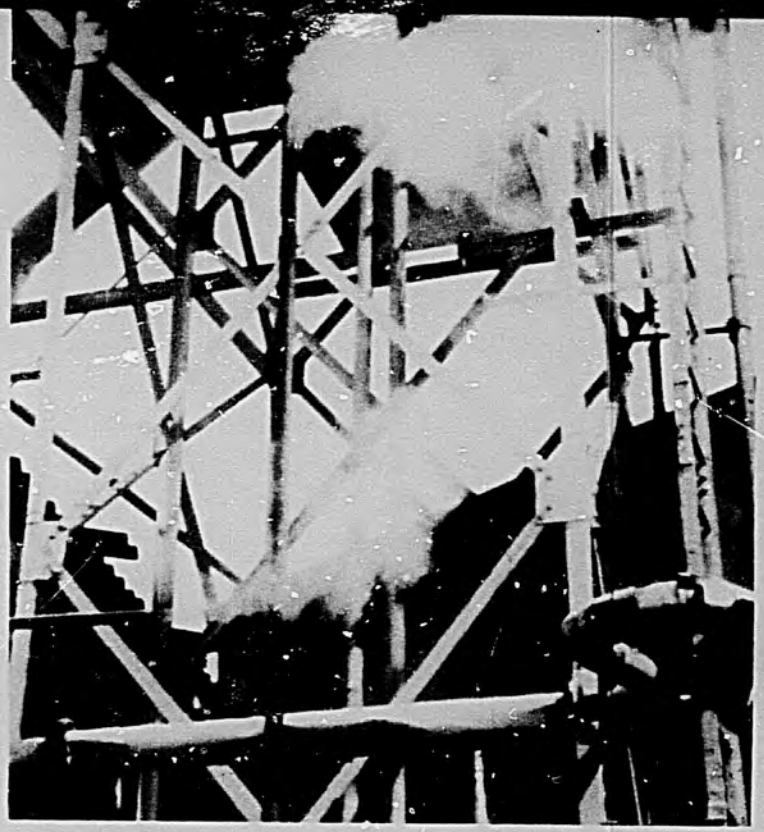

FIGURE 5. *Flash Steam from Malfunctioning Condensate Return System. Such steam can be economically used to meet a portion of low pressure steam needs.*

