Waste-Product Utilization in Kenya: Waste-Oil Recycling and Furfural Production

By

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This research paper is my original work and has not been presented for a degree in another University.

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This research paper has been submitted for examination with our approval as University Supervisors.

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TABLE OF CONTENTS

Chapter One

Chapter Two

Chapter Three

Chapter Four

Chapter Five

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LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BTU - British Thermal Unit

SAE - Society of Automobile Engineers

PTA - Preferential Trade Agreement

ABSTRACT

Kenya's rapid industrialization since independence has generated immense benefits and economic opportunities for many. However, as population increases, burgeoning towns and a rapidly expanding manufacturing sector have been accompanied by growth of wastes and environmental pollution. Improper disposal creates health hazards, pollution of the environment and resource waste. In this respect, waste disposal has generated widespread concern, calling for need to salvage and re-use waste resources by adopting economically viable waste disposal practices.

Increasingly, developing and industrialized countries are discovering the benefits emanating from processing waste products. The utilization of waste products preserves valuable resources while solving potential environmental problems. Regrettably, Kenya has not gone far in the use of waste-resources. Many opportunities for industrialization are missed because waste-resources are inefficiently disposed. This study explores the problems associated with the disposal of two waste-resources; the recycling of waste-oil from imported virgin base-oils; and the utilization of maize-cobs in the production of furfural, a chemical intermediate with various important industrial uses.

The Kenyan Government is expected to play a leading role in stimulating interest and effecting programmes for waste-product utilization. To overcome problems associated with waste-product utilization in Kenya, the government should:

(a) develop an incentive structure to accelerate the development of waste-oil recycling industry and overcome the tactics of multinational oil companies which frustrate the growth of the waste-oil recycling industry in Kenya.

(b) increase its involvement in the independent evaluation of feasibility studies to avoid shortcomings and deficiencies in state-sponsored projects.

(c) enter into agreements with private foreign investors to share risks and accountability in the event of a project's collapse.

Finally, further research should be conducted in all aspects of resource wastes: collection, storage, processing, salvaging and utilization.

CHAPTER ONE

1.0 Introduction

Kenya's rapid industrialization since independence has placed heavy demands on domestic and imported raw materials. Such growth strains the country's resources. Moreover, population increases, burgeoning towns, and a rapidly expanding manufacturing sector have been accompanied by a rapid rise in wastes and environmental pollution. Consequently, the need to reclaim wastes and conserve resources is overwhelming. Yet, the Salvage Industry that uses waste-products is among the least developed industries in Kenya. The few industries that exist are poorly equipped; some are stymied and cannot penetrate domestic markets that multinationals dominate. Furthermore, serious planning and management mistakes have been committed, including: delays in plant construction; inefficiency in raw material collection; and high rates of capacity under-utilization. This study proposes ways to overcome these problems and discusses measures the government can take to encourage resource-waste utilization.

Increasingly, developing and industrialized countries are discovering the benefits emanating from processing waste-products. The utilization of waste-products preserves valuable resources while solving potential environmental problems. This study shows that serious problems exist in the waste product utilization projects in Kenya.

Historically, chemical industrialization proceeded along the path of waste-product utilization. For generations, concern grew over the conservation, utilization and efficient disposal of waste resources. This paper explores the problems associated with the disposal of two waste resources; the recycling of waste-oil generated from imported virgin base-oils; and the utilization of maize cobs in the production of furfural, a chemical intermediate with various important industrial uses.

1.1 Statement of the Problem

Large amounts of wastes are disposed on land and in water in Kenya. Most wastes are derived from chemical and agro-industries which produce plastics, synthetic rubber, pharmaceuticals, paints, textiles, leather, electroplated items, lubricants, glass, paper and animal and plant residues. These industries account for two-thirds of hazardous and non-hazardous wastes. The indiscriminate disposal of some of these wastes has posed serious health and environmental problems.

Concern has therefore grown rapidly about the need to dispose wastes economically and safely. This concern has been considered at two levels: one, the efficient utilization of resources; and two, acceptable disposal methods of used products to prevent environmental pollution.

Regrettably, Kenya has not gone far enough in waste resource use. Although large volumes of wastes are being recycled annually, much more remains to be done. Infact, some waste-product utilization projects have not performed well. Thus, many opportunities for industrialization are missed because waste-resources are inefficiently disposed. This study therefore hopes to fill an information gap by shedding light on the potentials and problems in the use of waste-products. In addition to providing an overview of waste-product recycling, the paper focusses on two case studies, namely waste-oil recycling and furfural production in Kenya.

Kenya is an oil-importing country and expends large sums of foreign exchange to purchase lubricants annually. The waste-oil, derived from the lubricants, is then dumped directly into the environment, gravely polluting marine and ground water sources. Increased reclamation would not only alleviate environmental degradation but also reduce dependence on imports of virgin base-oil, realize considerable savings in energy and foreign exchange, and provide Kenyans with employment and incomes.

The utilization of maize-cobs marked an important phase in the chemical industrialization in Kenya. The programme, however, did not last long. Barely eighteen months after starting production, the company went into receivership. The problems that bedevilled the company and contributed to the failure of the furfural project are explored in this study.

1.2 Objectives of the study

In Kenya, waste-oil recycling offers possibilities of resource conservation and reduction of import dependence. This study therefore examines appropriate disposal methods to avoid indiscriminate dumping and to ensure resource conservation and environmental protection. Moreover, the impact of increased re-use of used oil on imports and balance of payments will be investigated.

The need to formulate legislation on waste-oil management and pollution control is also considered. In this respect, we explore the role the Government can play in influencing efficient collection and channelling of used oil to refining plants.

Multinational oil companies have used various methods to frustrate the growth and development of the waste-oil recycling industry. This paper considers measures that can counter multinational pressure.

Regarding maize-cobs utilization, the paper examines some of the economic causes during the pre-commissioning period that led to the failure of the furfural project. The objective is to draw relevant lessons from such a disappointing industrial experience so as to avoid similar mistakes in the future. Other aspects for examination include:

(a) shortcomings of the feasibility study;

(b) the financial structure of the Kenya Furfural Company;

(c) the projected and actual financial performance;

(d) poor designs and misspecifications of the plant's equipment and components.

The government's intervention to secure foreign loans on behalf of private investors will also be evaluated. In this respect, criteria for guarantees will be considered.

1.3 Importance of the study

This study shows that considerable potential exists for technical progress and realizing economic opportunities in recycling waste-products. It also highlights the fact that though large volumes of wastes are being recycled annually, still more needs to be done to expand salvage operations. Furthermore, collection, handling, and sorting out waste-materials is labour intensive and would therefore create many more jobs for unskilled workers if adequate incentives were developed.

Few studies exist on the waste-oil recycling industry in Kenya. In this respect, this study attempts to fill an important information gap on the potentials of this industry for the economy. Further expansion of the waste-oil industry would drastically lessen import dependence and substantially minimize environmental pollution and resource waste. It is intended that findings from the survey will assist policy-makers in formulating proper prescriptions to resolve the problems and bottlenecks in the industry.

The collapse of the furfural project has raised questions about the Government's posture towards private investments in which it is a shareholder. The government has in the past issued guarantees to foreign financiers on behalf of private investors. Many of these projects have collapsed, thus transferring the burden of servicing foreign loans to the public. This study is significant since it raises the question of accountability. It draws crucial lessons from experience and may therefore assist policy-makers to save the taxpayer the burden of servicing loans absorbed by a subsequently collapsed venture.

CHAPTER TWO

LITERATURE REVIEW AND METHODOLOGY

2.0 General Definitions

Wastes:

Atkinson (1976) defined wastes as "... residue by-products of manufacture which are either re-processed, sold or rendered harmless and dumped". The term by-products gives the impression of secondary or tertiary materials produced in conjunction with key products of manufacture. Atkinson's definition is limited since it takes no account of manufactured products that are used and finally wasted. A more comprehensive meaning of wastes is given by Henstock:

> The economist's definition of wastes is presumably that which it is cheaper to throw away than to make further use of. This does not mean that waste is useless, some of it certainly is not. The situation would be quite different if raw materials became much more expensive and costs of disposal were vastly increased ... this definition concerns one user only. It might be economic for him to throw something away but uneconomic for the nation (or for mankind) particularly in the long-run . (Henstock, 1975: 3-4).

Henstock's definition incorporates by-products (which may be difficult to dispose) and manufactured products which, if made available after use, may be less expensive than virgin materials.

Recycling

According to Porteous (1977), recycling is a term that has been much abused. The meaning it conveys, he says, is getting something back from wastes, e.g. de-inked, re-pulped newspaper made into newsprint once more. He draws a distinction between recycling and re-use. Re-use implies cleaning, re-filling, and consumption typified by the returnable bottle (which makes several trips from the bottler to the consumer). Recycled products are unfit for re-use. They, unlike the bottle, have to be cleaned and broken down for remelting to make more products.

Porteous identifies two types of recycling: direct and indirect. Direct recycling involves the use of a waste-product as raw material to produce the original product from which the waste was derived. The use of mis-shaped or broken bottles to re-manufacturer bottles is a typical example. Direct recycling is therefore a reproductive phenomenon.

Indirect recycling involves the use of waste for purposes other than the reproduction of the material from which it was derived e.g. the use of broken bottles for fencing to prevent intruders. When waste reclamation is more expensive than the extraction of the basic feedstock, indirect recycling becomes a viable alternative. In many cases direct or indirect recycling possibilities are dictated by market forces.

The waste-oil recycling industry defines re-use differently as:

(a) recycling

(b) reclamation

(c) re-refining.

Regarding waste-oil, the American Society for Testing and Materials (ASTM) defined recycling as:

> ... processing used oil in order to regain useful material (Bowman, 1982:87).

Reclamation refers to cleaning the waste-oil through filteration, dehydration and centrifuging to physically remove the insoluble contaminants, stones, rags, leaves, or twigs.

Re-refining refers to the production of high quality base stocks through chemical treatment and distillation. It differs from recycling in that the latter denotes waste-oil treatment to gain useful material, but not necessarily high quality base stocks.

Although subtle differences exist between recycling, re-refining, and re-using, many writers employ these terms interchangeably. This paper uses the term recycling and re-refining.

2.1 Aspects of chemical industrialization: utilization of waste products in an economy.

During the early phases of chemical industrialization in Europe, public concern about the nuisance of certain chemical wastes generated anxiety about their cautious disposal. This paved the way for a dramatic discovery of their potential use. Many items which were initially regarded as waste turned out to be a valuable feedstock.

For almost a century, the chemical industry in Europe was dominated by the production of a few chemicals that sustained an important nexus of trade within the continent. Central to this small family of traded chemical products was sodium hydroxide (caustic soda), often referred to in the chemical industry as the alkali trade. The demand for alkali derived from the increasing demand for soap, textile, and glass manufacture. Soap is manufactured through the alkaline hydrolysis of vegetable fats. With rising standards of living and cleanliness, coupled with population increases, soap consumption showed a marked rise, initiating a phenomenal expansion of the soap industry and the demand for sodium hydroxide (Reuben & Burstall, 1973:12). The textile industry required much bleaching powder, which was produced by reacting slaked lime with chlorine gas. Chlorine gas was generated from one of the waste-products from alkali manufacture: hydrogen chloride gas.[1] Glass production through the fusion of silica and salt cake (sodium carbonate) also developed with the alkali trade, since salt cake was one of the by-products in the series of reactions leading to sodium hydroxide.

Despite the increasing demand, the growth of the synthetic alkali manufacture was slow. This sluggish growth was attributed to the imposition of salt tax (Reuben & Burstall, 1973:14). It was after 1824, when the excise duty on salt was repealed, that the alkali trade developed rapidly through the Leblanc process (Reuben & Burstall, 1973:14).

The Leblanc process uses salt as the basic feedstock in the production of caustic soda. Salt was an important ingredient because it was cheaply available. As such, massive amounts of alkali could be produced at low cost. The alkali industry during the first half of the 19th century was virtually the chemical industry (Hardie & Pratt, 1966:27), while the Leblanc system was the

> ... nucleus that gave pattern to the heavy chemical industry (Hardie & Pratt, 1966:28).

From that system, one major by-product, hydrogen chloride gas, was initially regarded was waste. The gas was allowed to diffuse into the atmosphere, damaging nearby crops and woodlands (Hardie & Pratt, 1966:31). Complaints about foul smell, terrible headaches and stomach problems were common (Campbell, 1971:32). The following comment reveals the anxieties of the time:

> ... the gas from these manufactories is of such a deleterious nature as to blight everything within its influence ..., the herbage of the fields in their vicinity is scorched, the gardens neither yield fruit nor vegetables ; many flourishing trees have lately become rotten naked sticks. Cattle and poultry droop and pine away. It tarnishes the furniture in our

> houses, and when we are exposed to it, which is a frequent occurence, we are afflicted with coughs and pains in the head ... all of which we attribute to the Alkali Works (Campbell, 1971:32).

The above comment, among others[2], reflects the rising anger and frustration of residents in the neighbourhood of alkali factories. The situation was further aggravated by another waste by-product called calcium sulphide. Many waste heaps were an eye-sore to passers-by and

> ... apart from the nuisance created by the smell from the waste heaps (calcium sulphide in an atmosphere rich in acid fumes!) the loss of sulphur was a severe economic drain on the process (Campbell, 1971:44).

Protests by residents in the vicinity had reached a crescendo. Grievances were aired to Her Majesty's government. After much feet-dragging, the authorities decided to intervene. The huge sulphide heaps and obnoxious gases had to be contained somehow. The Alkali Act was passed in 1863 and forced manufacturers to condense at least 95 per cent of the hydrochloric gas (Haber, 1958:11). The gas, initially regarded as waste, yielded chlorine on oxidation, which was a key chemical product in the preparation of bleaching powder. Large-scale production of chlorine was thus made possible and has

> ... continued as a key chemical operation into the modern times (Hardie & Pratt, 1966: 32).

The development of waste-product utilization was a major innovation in the history of chemical industrialization. The innovation was not confined to hydrochloric gas trapping and subsequent use. A satisfactory method of recovering sulphur from alkali waste was discovered in 1882 by Alexander M. Chance[3]. As early as 1770, Scheele had discovered a method to generate chlorine gas from a mineral, pyrolusite, containing manganese dioxide. The reaction left a crust of manganese chloride that was dumped. Between 1866 and 1869, a successful method of manganese recovery was developed[4]. This was a leap forward in waste-product utilization.

Little is known about utilization of wastes between 1870 and 1945, though sewage treatment began on a considerable scale in the 1920's (waste sludge found use as a fertilizer). Major developments only began after the Second World War in Britain, France, United States and Japan.

2.2 Waste-product utilization in selected countries.

Waste resource recovery and recylcing has become increasingly evident in recent years. The trend towards the increasing manufacture of valuable materials from wastes was stimulated by growing concern to conserve resources and minimize environmental pollution. This latter aspect has been given official backing through a series of legislative and statutory regulations. Indeed, recycling efforts have been partly motivated by regulations enforced by environmental agencies and government institutions. Growth trends in resource-waste use for selected countries are given below.

In Britain, waste-paper recycling has been increasing between 1967 and 1975. Waste paper accounted for 36 per cent by weight and 65 per cent by voulme of refuse. The trend of its recovery and recycling is summarized in Table 2.1.

Collection of waste-paper has, since 1962, been widespread. In 1969, ten countries collected waste-paper amounting to more than 20 per cent of paper and cardboard production. Table 2.2 is a summary of waste paper collection in thirteen countries.

TABLE 2.1

Availability and Proportions used of recoverable paper, Britain, 1962 - 1975.

Year	Recoverable paper Tons	Waste-paper recycled (%)
1962	4,741,726	28.5
1964	5,481,085	27.7
1966	5,460,013	29.6
1968	5,816,906	29.9
1970	6,115,398	32.5
1972	6,051,733	30.9
1974	6,746,261	31.5
1975	5,030,214	34.2

Source: Porteous, A., Recycling resource refuse, Longman, 1977, pg 41.

TABLE 2.2

Collection of waste paper as a percentage of paper and paper board production, 1969.

Country	Percentage
Netherlands	38
Switzerland	34
Belgium	29
Great Britain	29
France	26
Spain	26
Sweden	23
Italy	22
United States	20
Denmark	18
Norway	16
Finland	15
Canada	12

Source: Colon, F.J., "Recycling of paper" in Waste in Process Industries, Conference papers, Institute of Mechanical Engineering, 1976, pg 130.

Glass and plastic scrap are collected for recyling in Britain. Porteous estimates that 10 per cent by weight of refuse is glass, nearly all being discarded packages. Moreover, 90 per cent of all containers manufactured are not intended for re-fill (Porteous, 1977:30). Production of plastics in 1975 stood at 1.75 million tonnes. Scrap constituted 20 per cent and nearly all of it was recycled (Atkinson, 1976:8).

Glass collection for re-use in West Germany showed a 100 per cent increase between 1974 and 1977. During this period, average annual estimates of production put the figure at 2.3 million tonnes (see Table 2.3).

TABLE 2.3

Waste glass collection for re-use in
West Germany, 1981.

Year	Amount collected (tonnes)
1974	150,000
1975	200,000
1976	260,000
1977	300,000

Source: Holmes, John R., Refuse Recycling and Recovery, John Wiley & Sons, 1981 pg 136.

Scrap collection from the can industry (aluminium, tin and ferrous) in Britain accounted for 10 per cent of total production in 1974. Nearly all scrap recovered was recycled (Atkinson, 1976:7). Table 2.4 indicates the materials recycled in Britain in 1974, including scrap from the can industry.

TABLE 2.4

Materials recycling in the United Kingdom
as percentage to total production, 1974.

Material	Percentage recycled
Iron	55
Lead	50
Copper	45
Aluminium	25
Zinc	20
Paper and allied products	20
Glass	10

Source: Holmes, J.R., Refuse Recycling and Recovery, John Wiley & Sons, 1981, pg 14.

In Japan, much resource recovery and recylcing occurred. In 1980, about 292 million tonnes of industrial wastes were generated and 124 million tonnes were recycled. 88 million tonnes were recycled directly. Table 2.5 is a summary of treatment and disposal of industrial wastes by type in 1980 in Japan. Table 2.6 shows rates of resource recovery between 1977 and 1979.

On average, recovery rates for specific wastes show sharp unexplained declines between 1977 and 1979, though total resource recovery rates increased in the same period (see Table 2.6).

The recovery of waste-oil, acids and alkalis prevent further pollution of the Japanese marine and land resources. In this respect, recycling can be regarded as a double-edged sword: generating valuable products for the economy while at the same time preventing further damage to the environment.

The salvage industry in the United States also showed high rates of recycling as a percentage of total consumption. About 190 million tonnes of manufactured materials - glass, textiles, rubber, iron and steel - were consumed in 1968 and 1969. 48 million tonnes were salvaged and recycled during the same period. This constituted 25.2 per cent of total consumption (see Table 2.7). Bernard, Parker and Richardson argued that the secondary materials industry had been declining. They admit that the industry had never been a major

TABLE 2.5

Treatment/Disposal of Industrial Wastes by Type: Japan, 1980.

Tonnes

	Generated* amount	Processed* amount	Residues from processing	Recycled amount (total)	Recycled amount (after processing)	Disposed amount (total)	Disposed amount (after processing)
Cinders	1,797	1,315	15	429	423	1,368	1,459
Sludge	88,190	77,940	9,287	5,844	3,621	13,693	6,829
Waste oil	2,419	1,674	207	830	725	122	20
Waste acid	10,219	2,245	132	6,148	6,120	1,958	1,454
Waste alkali	6,090	4,474	347	1,603	1,562	360	51
Waste plastics	2,232	788	220	756	699	908	745
Waste paper	1,624	276	119	1,307	1,229	160	110
Wood chips	6,628	3,447	517	3,024	2,698	674	483
Waste textile	101	43	3	43	42	18	16
Waste rubber	92	25	5	16	15	56	52
Animal/plant residues	4,323	1,199	132	2,990	2,874	266	250
Metal scraps	13,111	208	178	12,735	12,592	346	311
Glass/waste ceramics	2,297	401	348	824	655	1,420	1,211
Slags	60,561	27,494	26,958	45,419	23,204	14,606	9,863
Demolished building materials	30,007	5,187	4,881	2,262	1,823	27,439	22,907

TABLE 2.5 CONTD.

	Generated* amount	Processed* amount	Residues from processing	Recycled amount (total)	Recycled amount (after given processing)	Disposed amount (total)	Disposed amount (after given processing)
Livestock excretions	49,629	25,298	9,963	31,563	22,172	2,731	2,159
Livestock corpses	62	14	1	3	3	47	47
Dust	11,731	3,651	1,109	8,407	7,531	782	519
Others	1,199	20	3	50	50	1,132	1,129
TOTAL	292,312	154,399	54,525	124,253	88,038	63,086	49,847

Source: Plastic Waste: Resource Recovery and Recycling in Japan, Survey and Public Relations Department, Plastic Waste Management Institute, 1985, pg 36.