- Consideration of self-generation of electricity from waste heat

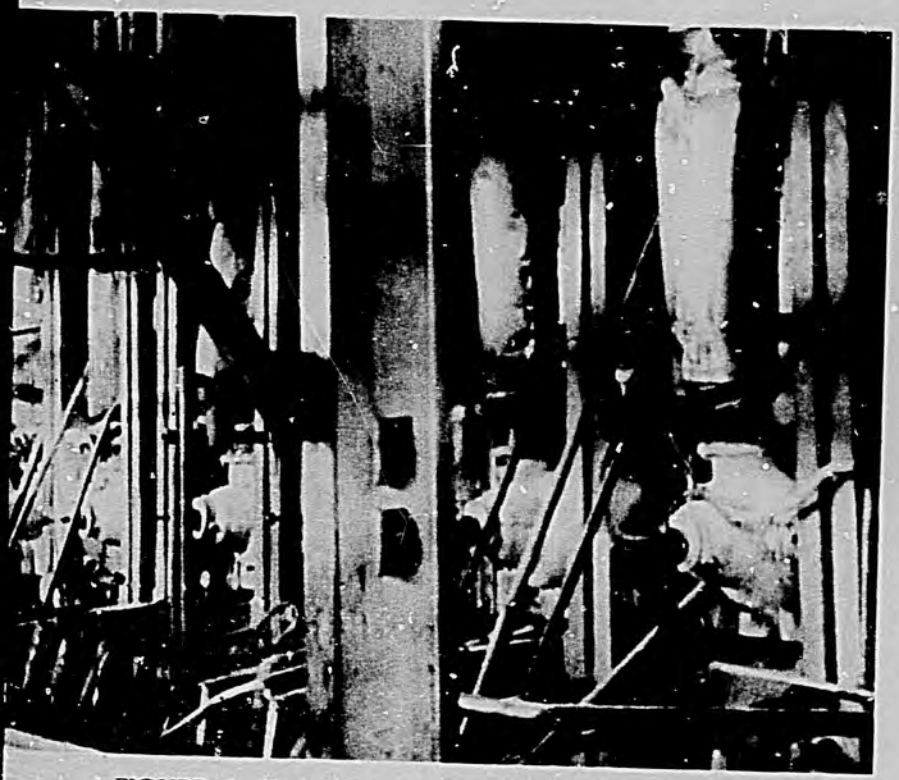

FIGURE 6. *High Temperature Furnace Burners. Such burners should incorporate preheating of combustion air, as shown here through pipes entering above each burner.*

FIGURE 7. *Capacitor Bank for Power Factor Correction. Correction of power factor leads to lower KVA demand and corresponding lower electrical demand charges.*

Electrical Measures

- Correction of power factor
- Elimination of compressor system air leaks
- Equipment maintenance and scheduling improvement
- Installation of high efficiency lighting

# Creating Awareness and Acceptance of Potential Opportunities

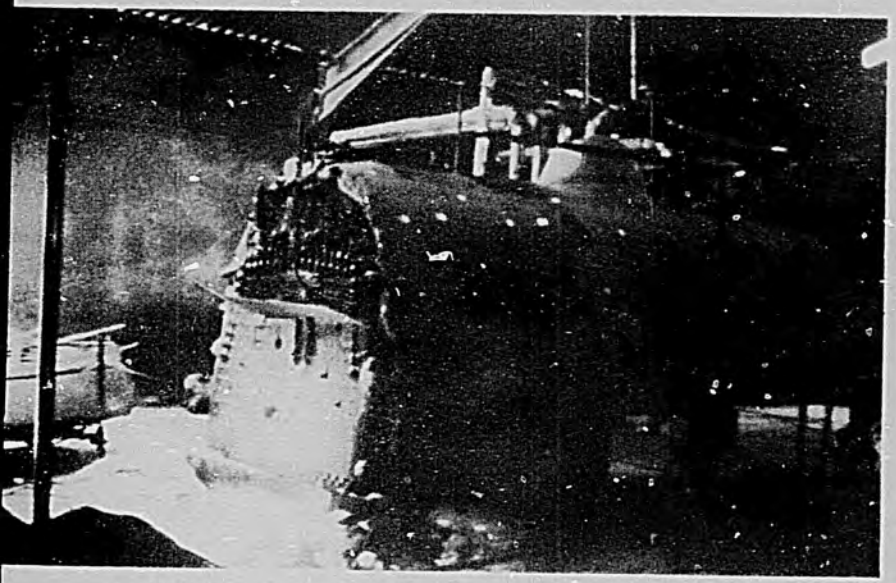

FIGURE 8. *Locomotive Boiler Burning Wood Wastes. Locomotive boilers have been converted and used successfully for combustion of wood and wood wastes.*

Fuel Substitution

- Use of readily available wastes or wood to substitute for imported oil
- Elimination of wasteful use of biomass fuels through better equipment design and operation.

The conservation message was presented by the project in two major ways. First, training was oriented toward technical information transfer; second, public information was designed to increase general awareness.

FIGURE 9. *Orientation Visit for a Group of Energy Audit Trainees. The site being toured is an industrial site previously audited.*

FIGURE 10. *Energy Audit Training. Boiler combustion test underway to determine the efficiency of the boiler in the background.*

FIGURE 11. *KREDP Technical and Public Information. Shown are conservation information materials prepared for the public, industry and hotels, respectively.*

## Training

Three types of training were carried out:

- Formal courses for industry, institutions and Government,
- On-the-job training for government technical staff and energy planners, and
- Overseas conservation courses for senior personnel.

**Formal Training.** A total of 9 courses were offered in energy management covering the basics of energy auditing, combustion, boiler operation and maintenance, waste heat recovery, steam system design, maintenance and operation, elecrical rates and management options, and economic evaluation of investments. In the basic 4 day courses, 152 private sector staff were trained and 14 Government personnel. Each person also received a comprehensive set of technical literature to assist in the application of classroom training.