* Generation refers to the amount of waste material produced.

Processed amount refers to the amount of generated waste retrieved and re-processed.

TABLE 2.6

Rates of Resource Recovery of Industrial Wastes by Type (estimated by the MITI), Japan, 1980.

	Rate of resource recovery	
Type of industrial waste	1977	1979
Cinders	26.1%	23.33%
Sludge	10.9	10.46
Waste oil	25.0	24.79
Waste acid	33.0	19.37
Waste alkali	40.3	19.50
Waste plastics	54.2	25.80
Waste paper	76.1	35.61
Wooden chips	24.8	22.27
Waste textile	79.3	40.20
Animal plant residues	83.0	31.94
Waste rubber	17.5	19.30
Metal scraps	92.5	98.69
Glass and waste ceramics	47.6	36.54
Slags	62.8	81.37
Demolished building materials	3.5	1.58
Dust	44.9	75.14
Wastes given processing	3.9	35.45
Others	13.3	7.51
TOTAL	48.6	54.55

MITI = Ministry of International Trade and Industry.

Source: Survey & Public Relations Management, Plastic Waste: Resource Recovery & Recycling in Japan, Public Waste Management Institute, 1985, pg 37.

sector like transportation or agriculture, but could generally be found 'breathing' on the fringes of any major sector (Bernard, Parker and Richardson, 1974:148). They further assert that the salvage activities employed about 70,000 people, and generated income amounting to US $ 4.5 billion. It emerged in their discussion that the industry was heterogeneous, involving many small firms.

Waste disposal of paper increased between 1956 and 1967. Bernard et al quote projections made by Midwest Research Institute, United States, for the years 1976 and 1980 (see Table 2.8). Based on historical trends, waste-paper recycling was expected to decline as percentage to total consumption.

In conclusion, it must be noted that salvage operations are labor-intensive and hence can provide many jobs to unskilled workers.

TABLE 2.7

Recycling rates in the United States (1968 - 1969).

Material	Total consumption (million tons)	Total recycled (million tons)	Recycling as per cent of consumption
Paper	53.110	10.124	19.0
Iron & Steel	105.900	33.100	31.2
Aluminium	4.009	0.733	18.3
Copper	2.913	1.447	49.7
Lead	1.261	0.625	49.6
Zinc	1.592	0.201	12.6
Glass	12.820	0.600	4.2
Textiles	5.672	0.246	4.3
Rubber	3.943	1.032	26.2
TOTAL	191.220	48.108	25.2

Source: Bernard, Parker & Richardson, Solid Waste Disposal, Ann Arbor Science Publishers, Inc., 1974, pg 147.

TABLE 2.8

Comparison between consumption and waste-paper recycled in the United States in million tonnes and per cent.

	1956		1966		1967		1976*		1980*	
Category	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Consumption	36.5	100.0	52.7	100.0	51.9	100.0	(74.4)	100.0	(85.0)	100.0
Recycled	8.8	24.2	10.5	19.9	9.9	19.1	(13.6)	(18.3)	(15.1)	(17.8)
Waste disposal	(22.2)	(60.8)	34.6	65.7	34.5	66.5	(51.1)	(68.7)	(59.2)	(69.6)

Source: Bernard, Parker & Richardson, Solid Waste Disposal, Ann Arbor Science Publishers, Inc., 1974, pg 153.

NB * Projections.

2.3 Waste Product Utilization in the Kenyan Economy.

The recycling of waste-resources has expanded both in range and scope in Kenya, though considerable untapped potentials still remain. Little information exists on how much of particular waste-products are being recycled. At present, there appears to be no strong economic pressure to drive entrepreneurs to utilize waste-resources. As long as their raw material requirements encounter no supply bottlenecks, recycling will virtually remain underdeveloped. Of late, however, attempts have been made in waste-resource use, with recycling becoming extensively practiced in some areas. Studies by Ikiara show that recycling of scrap metal i.e. iron, steel, lead, and copper, has become substantial (Ikiara, 1983: 47 - 54). For instance, Coughlin estimates that 35,000 tonnes of steel are recycled annually, saving the country KShs. 78 million in foreign exchange. He also suggests a National Steel Clean-up Month be declared to collect waste metal and abandoned cars for recycling (Coughlin, 1985:93).

The recycling of chemical substances has also expanded. Organic solvents like Benzene and Carbon tetrachloride are recycled from waste mixtures at the Chemistry Department, University of Nairobi. Some soap manufacturers, like East African Industries, reclaim glycerine from soap waste. Caustic soda from cotton textiles mills and lead from scrap batteries are also recycled. The steel sheet galvanizers generate zinc oxide as waste. Since facilities for domestic recycling have not been established, the waste is exported for recycling. Leather tanning industries generate an expensive chromium compound as waste. The Bata Shoe Company in Limuru retrieves the compound from factory effluents, thus reducing production costs considerably. The reclamation also minimizes environmental pollution.

Reclamation activities, especially in the informal sector, thrive on the fringes of many major industries. Indeed, most waste collection and sorting are done by the informal sector. Ikiara asserts that a strong complementarity exists between the formal and informal sectors for waste-product reclamation.

Waste-paper recycling has expanded rapidly in recent years. Thampoe Jeyansingham reports that 10,000 tonnes of waste-paper are recycled annually, but laments that this constitutes only a 12.6 per cent recovery rate though this could be increased to 20 - 25 per cent. (Jeyansingham, 1985, Part 1:24).

Jeyansingham also considers the possibility of producing various types of paper from different agro-industrial wastes. He estimates that 900 - 1,000 kgs of cotton wastes can be collected a day to produce high quality handmade paper. This simple operation is economically attractive to small-scale investors and has a rate of return on investment of 37.8 per cent.

A single unit producing 60 tons annually can employ about 30 people. He observes that 10 tonnes per year units have been very successful in India.

In another feasibility report, Jeyansingham argues that speciality grades of paper (all imported) can be produced from sisal waste. Presently about 5,000 to 7,500 tonnes of the waste are generated annually (Jeyansingham, 1985, Part III,1). A major drawback of such a venture is the high cost of the capital investment involved, estimated at KShs. 240 million.

A study on agro-industrial wastes by Rasheed observes that no extensive use is made of most wastes and by-products. (Rasheed, 1982: Annex IV). For instance, he concluded that the fruit and vegetable processing industries sold all their vegetable rejects to farmers. While citrus fruit peels could be used to make marmalades, citrus seeds have a valuable oil that can be extracted commercially.

Rasheed's report further describes the use of by-products from the coconut industry. He cites a small company, the Mombasa Coir Industries, that makes briquettes from coir dust. He also cites a Kiwi factory in Mombasa that has been disposing dye-extracted seeds. In 1981, 360 tonnes of such seeds were wasted compared to 300 tonnes in 1980. Rasheed holds that the wasted bixa seeds could have been transformed into a nutritious animal feed, since a little of the dye, which is resposible for the colouring of the egg yolk, remains at the end of the dye-extraction process.

In his study on glass manufacturing in Kenya, Coughlin suggests that big savings could be realized if broken glass were recycled. The wastes, he argues,

> ---- melts more readily than sand and chemicals --- (and) that for every additional tonne, --- (the Company) would save 15 per cent of the normal amount of energy required (Coughlin, 1986:14).

Coughlin further demonstrates that in addition to energy savings, raw materials costs could be substantially reduced with the further advantage of putting many more hands to work.

A study on the recycling of photographic wastes was conducted by Makopa in 1980. In his comparative analysis, Makopa demonstrated that silver could be recovered from photographic and laboratory wastes with a high silver content obtainable from the latter. He observes that fixer solutions[5] (with high silver content) from virtually all ordinary photographic studios and hospitals throughout the country are wasted. And yet, for every 4 litres of fixer solution a profit of KShs. 196 can be realized (Makopa, 1980:47).

Plastic components after the film is removed can also be recycled. In Kenya, however, the progress of resource conservation in the plastics industry has been disappointing. Mwangi argues that recycling of plastic waste could generate considerable employment and savings in foreign exchange. He concludes with a strong policy recommendation for initiating a recycling industry for paper, glass and metal (Mwangi, 1984:156).

The growing amounts of wastes and their disposal are becoming an acute urban problem. Recycling needs to be invoked nationwide. As wastes continue to pile, disposal will become a social problem especially in those industries where expansion is rapid. This will enhance concerns over effective reclamation and re-use of waste resources.

2.4 Recycling selected wastes: waste-oil recycling and furfural production.

In this section, we review literature on varied aspects of waste-oil recycling and furfural production.

2.5 Waste-oil recycling

This subsection considers appropriate disposal methods, and the technologies and economics of waste-oil recycling.

Waste-oil disposal methods

A wide range of alternatives exist for disposing waste-oil. Most are associated with pollution of man's environment. The crudest form of disposal is indiscriminate dumping into the biosphere. According to a UNEP report published in 1984, nearly all waste-oil generated annually is directly or indirectly dumped into the environment (Irwin & Maltezou, 1984:21). This contaminates ground water sources, rivers, and marine environments.

Most pollutants ultimately reach the oceans, posing serious threats to marine ecology and commercial fisheries. Severe damage is also caused to coastal flora and fauna. The deleterious effect of waste-oil on marine and fresh water organisms have been well-documented (see John Black, The Dominion of Man, 1970). A further danger of indiscriminate dumping is the adverse effect of individual contaminants like lead and zinc on human health (Irwin & Maltezou, 1984:21).

Another method of disposal is the use of waste-oil as a dust suppressor on roads (Mobil Bulletin, 1966:7). For this method to be effective, the waste-oil has to be applied again and again since most of it is washed away especially during rainy seasons. However, serious environmental effects are associated with such disposal similar to indiscriminate dumping.

Incineration is another alternative of disposing waste-oil. Depending on the type of waste-oil and with appropriate technology, it can be regarded as an environmentally acceptable means of disposal (Maltezou, 1976:21). This method, however, can generate hazardous emissions such as oxides of lead and phosphorus though at very low concentrations. Other toxic emissions include chlorine, fluorine and phenolic compounds considered carcinogenic (see Table 2.9). Furthermore, incineration systems are generally associated with high costs. Despite this, the high BTU value of used oil makes incineration an economically appropriate method of disposal because the heat recovered supplements energy sources (Wills, 1971:1).

The burning of waste-oil as a fuel is yet another disposal technique. It is mixed with heavy fuel oil and has been used widely as a heat source for steam generation.

Waste-oil is also used in burning trash, garbage, and other municipal refuse. Similar applications have been found economically attractive in the burning of combustible industrial wastes (Irwin & Maltezou, 1984: 22).