**On-the-Job Training.** This training consisted of day to day interaction and guidance given to ministry staff assigned as counterparts. Staff were able to participate in a variety of activities ranging from industrial energy audits to computer analysis of energy survey data. Five staff were assigned as counterparts at various points in the project.

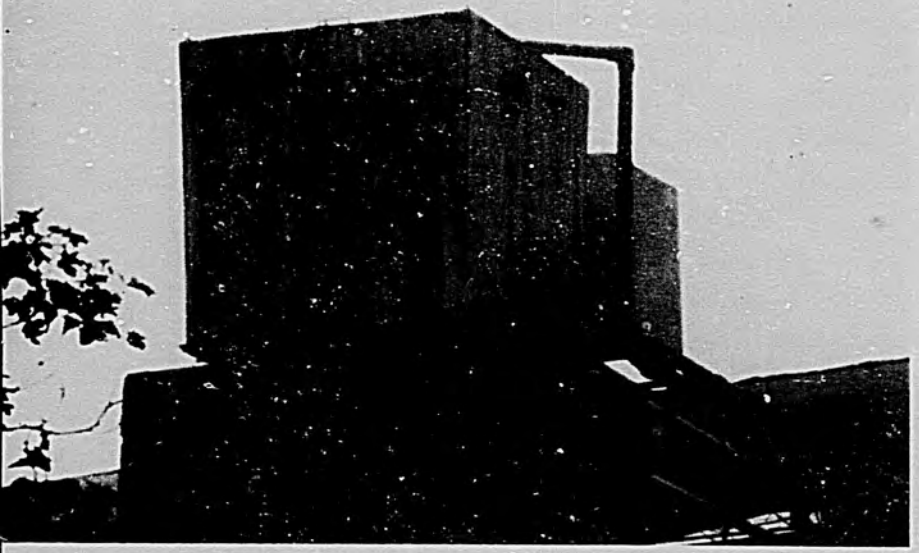

FIGURE 12. *Uninsulated Feedwater Tank. Picture demonstrates common poor practice, as the tank is uninsulated and is exposed to wind.*

**Overseas Energy Management Training.** The project assisted in arranging for 9 engineers to attend a six week training course presented at the Tennessee Valley Authority in the United States. Kenya's attendees did extremely well as the course as reported by TVA from test results. This training has had practical results. Two attendees, for example, reported applying their training at their factories identifying in the process major savings opportunities amounting to several million shillings.

## Public Information

In order to further spread the message on energy conservation a variety of public information material was prepared targeted at three major audiences. These were industry, institutions and Government, and the general (urban) public. Approximately 2500 of the industrial pamphlets were distributed, 500 for institutions and Government, and 41,000 for households.

Industrial and institutional information material proved to be valuable for stimulating management attention, and enhancing awareness, as well as in some cases forming a basis for in-house training. The following extracts illustrate the types of material prepared:

# 1. Boilers and Boiler Houses

A boiler is a device used to convert the internal energy of fuel and transfer that energy through steel to water for steam generation. The thermal efficiency (effectiveness of transfer of energy) of a boiler is determined by the magnitude of losses during conversion and transmission, the most important of which are:

- Dry and hot flue gas discharged through the chimney (i.e., oxgen, carbon dioxide, nitrogen and sulfur oxides).
- Loss due to heat carried away by moisture and hydrogen via the chimney.
- Heat radiated from the boiler surface to the atmosphere.
- Loss due to unburnt carbon and other combustibles in the fuel after combustion.

Another major area where losses are found within the boiler house is at the feedwater tank. Losses occur in several ways primarily:

- Losses due to unreturned condensate to preheat feedwater.
- Radiation and convection losses from the feedwater tank.

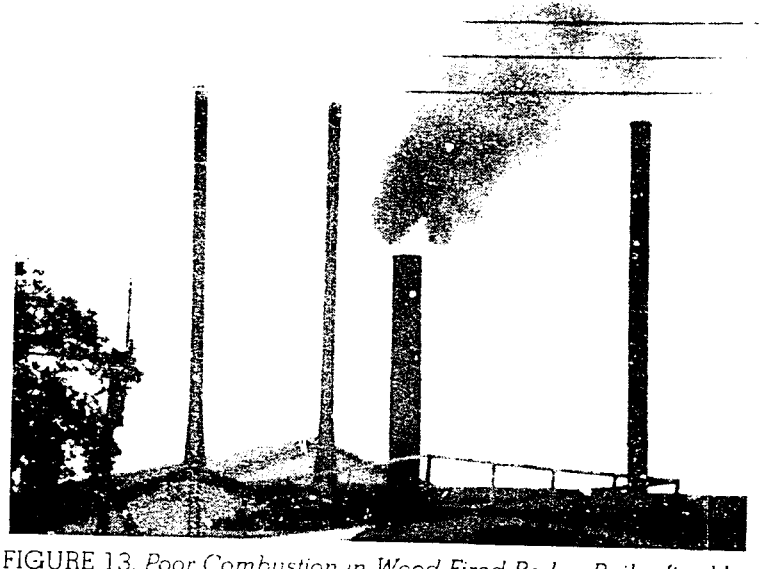

FIGURE 13. *Poor Combustion in Wood Fired Boiler. Boiler fired by wood and coffee-husk. Better combustion by use of an improved burning system could lower fuel cost and reduce pollution.*

The following are some of the more significant boiler related conservation opportunities:

## Selected Conservation Opportunities

| Measure | Impact |
|---|---|
| 1 Monitor and control combustion by frequent adjustment of air and fuel ratios. | Improved combustion. |
| 2 Measure oxygen or $CO_2$ composition of flue gases and adjust to minimize excess air. | Flue gas with 8% oxygen vs 3% oxygen (at 300° C) means waste of about 7% in fuel (indicates 58% vs 16% excess air). |
| 3 Monitor soot and scale in boiler and clean fire and water sides as necessary. | Increased fuel efficiency. |
| 4 Measure flue gas temperature and try to minimize, while keeping above dew point of gas (about 150° C for 1% sulfur fuel). | Flue gas with temperature of 320° C vs 220° C means about 5% greater heat loss up stack. |
| 5 Return all feasible clean condensate to a closed feedwater tank. | For every 6° C increase in feedwater temperature, 1% of boiler fuel is saved. |
| 6 Insolate feedwater tank. | For a 6000 litre uninsolated tank with a surface temperature of 80° C, losses are equivalent to 14,580 litres of fuel oil per year. |

FIGURE 14. *Recuperator Installed on Glass Furnace. Recuperators allow recovery of waste heat from flue gas, lowering fuel use by about 1% for every 22° C increase in combustion air temperature.*

## 2. Furnaces, Kilns and Dryers

There are many types of equipment falling into this category, but the basic concepts of energy efficiency can be applied to all. Overall efficiency in this type of equipment refers to the heat used per unit of finished product. While boilers may be 80-85% efficient, furnaces may range from 20-45% in efficiency for example, in forging and rolling steel respectively.

The basic principles of energy efficiency include:

- Proper insulation of walls.
- Minimizing heat loss due to to excess air and incomplete combustion.
- Scheduling to make full use of facilities.
- monitoring and maintaining equipment.

Heat recovery has perhaps the greatest effect on operational efficiency but has often been overlooked. Likewise proper operation and monitoring to minimize air infiltration and operate burners with proper excess air levels can drastically lower fuel use.