Like incineration, burning as a disposal technique generates toxic emissions. The oxides of barium, calcium, magnesium, and vanadium become sources of dangerous atmospheric pollution.

The methods of disposal described above cause varying degrees of environmental pollution and damage. Direct dumping and dust suppressing have more serious adverse effects. And although incineration and burning generate externalities e.g. cutting fuel expenses, reducing pollution, conserving the oil

TABLE 2.9

Pounds of Metalic Emissions into the Environment in United States*, Per 10,000 Gallons of Drainings of Waste-oil, 1976.

	Washington DC	Houston	San Carlos	Lyons
Zinc	58	32	54	44
Chromium	4.8	2.9	3.8	1.2
Lead	400	370	480	650
Phosphorus	255	189	173	173
Barium	57	45	31	38
Magnesium	23	61	19	25

* Calculated as oxides.

Sources: S.P. Maltezou, Waste-oil recycling: The New York Metropolitan Area Case, 1976.

resource and providing more heat per litre of fuel burned, they still pose threats to human health.

Treatment versus Recycling

A major problem of environmental pollution is the adulteration of river waters, and hence the need for water conservation. Industrial wastes contain toxic metals, acids, alkalis, oils and dissolved solids which can easily impair aquatic life. Effective methods to precipitate or neutralize these wastes exist. The Kenya Government Water Pollution Control officers are charged with the responsibility of proposing effective methods of control to industries. Unfortunately, they emphasize the need to treat rather than recycle wastes. This is a wrong approach. The right approach is to emphasize the benefits of recycling which takes care of pollution minimization at the same time. Often, it is not realised that recovering resource-waste from industrial processes can be quite profitable. Recycling not only prevents environmental pollution but also reduces an entrepreneur's costs by re-using the recovered material. Treatment differs from recycling in that it emphasizes neutralization of waste toxicity rather than recovery of toxic materials from wastes.

Disposal of waste-oil through recycling

The disposal of waste-oil through recycling offers the potential of significantly reducing the environmental damage. This activity generates its own waste resources which can affect the environment adversely. However, these environmental problems are controllable and pollution is minimized (UNIDO, 185:5).

According to S.P. Maltezou, the decision to recycle waste-oil depends on two viewpoints: private and social. The private decision to recycle would be based on the cost-benefit analysis of the project. The entrepreneur will take into account factors like recycling costs, available technology, credit conditions, government policy and the reliability of flow of waste-oil (Maltezou, 1976:6). The social decision to recycle depends on the balancing of social and private costs and benefits. The public benefits include resource conservation and environmental protection, lessening dependency on imports (lubricants), foreign exchange earnings, improvements in the balance of payments and net additions to national income. The public costs cited include resource waste and pollution of the environment.

2.6 Technology

Waste-oil recycling technologies are of four main types (UNIDO, 1985:10):

(i) The Acid/clay technology

(ii) The Distillation/clay process

(iii) Distillation

(iv) Distillation/Hydrotreating process.

The acid/clay technology

The acid/clay treatment involves four main steps:

(i) Dehydration of used oil

(ii) Acid treatment of dehydrated used oil to produce sludge free oil

(iii) Reaction with bleaching clay

(iv) Distillation and filtration.

The acid/clay process yields two by-products: acid sludge and spent-clay. It has a 72 per cent recovery rate.

The distillation/clay technology

The distillation/clay treatment involves the following three steps:

(i) Dehydration of used oil

(ii) Thin-film vacuum distillation

(iii) Clay treatment.

The problem with this type of technology is the disposal of spent clay. Other technologies are:

(a) Distillation

The waste-oil is subjected to vacuum distillation. It has a recovery rate of 76 per cent. The advantage of this process is that the spent-clay contains about 30 per cent lead by weight, which is marketed to re-refineries.

(b) Distillation/Hydrotreating

This process is similar to the distillation clay treatment except for the substitution of hydroheating for clay treatment. Again, the by-product (semi-solid) has a high percentage of lead.

The distillation/hydrotreating process has a recovery rate of 99 per cent. This technology is not only superior in this sense, but also has a highly valuable marketable by-product (spent-clay) rich in lead (30 per cent). It is the most expensive of the existing technologies.

2.7 The Economics of Waste-oil recycling

The economics of producing lubricants from re-used oil depends on the following:

(a) Total capital investment
(b) Operating costs
  (i) raw material costs
  (ii) collection, transportation and storage of the feedstock.

(a) Total capital investment

The fixed investment costs depend on the type of technology employed. The latter affects both the recovery rate and extent of pollution. It is imperative to identify the type of investment that minimizes environmental pollution and maximizes recovery rate. Total fixed investment accounts for at least 60 per cent of total investment costs. The rest is invested in transport and working capital (UNIDO, 1977:8).

(b) Operating Costs

The most important variable is the cost of feedstock, followed by the cost of decontamination chemicals, additives and wages. Government involvement in recovery and collection affects prices of feedstock. This was the case in Denmark and West Germany (Maltezou & Irwin, 1984: 23-24). Other factors influencing the price of feedstock include competition between collectors, distribution patterns of collection, distance from plants, and collector-source relations.

Transportation and storage are aspects that affect cost of production. The nearer the source of waste-oil to a recycling plant the lower the costs of transportation. Most recycling plants are in a 30 - 40 mile radius of their waste-oil source (UNIDO, 1977:2). Independent collectors have found it convenient to transport the waste feedstock from bus companies and transporters not far off from the plant. Independent collectors are assisted by company trucks that collect the waste-oil from identified centres.

Handling and storage also affect the cost of production. The two aspects are related in terms of ensuring quality and quantity of the feedstock. Waste-oil must be handled with care and kept away from acids (especially hydrochloric acid). Poor handling can lead to contamination from rain, solid waste and chemicals (UNIDO, 1985:3). The quality deteriorates and expensive methods will have to be employed to clean the waste-oil. Storage tanks must also be clean to prevent contamination. They should be washed and thoroughly dried from time to time.

Quality of lubricants derived from recycled waste-oil.

The performance quality of recycled lubricants has been suspect. There is a belief that recycled waste-oil is simply cleaned, packed and re-sold to consumers. However, from numerous quality control evaluations, substantial evidence exists that shows re-refined base stocks at least equal in quality to virgin base stocks.

In Australia, laboratory tests were carried out comparing commercial motor oil to re-refined oil. Table 2.10 summarizes the main characteristics. The tests were passed by the Australian Government quality control officials (Martin, 1974:197).

In the United States, re-refining industry was given a big boost when re-refined oils were accepted in military specifications (MIL-L-46152A). According to Bowman (1982:88), United States military engine oil specifications are respected worldwide, which means re-refined products can pass for approval.

TABLE 2.10

Performance Quality Tests for Re-refined Waste-Oil and Normal Commercial Motor Oil.

	Re-refined product	Normal Commerc Motor Oil
Specific Gravity at 60°F.	0.886	0.891
Viscosity at 100°F. centistokes	98.2	122.4
Viscosity at 210°F. centistokes	11.3	12.8
Viscosity Index	109	105
Flash point, °F.	485	485
Fire Point, °F.	530	535
Total Acid Number, mg m KOH/g	0.44	1.60
Pour Point, °F.	5	15
Conradson carbon residue %	0.35	0.85
Sulphated Ash, %	0.17	0.76

Source: C.B. Martin, "Oil Waste Reclaiming", in Solid Waste Treatment and Disposal, Ann Arbor Publisher, 1972, pg 197.

2.8 Furfural Production

After enumerating the uses of furfural, this subsection considersits commercial derivation, and the economics and technologies of furfural production.

Uses of Furfural

Furfural can be used directly, or indirectly as a chemical intermediate. The direct uses are:

(a) Selective solvent for refining of lubricants.

(b) Solvent in butadiene extraction. Butadiene is used as a chemical intermediate in the production of styrene-butadiene rubber (SBR) through a ploymerization process.

(c) Decolourizing agent for wood resin.

Uses of furfural as a chemical intermediate include:

(a) Furan resins as foundry binders to make liquid sand binders to prepare moulds and cores.

(b) Resins for fibre-glass plastics.

(c) Furan resins as a soil-consolidating agent.

Commercial derivation of furfural

Furfural can be commercially extracted from agro-industrial wastes and residues containing complex carbohydrates known as pentosans. Theoretically, any pentosan containing agricultural wastes can serve as a feedstock to produce furfural. In reality, however, a certain level of pentosan content or richness in the waste-product must be established to allow for viable industrial production (Kenya Government, Pre-feasibility Study, 1975:11). Table 2.11 shows various possible raw materials and their respective richness in pentosans.

2.9 Economics of Furfural Production

The economics of furfural production depend primarily on the following factors (UNCTAD/GATT, 1979: 13):

(a) Investment costs

(b) Production costs.

Investment Costs

The investment costs include plant machinery and equipment, technology, pre-production capital costs (cost of feasibility studies and pre-commissioning).

The type of raw material to be used is an important factor when considering investment costs.

The utilization of maize cobs as feedstock has the advantage of allowing the smallest factory size. Compared to bagasse, maize-cobs would require a smaller sized reactor (UNCTAD/GATT, 1978:14). This cuts investment costs considerably.

TABLE 2.11- Furfural yield of selected raw materials (percentage per dry weight)

Raw material	Pentosan content (average) (percentage)	Furfural yield in Industrial operations (percentage)
Maize cobs	30 - 32	10
Oat husks	min. 32	10
Almond husks	min. 30	9 - 10
Bagasse and Bagasse pith	25 - 27	8 - 9
Cotton husks	27	8 - 9
Hardwoods (birch)	21 - 24	6 - 8
Sunflower husks	23 - 25	6 - 7
Rice husks	16 - 18	6
Beech bark	19 - 21	5 - 6
Chestnut wood (after tannin extraction)	18	5 - 6
Olive presscake	21 - 23	5 - 6
Hazlenut husks	24	7 - 8

Source: UNIDO, Making and Marketing Furfural: Added Value for agro-industrial Wastes, Geneva, 1979, pg 6.

Investment costs can be further lowered if a furfural plant is integrated to a sugar mill. Many utilities can be shared. Power, steam and administration costs can be reduced appreciably.

Investment costs have to include provision for storage facilities, since large quantities of the raw material are required for sustaining production all the year round.

Production costs

Furfural production costs depend significantly on costs associated with the raw material: its collection, handling, storage, and pre-treatment. The price of maize-cobs depends on its alternative uses too. Maize cobs can be used as fule or animal feed. These alternative uses therefore dictate the cost of the raw material in furfural production.