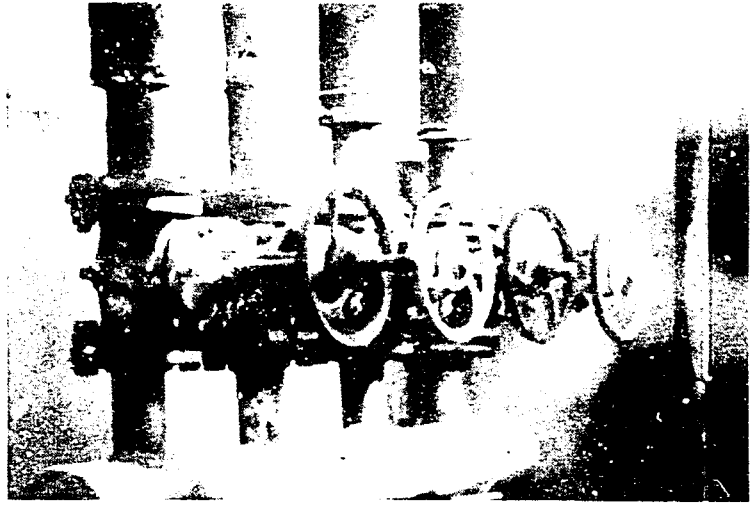

FIGURE 15. *Poorly Insulated and Leaking Steam Lines. Major losses frequently occur through leaky joints and valves, and deteriorated or inadequate insulation.*

## Selected Conservation Opportunities

| Measure | Impact |
|---|---|
| 1. Install insulation. | At 600 °C insulating brick has only 20% of the conductivity of fireclay brick. |
| 2. Practice waste heat recovery such as preheating of materials. | For every 22°C combustion air is preheated about 1% of fuel is saved. Preheating a steel billet from 25 to 50 °C reduces fuel needed by roughly 2% |
| 3. Monitor and control combustion by frequent measuring of flue gas composition with consequent adjustment of air-fuel flow rates. | Percentage of heat lost by flue gases decreases from 71% to 48% when excess air is decreased from 100% to 25%. (Excess air lowers flame temperatures and thus overall efficiencies.) |

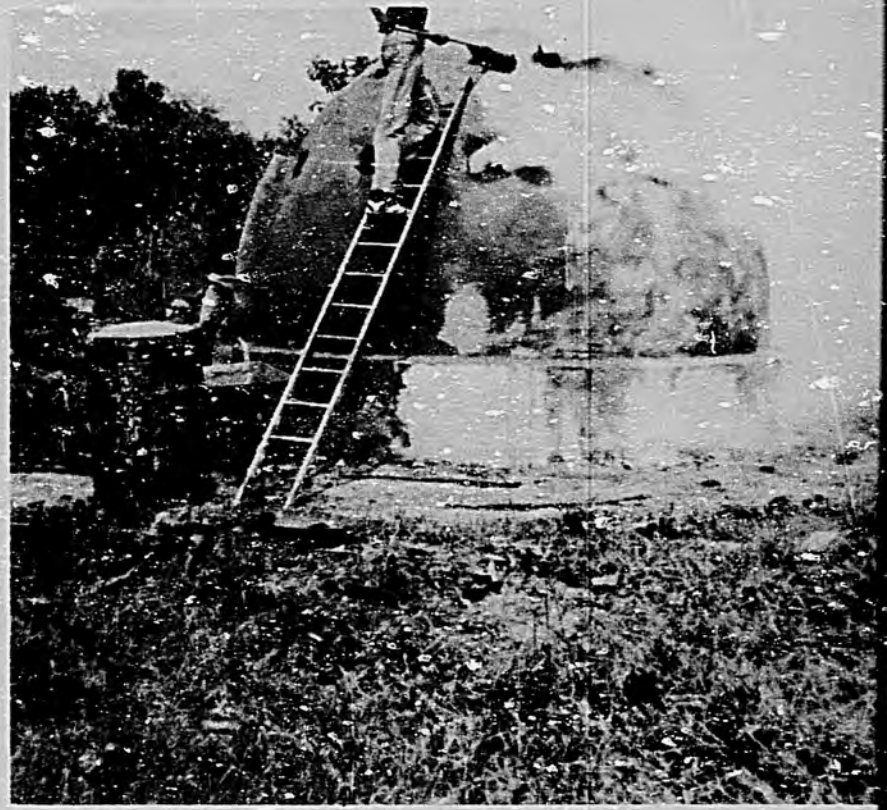

FIGURE 16. *Argentinian Half-Orange Charcoal Kiln. Another program of KREDP is the improvement of charcoal production techniques. This is being done with financial and technical support from the GTZ Special Energy Program.*

# Energy Audit Services

An energy audit involves a study of energy inputs and product outputs, in order to assess efficiency and identify conservation opportunities. Energy audit services were provided to about 20 firms. These audits were designed to reinforce technical training courses and to stimulate action in various large industrial sectors. In addition, audits were intended to provide actual case examples for use in future training programs. Although resource limitations allowed only 20 actual audits, a further 30 brief advisory plant visits were undertaken to extend technical services.

FIGURE 17. *Studying Possible Site for Recuperator Installation on Steel Rolling Mill.*

FIGURE 18. *Measurement of Steel Furnace Surface Temperature. Measurement is used to determine degree of heat loss and if insulation is adequate.*

Results of audits coupled with the stimulus of training have been impressive, with selected firms (24 responding to our survey) indicating annual savings of US$1,093,000 actually achieved. These savings which recur every year can be compared to the expenditure in the conservation technical assistance program of about $500,000. In most cases conservation investments to realize these savings were minor and had short pay-back times. Many more difficult or expensive opportunities are actively under consideration but yet to be undertaken.

## Selected Results

| Measures | Estimated Savings | Achieved Savings |
|---|---|---|
| 1. MEAT PROCESSING PLANT | $68,000-156,000 | $231,000 |
| • Boiler tune-up and repair. | | |
| • Steam system renovation. | | |
| • Condensate return. | | |
| 2. STEEL BILLET ROLLING | $142,000 | $112,500 |
| • Flue gas recuperation. | | |
| • Burner repair and operation control. | | |
| • Furnace repair and rebuild. | | |
| 3. TEXTILES | $103,000 | $112,500 |
| • Boiler maintenance. | | |
| • Condensate return. | | |
| • Steam system renovation. | | |
| • Flash steam recovery. | | |
| • Dyer waste heat recovery. | | |

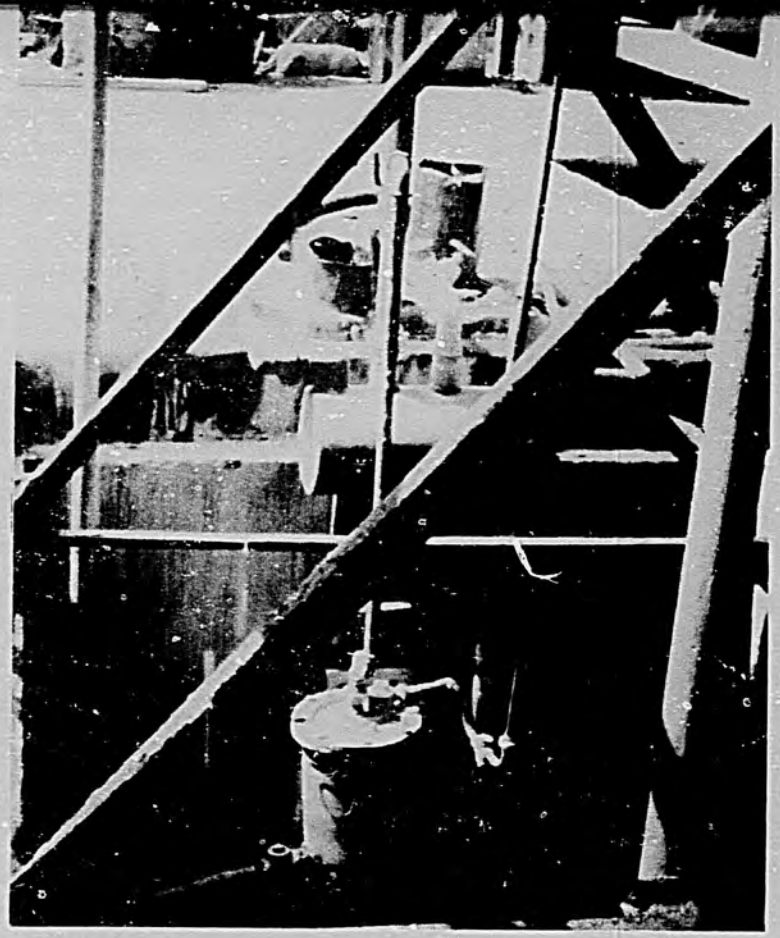

FIGURE 19. *Ogden Pump Used to Return Condensate to Boiler. Condensate from steam presents one of the major opportunities in plants using steam as with every 6°C increase in feedwater temperature about 1% of fuel is saved in the boiler.*