Cost of steam

Another crucial cost factor is steam. It accounts for 13 per cent of operating costs (UNCTAD/GATT, 1979:16). A plant producing 5,000 tonnes of furfural and 3,000 tonnes of acetic acid per annum would require 190,000 tonnes of steam a year (UNCTAD/GATT, 1979:15).

A further factor in the reduction of production costs is the final powdery residue from the furfural plant. It can be used to fire steam generators or sold as animal feed.

2.10 Technology

Furfural production technologies are of three main types, of which only two are available in the market. The Quaker Oats Company in the United States developed the discontinuous (batch) process and is, incidentally, the pioneer in this field. It controls 70 - 80 per cent of the world market for furfural. The American technology, however, is not available for licensing or purchasing. A prospective manufacturer of furfural is therefore left with two sources for the production technology: Escher Wyss of West Germany and Oy Rosenlaw AB of Finland, both of which are continuous processes.

The decisive factors in the different processes are the reactive conditions such as pressure and catalysts used. Furthermore, the design of the plant itself is particularly sensitive to the structure and density of raw material to be employed (UNCTAD/GATT, 1979:10). The former determines the type of equipment required to pump the feedstock into the reactor; the latter determines the size of the reactor itself (UNCTAD/GATT, 1979:11).

Over the years, the Escher Wyss and Rosenlaw processes have been modified to minimize environmental pollution resulting from effluent discharges rich in acetic acid. The two have now developed acetic acid recovery systems.

Other furfural production technologies have been developed in France, Italy, and Mexico. The French developed a discontinuous process using phosphoric acid as a catalyst. The Italian process uses sulfurous anhydride as a catalyst, while little is known about the Mexican technology. All the above mentioned are small suppliers, using expensive-to-operate corrosive acid processes relying on the old discontinuous (batch) technology.

2.11 Methodology

There are two parts to this research paper:

(1) the waste-oil recycling industry in Kenya

(2) furfural production in Kenya.

Information on the waste-oil recycling industry was gathered through questionnaires and visits to the plants. Secondary data was extracted from Government files and records. Additional information was sought from the Kenya Industrial Estates, Ministry of Energy and Ministry of Commerce and Industry. Interviews were held with officials of various multinational oil companies e.g. Kenya Petroluem Refineries Limited, Esso, Kenya Shell and Agip Limited. The author made various trips to the recycling plants in Kikuyu and Athi River.

For the furfural project in Kenya, information was gathered from company files, reports and Government records. During March 1986, the author visited the plant for a whole week and obtained valuable information. Additional data was obtained from the feasibility reports prepared by the Guiness Peat Group, London, and the Ministry of Commerce and Industry. The author interviewed the officials of Panell-Bell House Mwangi (auditing firm) who are currently the receivers of the furfural plant.

The inductive and deductive approaches are used in this study. Major breakthroughs in the systematization of knowledge have occured by utilizing either the inductive or the deductive approach in scientific inquiry. Both these approaches are used in the present study. We shall examine each of these in turn.

Induction is characterized by initially gathering facts about phenomena. Fragments of data may not help us in discovering relationships that can ultimately be formulated into a theory of explanatory and predictive validity. What one seeks to gather is data that lend as total a perspective as possible about a phenomenon. This then assists a researcher to construct highly general statements about certain regular relationships. The constructs then must stand the test of experiment and observation, otherwise their value for predictive and explanatory purposes may be found wanting.

Observation alone cannot be regarded as adequate in determining the truth or falsity of a theory (Hausmann, 1984:15). The position taken by Realists, as opposed to Positivists, is that one must not rely on observation or sensory experience as the ultimate test. The Realist goes a step further by generating concern about causation i.e. to furnish details that

> --- give us knowledge of unobservable natures, essences, and mechanisms that somehow necessitate (the) phenomena (Keat & Urry, 1975:4).

The case of unobservables in scientific inquiry assumes siginificance when one discovers that there is still more to be said about phenomena. The importance of theory is considerable. In the words of Hempel,

> scietific systemization is ultimately aimed at establishing explanatory and predictive order among the bewilderingly complex 'data' of our experience, the phenomena that can be directly observed by us. It is a remarkable fact, however, that the greatest advances in scientific systematization have not been accomplished by means of laws referring explicitly to observables i.e. to things and events which are ascertainable by direct observation, but rather by means of laws that speak of various <u>hypothetical, or theoretical entities</u> i.e. presumptive objects, events, and attributes which cannot be perceived or otherwise directly observed by us (Keat & Urry, 1975:17) emphasis original.

The histroy of science is replete with examples of unobservable entities, marking a watershed in the evaluation of research methodology. Electrons, magnetic, electric and gravititional fields are the presumptive objects Hempel is talking about. The indifference curve approach to aspects of economic phenomena (consumer demand theory), is another case in point. Other spectacular developments on the theme if unobservables centre on the concept of comparative statics as theorized by Paul Samuelson. And the perfect competition model, useful only as analytical tool, falls neatly within the ambit of theoretical formulations.

An inductive researcher, who gathers data in order to generate universal generalizations, is handicapped in his analysis by sheer inadequacy of data drawn from sensory experience alone. Indeed, some scholars even question the reliability of observation as a traditional method of analysis. There is the claim that

> . . .sensory experience is somehow influenced by theoretical beliefs and expectations (Papineau, 1978: 28-29).

A lucid account of this shift-of-aspect phenomena is offered by Norwood Hanson, suggesting the theory-dependence of observation (Papineau, 1978:29).

In spite of these limiting factors, industrial studies are best conducted by initially making familiarization tours. These not only enable the researcher to secure general understanding of the industry, but also assists him to define the parameters for investigation.

The deductive approach consists of theory formulation and evaluation - the so-called hypothetico-deductive method (Keats & Urry, 1975:16). In its simplicity, the researcher begins by putting forward a postulate and then draws upon facts to elucidate its operation. Unlike the inductive thinker who reasons from the particular to the general, the deductive researcher enunciates generalizations and hopes to rationalize their validity by amassing relevant data.

In his book The Logic of Scientific Discovery, Karl Popper establishes himself as a foremost deductive thinker. He mercilessly assails induction as a method and argues for a reversal in the schema of scientific analysis (Popper, 1959:27). For Popper,

> . . .there is no 'logic of discovery' by which we can arrive at theories from observations. . . . it makes no sense simply to 'observe' without reference to any hypothesis which is being tested. For without such a theory, one does not know what to look for (Popper, 1959:16).

But a major drawback in the Popperian scheme is the speed with which a hypothesis is abandoned when it fails to meet the requirement of observation. This is the reason why Imre Lakatos expressed dismay when he said:

> Conjectures (are) boldly put forward for trial, to be eliminated if they clash with observation (Lakatos, 1978:141).

The testing of a hypothesis, according to Popper, proceeds by making potentially falsifying observations (Friedmann, 1984:214) and thereby discarding the pillar of analysis for lack of sufficient empirical evidence. This approach has been referred to as "naive methodological falsificationism" (Lakatos, 1978:31).

Such a swift abandonment of theory has been seriously contested especially by Imre Lakatos. He argues: Don't discard a hypothesis unless a better alternative is found. He describes his approach as "sophisticated methodological falsificationism". The tenor of his reasoning is eloquently summarized:

> The sophisticated falsificationist regards a scientific theory T as falsified if and only if another theory T^1 has been proposed with the following characteristics:
> (1) T^1 has excess (more) empirical content. .
> (2) T^1 explains the previous success of T, .
> (3) some of the excess empirical content T^1 is corroborated (Lakatos, 1978:32).

The present research exercise will not be confined to any one of the two major scientific approaches. On the one hand, construction of hypothesis and the testing thereof constitute an essential part of this paper. This falls neatly under the deductive scheme of scientific inquiry. On the other hand, the data gathered might well reveal important considerations that result in the formulation of other hypotheses. Unexpected revelations may bring to light new dimensions of the phenomenon. If this comes to pass, the gathering of facts may well lead to the germination of an initially unintended hypothesis. For when one discovers additional relationships in the accummulated data, the postulation that follows can only be described as an outcome of an inductive process. In the final analysis, therefore, both approaches will have been used.

The following hypothesis are examined:

Hypothesis 1

The waste-oil recycling industry operates at low rates of capacity utilization.

Hypothesis 2

Compared to the potential, low volumes of waste-oil are recycled annually.

Hypothesis 3

Restrictive business practices by multinational oil companies hinder Kenya's development of the waste-oil recycling industry.

CHAPTER THREE

WASTE-OIL RECYCLING IN KENYA

3.0 Introduction

Since the energy crises of 1973, oil importing countries have been prompted to seek alternative sources of energy. High oil prices triggered an interest in exploration and development of drilling capacity. Consumers were also compelled to use oil more efficiently. As such, governments are becoming increasingly concerned to conserve and utilize efficiently resource-wastes and in so doing to preven environmental pollution. One way of achieving conservation is to recycle waste-oil generated from imported virgin sources. Indeed, the disposal of waste-oil into the environment may pose grave polluti hazards. Recycling alleviates environmental deterioration, reduces dependence on imports of virgi base-oil, improves the balance of payments, and adds to the national product.

In Kenya, the recycling of waste-oil offers possibilities for resource conservation and reduction of import dependence. In fact, waste-oil can be re-used many times over thereby minimizing environmental degradation.

This chapter addresses the following issues:

(1) Generation, recovery and collection of waste-oil.

(2) Base-oil production and importation.

(3) The government's role in the establishment of the recycling industry.

(4) The impact of multinational oil companies on the growth of the Kenyan waste-oil industry.

(5) The role the government can play in influencing efficient collection and channelling of used oil to re-refining plants.

Recycling waste-oil has distinct economic advantages. For an oil importing country like Kenya, it saves foreign exchange, improves the balance of payments, minimizes resource waste, adds to net national income, lessens dependency on imports of lubricants, conserves resources and protects the environment.

The waste-oil recycling industry in Kenya comprises two re-refineries, both of which are located in the suburban areas of Nairobi. The industry has not experienced much expansion since its inception in the late 1970's. Some of the reasons that can be attributed to sluggish growth are: frustration by multinational oil companies; high costs of production; and absence of government incentives to encourage recycling.

The recycling industry in Kenya is presently profit motivated. Although issues of pollution are raised by governmental authorities, an enormous amount of waste-oil is still discharged into sewage systems and nearby waterways every year. The public decision to recycle depends largely on the government's participation in the management of waste-oil.

3.1 Technology

The Kenyan recycling industry uses acid/clay treatment and the distillation/clay processes. Refanoil Manufacturing Company Limited uses the latter technology. The acid/clay process yields acid sludge and spent-clay which pose grave environmental problems for Refanoil. The company discards the acid sludge into the oxidation pond next to the plant. The spent-clay is supplied to East African Portland Cement Company free of charge for incineration in their kilns.