# Energy Efficient Stoves

The project initiated the development of an energy efficient charcoal stove which proved it could save from 25-50% of the charcoal ordinarily used for cooking. The improved stove costs about the price of a typical family's monthly expenditure for charcoal or about Kshs 90/-, so that a family can recover the cost of the improved stove in about 2 months from savings. Over 125,000 stoves are estimated to have been sold by mid 1985, and currently there are more than 5000 stoves being produced per month.

In the dissemination of the stove technology the project has focused on training and demonstration to private sector commercial producers and the traditional sector. These are located primarily in the country's urban centers. The improved stoves are estimated to have captured about 6% of the market for new and replacement stoves. Work is also underway to develop energy efficient wood stoves. Field testing of these has already begun.

For more information on energy efficient stoves, see the companion booklet, Improved Cookstoves in Kenya, also available from KREDP.

FIGURE 20. *Producers of Ceramic Liners for Improved Charcoal Jikos Shown at Work.*

# Fuel Substitution Opportunities

## Coal Substitution

Prospects for coal substitution for industrial fuel oil have in the past appeared attractive for Kenya even though both fuels must be imported. One major cement plant with a particularly favourable coastal location and a history of partial coal use (Bamburi Portland Cement) has achieved a successful conversion to coal. Further study of the coal substitution option was initiated under the KREDP, with initial focus on port facilities and conversion processes and economics. Recent reduction in the price of oil, the high cost to convert plants to coal use, and other factors, make further coal substitution unlikely at present.

## Domestic Biomass Material

A more practical and economic alternative for many firms is the greater utilization of domestic fuel resources. These resources consist of variety of materials, some being residues of agricultural processing such as coffee and rice husks, sawdust and wood-waste, jute, sisal-waste and cashewnut shells. In some cases existing or purposely planted woodfuel is a very attractive oil substitute, as in the tea and tobacco industries.

## Potentially Available Fuel Substitutes

| Material | Quantity Available Annually |
|---|---|
| 1. Materials at Centralized Sites | |
| Sawdust at rural sawmills | 63,000 tons |
| Coffee-husks | 35,000 tons |
| Municipal waste | 100,000 tons |
| Bagasse | 35,000 tons |
| Rice husks | 8,000 tons |
| Sisal-waste | 12,000 tons |
| Cashewnut shells | 7,000 tons |
| 2. Materials Dispersed Requiring Gathering and Transport | |
| Papyrus | 160,000 tons |
| Forest thinnings | 24,000-400,000 tons |

Assistance during the KREDP was given to several firms to convert to biomass materials as fuel. One involved the purchase and installation of a briquetting press for the densification of coffee-husks, and the conversion of an oil-fired boiler to burn the combination of wood and briquettes in an external furnace. A case study was written on this experience so that other interested firms could follow this example. In addition, technology assessment and public information work was undertaken to provide basic information on the potential for domestic fuel substitution.