Optimum Lubricants has no acid-sludge problems, but the spent-clay is supplied to the cement company in Athi River. Both these firms have not considered the possibility of recovering the clay for re-use. The imported clay (fullers earth) accounts for five per cent of production costs of base-oil. A significant amount of foreign exchange is used to secure the fullers earth from a German company, the Meinken Process FRG, who supplied the technology. The industry consumes roughly 60 tonnes annually, equivalent to 50,000 dollars.[1]

3.2 Total Capital Investment

Kenya at present has two re-refining plants, both of which are located a few miles from Nairobi. The largest is Optimum Lubricants Limited, situated in Kikuyu. Its fixed investments cost amounted to K40 million shillings. The plant can generate 2,500 tonnes of lubricants annually, and has nine full-time employees.

The other plant, almost half smaller in size, is Refanoil Manufacturing Company Limited. It is situated in Athi River, near Nairobi. It has a fixed investment cost of K18 million shillings and has capacity to produce 1,500 tonnes of lubricants annually. It employs eight full-time workers.

The distillation/clay process employed by Optimum Lubricants Limited is regarded as the most profitable and efficient, both in terms of high recovery rate and little wastage. However, the acid/clay technology adopted by Refanoil is the most widely used. In fact, 95 per cent of re-refineries in the United States are the acid/clay type (Maltezou, 1984:23).

3.3 Generation, Recovery and Collection of Waste-oil

Generation refers to the amount of waste-oil drained out of car and industrial engines. About 30,000 tonnes of lubricants are marketed in Kenya annually, and of these, 15,000 tonnes of waste-oil are generated. In countries like West Germany and Italy, about 40 per cent of generated waste-oil is recovered. Japan recovers about 34 per cent (Plastic Waste, Japan, 1985:36), while United States reclaims 40 per cent of generated oil. Nearer home, Zambia retrieves 16 - 18 per cent. Kenya, on the other hand, retrieves only 14 per cent. Therefore, compared to the potential (15,000 tonnes), low volumes of waste-oil are recycled annually (less than 2,000 tonnes), see Hypothesis 2, pg 51). The rest is dumped directly or indirectly into the environment. This is a massive waste of resources.

The Refanoil Manufacturing Company obtains its waste-oil feedstock from the Kenya Railways, with whom they have their biggest contract. Kenya Ports Authority and Cargo Handling Services have been other sources of waste-oil for Refanoil. The company has not explored links with the oil companies to collect used oil from gasoline service stations and garages. Esso, Caltex, Agip, Shell and Total acknowledged that no such attempts have been made. With regard to the possibility of marketing re-refined lubricants, the multinational oil companies flatly refused, some said that their business policy is to promote the company's products and not the products of others.[2]

Optimum Lubricants Limited also competed for the railway supply, though it continued to rely on independent collectors.[3] Mr. Kantaria, the proprietor, argued that waste-oil supply had never been a problem; the problem, he says, is the market since no independent petrol stations exist to sell its products.

Recyclers have not bothered to exploit other existing sources. What seems lacking is an efficiently organized system of recovery, collection and transportation. However, other sources need to be identified to facilitate operations. While the two recyclers compete for the railways contract because of the huge amounts the parastatal can generate yearly, other important sources exist.

Industrial sources generate an average of 16 per cent of total waste-oil in Kenya. Unfortunately, no estimates exist for the amount of waste-oil generated in Kenyan industries. The metal, rubber, plastics, machinery and transportation equipment industries in the country generate considerable amounts. These constitute important sources and therefore need to be exploited.

Automotive sources also generate waste-oil. These include service stations and garages. Automotive transportation organizations e.g. bus companies, can be potential sources of waste-oil. Big transporters like Murgian & Sons, Ba Yusuf Brothers, Mawingo Bus Services, Coast Bus Services, Goldline Services and Jogoo Kimakia have been important sources for the recyclers. The transport proprietors own big garages, petrol and gasoline stations where the drained waste oil is tapped. The waste stored in drums is collected when it reaches a truckload. It is then transported to the re-refining plants. About 1,000 tonnes are secured from these sources.

Other centres that need to be identified and examined include airport and marine sources. Unless close Nairobi sources are exhausted, marine sources will remain unexploited for some time to come.

According to estimates (see Table 3.1), marine sources generated the largest volumes of waste-oil in 1980 and 1981. The feasibility study prepared by Kenya Industrial Estates did not consider Mombasa as an appropriate location. In fact, it identified only the automotive sources in Nairobi, though mention was made of the industrial sources. Since the garages of most large transporters are headquarted in Nairobi, it was considered convenient to establish the plants near the automotive sources.

TABLE 3.1

Estimated Volumes of Waste-oil generated by various sources in Kenya

	TONNES	
	1980	1981
Industrial	2400	2400
Marine	3600	4800
Railway	38	25

Source: Author's estimates based on UNIDO (1985), assuming that 40% of the lubricating oils used can be collected.

3.4 Recycling within the PTA

The only countries within the PTA region that recycle waste-oil are Zimbabwe and Zambia. Shell Limited is the proprietor of the oil recycling plant in Zimbabwe. It is estimated that the collection rate in Zambia is 16 - 18 per cent (interview, Soares, 1985). The rate comes close to that estimated by the United States Environmental Agency for Developing Countries (see Appendix 3 (i)). The Zambian recycling plant has been operating for 18 years. It is the oldest within the PTA.

3.5 Base Oil Production and Importation

Kenya's recycling industry has an annual output capacity of 4,000 tonnes. This constitutes 13 per cent of total imports (see Appendix 3 (iii)). Actual production, however, is well below the break-even point. Optimum Lubricants would break-even at 43 per cent capacity utilization; Refanoil at 44 per cent (see Appendix 3 (ii)). Presently, Optimum operates at 25 per cent of capacity, while Refanoil operates at 24 per cent capacity. These are low rates of capacity utilization especially in view of the large amounts of waste-oil still being dumped into the environment (see hypothesis 1, pg 51).

Base-oil is imported directly by the multinational oil companies (Shell, BP, Esso, Caltex, Kobil, Agip, Total and Kenol). These virgin base stocks are then blended locally. Only four companies, Shell, Esso, Caltex and Kobil have blending equipment to process required grades of lubricants by mixing virgin stocks with additives and anti-oxidants. Total and Agip have processing agreements with Shell.

TABLE 3.2

Annual Production of Base Oil 1985

(Tonnes)

	Capacity Production	Actual Production	Capacity Utilization Percentage
Optimum Lubricants Limited	2,500	624	25
Refanoil Manufacturing Company Limited	1,500	360	24
Total	4,000	984	24.6

Source: Interviews with Companies, 1985.

TABLE 3.3

Lubricant Sales in Kenya, tons

	1975	1976	1977	1978	1979	1980	1981
Branded Motor Oils	14074	15315	16672	16211	17332	19005	13330
Unbranded Motor Oils	63	81	81	129	353	419	250
Industrial Oils	3590	3187	4001	4382	4818	5939	5936
Railway Oils	383	38	204	114	62	94	63
Marine Oils	961	1333	4397	9126	22288*	9062	11977
TOTAL	19071	19954	25355	29962	44853	34579	31566

Source: Kenya Statistical Abstract, 1984.

Average density of oil = 0.88 kg. 1 litre

*Abnormal number of ships re-fuelled at the Mombasa Port.

Note: The Kenya Statistical Abstract, 1985, gives only the totals of the above lubricants as follows:

1982	1983	1984
23425	23330	24226

Average lubricant sales (1978 - 1984) = 30,277 tons per year.

3.6 Marketing

Marketing difficulties have been part of the history of the waste-oil recycling industry. They emerge at three levels:

(a) allegations about the poor quality of their products

(b) unfair practices by Multinational Oil Companies

(c) pricing.

(a) Allegations about the poor quality of their products

The multinational oil companies allege that the waste-oil recyclers market poor quality products. They have also encouraged the use of car stickers stating,

> "Do not use CB, SB and re-refined oils." *

This has denied the recyclers some market-share for genuine products that meet international car manufacturers (engine) specifications.[4] For instance, the lubricants for Refanoil Manufacturing Company have satisfied the recommended specifications of Kenya Bureau of Standards and Kenya Industrial Research Development Institute.[5] Optimum Lubricants has managed to escape such severe market censure by using an international brand name Castrol, for which it pays royalties (two per cent of market sales).

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* CB and SB are multinational obsolete grades (lubricants) marketed in the 1940's and 1950's.

Lubricants are among the oldest products marketed locally. Surely, they should have been among the very first with national quality standards. Yet, ten years of Kenya Bureau of Standards (KBS) existence has still not witnessed the formulation of quality specifications for such a widely consumed oil product.

The KBS can only enforce standards if national quality formulations for specific products have been established. Since the lubricants market is not under regular KBS supervision, danger exists of obsolete grades being dumped in the market. As a result, consumers incur heavy costs through engine knocks, and faster wear and tear.

(b) The impact of Multinational Oil Companies on the development of the waste-oil recycling industry in Kenya

The multinational oil companies witnessed phenomenal growth in the post-war era. The oil business expanded rapidly accompanied by the growth of numerous small firms. These developments had the effect of changing the scope of the oil companies operations.

One change involved the desire to reduce fluctuations of the level of profits, the other to maintain a strong hold on the markets they controlled. Consequently, the multinational oil companies integrated forward in refining, transporting, marketing and distributing oil, thus shunning the riskier side of crude oil extraction to small entrepreneurs. It is this aspect of marketing and distribution that limits the Kenyan recyclers operations.

unclear

Controlling nearly all the distribution channels in the country, the multinational oil companies have blocked the sale of the recyclers oil products out of the gasoline stations in Kenya. Survey evidence showed that the petrol stations are the major distribution outlets for the products of multinational oil companies. These outlets are owned by the oil companies. In most cases, they are leased out to private management. Agip petrol stations, for instance, market only Agip products; Caltex, Shell and Total never sell each other's products. Infact, officials of the companies interviewed argued that their business policy was to promote the company's products. Since the waste-oil recyclers have no petrol stations of their own, product marketing is severely restricted. Optimum Lubricants Limited, for instance, relies on thirteen spare parts shops it owns in Nairobi, Mombasa and Kisumu to market its products. Refanoil Manufacturing Company, on the other hand, encounters even more severe marketing problems. It has no retail outlets. Both the waste-oil recyclers rely on obtaining contracts from Government Ministries and other big transporters. These contracts, however, are insufficient to maintain high rates of capacity utilization at their factories.

In addition to blocking waste-oil recyclers products, the multinational oil companies have refused to purchase base-oil from recyclers. Except for high-grade base-stocks, which the recyclers cannot supply, the oil companies could increase the capacity utilization rates of recyclers if base-oil stocks were secured from them. The multinational oil companies have therefore not only blocked the sale of waste-oil recyclers products, but also refused to purchase the raw material (base-stock) to blend lubricants locally (see hypothesis 3).

Various other methods have been used to frustrate the growth of the waste-oil recycling industry. For instance, the multinational oil companies have sometimes marketed cheap obsolete grades (Kenya Sunday Times, 22 December 1985) with low percentages of expensive additives thus incurring lower costs of production compared to re-refined lubricants.

The economics of recycling for the two firms are very promising. The break-even point for Refanoil is 55 tonnes a month equivalent to 44 per cent capacity utilization; Optimum Lubricants breaks even at 98 tonnes a month equivalent to 43 per cent capacity utilization. But because the mulatinational oil companies are blocking the sale of their products, the recyclers are not breaking even. These unfair business practices can only be countered by Government intervention.

(c) Pricing

A five litre DSAE 30 or DSAE 40 (HD) grades* (see Appendix 3(iv)) sells between KShs. 90 - 125. The high cost results from additional concentrations of additives that increase the total base number (TBN) i.e. the alkalinity level of oil to prevent acid formation in engines. In order to sell DSAE 30 or 40 (HD) grades, Refanoil has to drop its price to KShs. 85. Its high grade, good quality oil is cheaper than some multinationals' obsolete, low quality oils which sell at KShs. 90 - 125 range.

Although multinational oil companies market lubricants with particular grades specified on the container, significant differences exist in total base number for equivalent HD and HB grades. For instance, Refanoil DSAE 40 grade is equivalent to Shell's Rotella 5X40 and Caltex's RPM Dello 200 30 (see Appendix 3(iv)). But the total base number (TBN) differs for the equivalent grades as indicated in Table 3.4.

* HD - Heavy Duty
DSAE - Society of Automobile Engineers

NB Rotella 5 x 40 or RPM Dello 20030 are brand names for the respective multinational oil companies. Also, while HD means heavy duty, HB refers to the earliest grade marketed in 1940's and 1950's.

TABLE 3.4

Comparison of Equivalent Heavy Duty (HD) grades of lubricating oils from Refanoil, Caltex and Shell.

	Brand name	Total Base Number (TBN)
Refanoil	DSAE 40	7.8
Caltex	RPM Dello 100 30	5.0
Shell	Rotella 5X40	7.0

Source: Kirdi Report, 6/6/85 Laboratory Report No. 7772, A guide to Shell Lubricants, February 1980; Caltex Production Guide, 1983.

TABLE 3.5

Comparisons of Equivalent HB grade of lubricants from Shell and Caltex.

	TOTAL BASE NUMBER (TBN)
Shell	4.3
Caltex	3.0

Source: A guide to Shell Lubricants, February 1980,
Caltex Production Guide, 1983.

Furthermore, evidence shows that the multinational oil companies continue to market low grade products (see Table 3.5). Even with these low grades, significant differences exist in total base number for the equivalent HB grade between the multinationals.

The above obsolete grades are equivalent to S130 and S140 which Refanoil does not market. In fact, the multinational oil companies market the obsolete grades which compete with high quality grades of Refanoil. Their prices run well below KShs. 85 the lowest Refanoil can offer.

3.7 Exports

The export market provided a potential source of revenue. Optimum Lubricants exported to neighbouring Rwanda and Burundi, successfully securing markets against international competitors. Approximately 100 tonnes were exported between 1982 and the first half of 1984. It stopped exports because of bureaucratic obstacles connected with the export compensation scheme.

3.8 The role the government played in establishing the recycling industry

The first re-refining project proposal was submitted to the Government for consideration in August 1977 by Pefanoil Manufacturing Company Limited, a private firm with a minority foreign shareholding. Approval of the project was communicated to the company; the decision was documented in a Kenya Industrial Estates Paper No. 285 of 1979. The cost of the project then was estimated at K Shs. 5 million, though this increased to K Shs. 18 million just before the plant commenced production (June 1984). Machinery and technical assistance were supplied by Eskeyar Engineering Company of India, with 80 per cent of the machinery and equipment fabricated locally.

The idea of establishing a recycling industry was initiated by the Kenya Industrial Estates (KIE). Several prospective candidates applied, including Optimum Lubricants, Refanoil and Nairobi Oil Products.

Refanoil was given the go ahead by K.I.E. with the understanding that any would-be investors would be stopped from venturing into a similar project in the next five years. (Ministry of Industry, letter dated 19/2/1980). Peter Karanja was the sole owner of Refanoil in 1979. After running into financial problems, he approached Low and Bonar (E.A.) Limited, a multinational based in Nairobi to sell the plant. Bonar bought 36 per cent of the shares while Mr. Karundito acquired the rest.

In 1981, an Austrian company, Austroplan, was involved in the construction of a waste-oil refinery at Kikuyu. Refanoil protested bitterly, arguing that the New Projects Committee had given assurances that no other plans would be approved.

Refanoil argued that this was a breach of contract and filed a suit for damages against KIE worth KShs. 12 million. Nothing more was heard about the suit.

Refanoil pointed out that on the basis of their feasibility study, only one project would be viable because a 1,500 tonne plant would require most of the local used oil. This is not true. Potentially, 15,000 tonnes of waste-oil is generated annually (see Appendix 3(iv)).

This example demonstrates that independent feasibility studies are necessary if the government (through its ministries) is to avoid costly mistakes. On the basis of such studies, it can furnish concrete assurances to investors that no other plants will be allowed to operate in so many years. Unfortunately, for waste-oil recycling, decisions were made without adequate study and consultation.

3.9 Incentive structure to encourage recycling

The Kenyan Government can play a crucial role in influencing efficient collection and channelling of used oil to re-refining plants. What is needed in this area is a comprehensive policy regulating collection and disposal of the used oil.

First, the government could conduct mass publicity campaigns on the environmentally damaging aspects of pouring waste-oil into municipal sewers and river streams. Bumper car stickers, national announcements on radio and television and posters at receiving centres can have an impact on motorists, especially those who change oil in their own cars.[6]

Labelling can serve to rouse motorists' conscience. In the United States, the <u>Used Oil Recycling Act</u> insists on the following label, prominently displayed on the lubricant container:

> Don't pollute - Conserve Resources.
> Return used oil to collection centres.

In addition to raising the national awareness the media must make known the whereabouts of used-oil receiving facilities for motorists and industries. Urban councils should secure containers from the recyclers while assisting the latter in locating convenient sites.

Since indiscriminate dumping is deleterious for the ecosystem, the government can formulate legislation penalizing motorists who improperly dispose waste-oil.

To encourage recycling, sales tax on re-refined lubricants should be reduced. Further, the government can exempt certain volumes of virgin base stocks from taxation as long as the marketed lubricating oil is a mixture of virgin and re-refined base stocks (Bowman, 1982:87). For instance, if the virgin base stocks do not exceed 60 per cent of the blended mixture, then say 40 per cent of imports can be exempted from excise duty. With this arrangement, the multinational oil companies could be encouraged to use recycled oil. Subsidies for re-refiners may also serve as an incentive serving as a bonus to an industry that minimizing environmental pollution.

CHAPTER FOUR

FURFURAL PRODUCTION IN KENYA

4.0 Introduction

The development of the waste-products industry is one of the most spectacular, though nascent, aspects of economic life in Kenya. The desire to increasingly manufacture products from waste resources arose not only from the need to conserve and efficiently dispose resources, but also transform waste into a big source of revenue. Although use of waste products is relatively underdeveloped in Kenya, there exists no clear policy drive to change the situation.

Kenya's attempts to utilize waste products have had only limited success. In general, seemingly promising projects floundered even before production commenced. This case study is devoted to examining the various forces that led to the collapse of a waste-product utilization project in Kenya, the Kenya Furfural Company Limited. The analysis will first focus on the historical background of the company, followed by a brief description of the technology it employed in the production process. The economics of furfural production will also be explored. Finally, a thorough treatment of lessons from this disappointing industrial experience will be drawn.

4.1 Historical Background

The Kenya Furfural Company Limited was initiated in December 1976 after the government's decision to accept proposals put forward in a feasibility study prepared by the Guiness Peat Group, London. The investment agreement was signed in January 1977.

The project would utilize maize-cobs as basic feedstock to produce 5,000 tonnes of furfural, 3,000 tonnes of acetic acid, and 300 tonnes of formic acid. Eldoret was chosen as the site for the plant for two decisive reasons. It is located in the main maize growing zone in Kenya; and it has good infrastructural facilities, including road and rail links to Nairobi and Mombasa.

The furfural project was financed by the Government of Kenya, Agricultural Development Corporation, Development Finance Company of Kenya, Industrial Development Bank, European Investment Bank, Kale-Agro Industries and the technical partners. There were three technical partners in the project.

(i) The Guiness Peat Group, which was responsible for the formation of a joint venture company, to build and operate the furfural company, and provide marketing and financial assistance.

(ii) Escher Wyss (Sulzer Brothers), was responsible for the provision of furfural technology, technical assistance, training of key personnel, factory start-up and commissioning assistance to Foster Wheeler Company.

(iii) Foster Wheeler which was responsible for: design, erection and supply of all items pertaining to the plant, including design of site layout, the factory and its buildings; the commissioning and start-up of plant to guaranteed standards.

The Guiness Peat Group is a multinational company with worldwide experience in banking, processing and marketing. It was responsible for marketing policy and strategy. As such, the Kenyan output of 5,000 tonnes of furfural per year had already been assured 3.8 per cent of the international market (Guiness Peat Group, Feasibility Study, 1976:19). Likewise the raw material supplies were considered and no bottlenecks were anticipated. This being the case, the Guiness Peat Group would have been expected to concentrate more on the management of the factory, performance, production, costs, product quality and output reliability in order to realize maximum contribution to the Kenyan economy.

4.2 Total investment costs

The total investment costs for the Kenyan project was K350 million shillings. This figure included pre-operating costs, early development costs, technology, plant machinery and equipment.

4.3 Production economics

The economics of production are considered under the following subheadings:

(a) the cost of raw material

(b) cost of steam

(c) cob collection and delivery.

The cost of raw material

The average cost per tonne of maize cobs was estimated to be K235 shillings.* At this price, the cost of raw materials accounted for 25 per cent of total variable costs. An efficient system of collection and delivery was necessary.