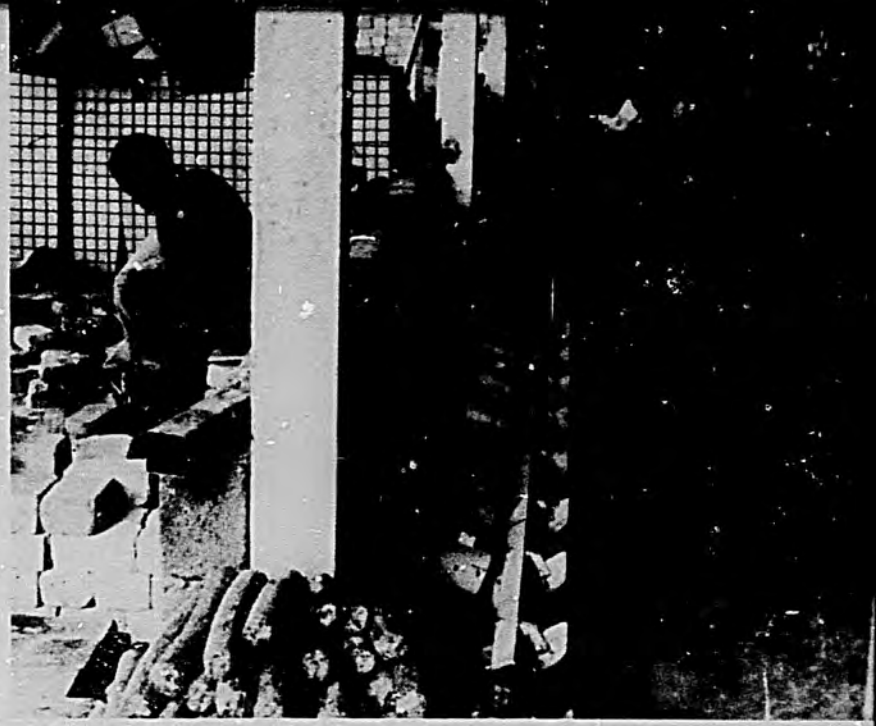

FIGURE 22. *Preparation of Coffee-husk and Sawdust Briquettes for Boiler Fuel. These materials proved to be a very cost effective substitute for imported oil, and together with a converted oil-fired boiler resulted in major fuel cost reductions for the plant.*

# Future Opportunities

Many opportunities remain for conservation and fuel substitution initiatives to be successfully applied to improve the efficiency of Kenya's energy system and reduce its foreign exchange costs. Even with lower imported oil prices most of these conservation measures are economically beneficial. Several of the more important opportunities are:

## Energy Audits

Past audits have been very successful, but were undertaken for a limited number of firms and focused primarily on short-term and low-cost opportunities. Further audit activities by Government, and audit and conservation services by the private sector are required in order to:

- Audit all medium to large scale firms and significant institutional and government energy users,
- Address medium to long term and higher cost opportunities for previously audited firms, and
- Follow-up previous audits to stimulate implementation

## Training

Creating awareness and providing essential technical information to the private sector has been extremely valuable in producing self-help conservation efforts. Further training is needed to:

- Expand government's capability to design, monitor and implement conservation activities,
- Continue to stimulate conservation actions by private sector and Government engineers and managers responsible for energy management, and
- Create on-going local capability to service industrial and institutional needs for technical support in energy conservation.

## Fuel Substitution

There has thus far been limited experience and success with substitution of domestic biomass fuels for oil in plants in Kenya. The first major government initiative was the "Coal Conversion Action Plan Study" done in conjunction with the World Bank. This study found that significant additional coal substitution was unlikely, but indicated that further potential exists for domestic (biomass) fuel use. Future fuel substitution work should address:

- Supply of domestic fuels by type and source,
- Fuel processing requirements, technology and cost,
- Utilization methods and technology, particularly for

substitution for oil in existing plants, and

- Market size and location given the sources and costs of different supplies, and the geographic location and size of consumers.

## Incentives and Financing

As more and more firms become aware of conservation and fuel substitution opportunities, there will be a greater need to provide sufficient incentives and financing to see that opportunities are realized fully and rapidly. Various constraints impede implementation and should be both better understood and explicitly dealt with. Areas that should be addressed include:

- Current constraints to conservation for public, parastatal, private and Government firms and institutions,

- Incentives which assist in stimulating action such as reducing levels of duty and sales tax, stream-lining import licensing procedures, and reducing income taxes, and

- Financial and technical assistance in preparation and implementation of investment projects.

## Acknowledgements

This booklet was prepared by Mr. Mike Jones of International Energy Management and Technology, Inc. Mr. Jones was the long-term Energy Conservation Adviser to the Ministry of Energy and Regional Development under the KREDP.

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