Still, cost contribution of raw materials to total variable cost is low in Kenya compared to elsewhere. UNCTAD/GATT (1979) estimates the percentage contribution of raw material at 32 per cent. Higher costs can arise in places where the raw material is in competitive demand.

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* Receivers' Report, 1982.

In Western Kenya, the maize cobs were burnt or left to rot in the fields. Serious alternatives did not exist and therefore the price of maize cobs was not influenced by other uses to which the agro-industrial waste could have been put.

In November 1979, the government announced an increase in the price of maize to K80 shillings per bag. This measure was to induce farmers to grow more maize. Consequently, the farmers would earn additional incomes not only from increased acreage, but also from the sale of additional maize-cobs.

According to the feasibility study (1976), the cost of a tonne of maize-cobs was estimated to be K96 shillings. The discrepancy between the study and the Receivers report on this score is considerable. The latter estimated a tonne at K235 shillings. On this core alone, the project was undercosted.

Cost of steam

According to a Ministry of Energy Report, some 40,000 - 60,000 tonnes of bagasse could be made available as surplus from two sugar factories (Kenya Government, 1983:33). Thampoe Jeyansingham, a UNIDO expert, estimates that a tonne of damp bagasse can generate 2.3 tonnes of steam (Jeyansingham, 1985, Part III). The available 60,000 tonnes of surplus bagasse could therefore have generated 138,000 tonnes of steam, thereby reducing steam costs considerably.

The integration of a furfural plant to an existing industrial complex was a subject omitted altogether in the feasibility report prepared by the Guiness Peat Group. This meant that expensive equipment for steam generation had to be installed. Yet, the maize and sugarcane growing zones criss-cross each other. By establishing the plant near a sugar mill, say Mumias, investment costs could have been reduced.

Cobs availability

For the Kenyan plant, the basic feedstock was maize-cobs. About 50,000 to 60,000 tonnes of cobs were required annually to generate 5,000 tonnes of furfural. This is roughly equivalent to 260,000 tonnes of a maize harvest. By 1982, Kenya was already producing twice the yield needed for the plant (see Table 4.1). Therefore, with regard to raw material requirements, no problems were foreseen by the company.[1]

TABLE 4.1

Kenya's Maize Production ('000 metric tonnes)

Year	Grain (tonnes)
1977	424.0
1978	236.3
1979	241.7
1980	217.9
1981	472.9
1982	571.3

Source: Kenya's Statistical Abstract, 1984, pg 100.

Cob collection and delivery

At full capacity, the Eldoret plant would have required 65,000 tonnes of maize cobs collected from the Kitale-Eldoret-Bungoma triangle during 120 days of the year.

When the factory started production in late 1980, it became obvious that the rail transport proposed by the feasibility study was too expensive. So the management relied on hired vehicles and outside transporters since the company had few vehicles of its own. To overcome this problem, the company purchased a fleet of six tractors and twelve trailers to collect maize-cobs from established collection depots.

The purchase of tractors and trailers was not included in the feasibility study. The purchase was merely a reaction to the excessive cost of rail transport. To some extent, the company's liquidity problems can be traced to such unplanned for expenditures.

In all, ten collection depots existed at Kongoni, Kimilili and Kitale. The raw material was delivered at the Eldoret site straight onto the conveyor.

Storage facilities allowed for a buffer stock of 15,000 tonnes. From the conveyor, the cobs passed a magnet that trapped iron particles before they proceeded to the cob crusher.

4.4 Technology

The Kenyan plant at Eldoret used the Escher Wyss process based on hydrolysis, secondary steam generation, furfural distillation and acetic acid extraction. A brief description of the Escher Wyss process is given in Appendix 4(i).

4.5 Marketing

The Quaker Oats Company of the United States controls about 70 per cent of the world market for furfural. Kenya was to capture four per cent of the world market. Although the main market for the Kenyan product was to be Western Europe, most ended up in the Middle East and the Far East. The product was to fetch a price of US $1,000 per tonne or US $30 less than the world price at the time of the feasibility study (1976).

About 70 per cent of the world production of furfural is converted by hydrogenation into furfural alcohol. It was projected that though the demand for furfural would remain virtually static, the demand for furfural alcohol would grow by 3 - 5 per cent in the 1980's. The partners agreed that all the furfural produced in Kenya would be bought by the Guiness Peat Group which would arrange for hydrogenation into furfural alcohol in Europe.

The acetic and formic acids from the project were to be marketed locally, though most were to be exported to neighbouring East African countries.

At full production, 3,000 tonnes of acetic acid and 300 tonnes of formic acid were to be produced. Twiga Chemicals Industries Limited had agreed to distribute and market the acids in Kenya and outside. Appendix 4(iv) shows some of the potential consumers of formic acid; Appendix 4(v) indicates the targeted consumers of acetic acid as identified by the Twiga Chemicals Industries Limited.

4.6 Factors that led to the collapse of the furfural project in Kenya

Like most modern enterprises, the primary goal of the Kenya Furfural Company was the long-run maximization of profit with the minimization of risk. But the minimization of risk, and in particular the risk of failure, involves countering potential blows to an enterprise while still in infancy.

The failure of the Kenyan furfural project can be attributed to several factors, some of which were even apparent when the project was still in embryo. This section discusses the following issues:

(a) shortcomings of the feasibility study

(b) structure of finance

(c) delays and poor design of delivered equipment.

4.7 The shortcomings of the feasibility study

The capital and pre-operating budget for the Kenya Furfural Company was based on estimates and projections compiled by the Guiness Peat Group, London. These were contained in the feasibility study. Though covering many aspects related to the project, it was not comprehensive enough. It failed to consider factors that were ultimately responsible for unbudgeted expenditure (Kenya Furfural Company, letter, October 1977), such as:

(a) effluent treatment plant
(b) residue processing equipment (briquetting unit)
(c) workshop.

Furthermore, certain industrial regulations were not considered. Kenyan regulations and operating conditions necessitated additional equipment and operating costs not covered in the original report. These included electricity distribution, cob collection, and effluent discharge and treatment.

According to the feasibility study, the Kenyan project was to cost K170 million shillings. By October 1977, two years before it was expected to come on stream, the Kenya Furfural Company had exceeded this by K70 million shillings (see Appendix 4(vi)).

In November 1979, an additional KShs. 30 million were required to finance unbudgeted capital expenditures (see Appendix 4(vii)). The experience of 1978/79 harvesting season indicated that the proposed methods of cob collection incurred greater costs than had been anticipated. It was agreed that an additional fleet of 18 tractors and 36 trailers would be ordered by January 1980 supplementing the company's existing transport (see Appendix 4(viii)).

Exchange-rate fluctuations were not considered in the feasibility study. In a space of nine months, the Kenyan currency changed from 9.4 to 10.5 against the dollar. A shortage of KShs. 2.4 million was created. It is difficult to estimate the precise impact of exchange-rate fluctuations (almost never constant). Suffice it to say that fluctuations do affect budget expenditures (Weston & Brigham, 1982: 1011).

An indepedent pre-feasibility study prepared for the Ministry of Commerce and Industry in 1975 to produce 5,000 tonnes of furfural show wide disparities compared to the Guiness Peat Group report. In November 1975, the plant cost was estimated to be KShs 36 million. In August 1976, just ten months later, the Guiness Peat Group put the plant cost at KShs. 68 million. During the two periods, the price of furfural remained fixed at 1030 US dollars. While the Ministry's report considered a company's own fleet of trailers and trucks, the Guiness' study opted for the expensive rail transport. An interesting aspect of the Ministry's report, however, appears in the projected cash flow statement. It reflected no cash problems for a prospective manufacturer.

A further aspect of the Ministry's report is capacity utilization. Production was expected to be 70 per cent capacity in the first year, 90 per cent capacity in the second year, and 100 per cent capacity in the third and subsequent years. In contrast, the Guiness report indicated 50 per cent production in the first, 80 per cent capacity in the second, and 100 per cent capacity in the third and subsequent years. These differences are finally reflected in sales and show disparities in revenue.

Finally, the Ministry's pre-feasibility report shows a low gearing ratio in its financial structure. Loan capital was just about 30 per cent of equity, with the bank overdraft roughly 6 per cent of equity.

Drastic differences clearly existed between the two feasibility reports.

4.8 Liquidity problems

The importance of liquidity and working capital for a firm arises from the fact that most operations are financed on a day-to-day basis.

Many decisions related to continued operations or closures of firms have centred around the condition of working capital. The strength or weakness of the latter reflects on a firm's ability or inability to meet its current obligations.

The cash flow statement revealed severe financial constraints. The cash flow problem peaked in the second year, then declined to US $576 (see Table 4.3). Such a poor cash record forebode ill for the plant. It was an indication of worst things to come.

Tables 4.3 and 4.4 provide clear evidence of working capital and cash flow problems. The starred figures in brackets in Table 4.4 show working capital constraints during the first two years. Production capacity during the first and second years is 50 per cent and 80 per cent respectively. At 100 per cent production (i.e. 5,000 tonnes of furfural a year), working capital showed some improvement (third year). Despite this, the study did not volunteer to explain how these problems would be overcome. Worse still, it did not provide measures that would tide the project over during these early years.

TABLE 4. 2

Financial structure and projected total capital requirements, 1976.

Equity		KSHS. MILLION
Kenya Government Agencies and local private investors	26.21	
Foreign investors	15.79	
		42.00
Loan Capital		
Buyer credit repayable 7 years after commissioning at 8% and long-term loans repayable over 12 years at 6½% with a 2-year repayment moratorium		97.44
Working Capital		
To be provided by Bank Overdraft (maximum in Year 2)		29.82
Total capital requirement		169.26

Source: Feasibility study, Guiness Peat Group, London, pg 27.

TABLE 4.3 - Feasibility Study Cash Flow ($'000)

Year/cash inflow	0	1		3	4	5
		(636)	([illegible] 20)	(3292)	2667	1141
Share capital	5000	-	-	-	-	-
Loan capital	11600	-	-	-	-	-
Sales gross revenue	-	1850	[illegible]76	6241	6825	6825
10% export incentive	-	27	38	497	591	591
	16600	1241	2[illegible]94	3446	4749	6275
<u>Cash outflow</u>						
Fixed Assets	16092	-				
Pre-startup expenses	717	-				
Cost of sales (excluding interest and depreciation)	-	2062	[illegible]38	3865	3865	3865
Loan repayments	-	774	[illegible]92	1392	1392	1392
Loan interest	418	820	[illegible]48	647	544	442
Overdraft interest @ 8½%	9	205	[illegible]8	209	89	Nil
Net cash flow	(636)	(2620)	([illegible]2)	(2667)	(1141)	(576)

TABLE 4.4 - Feasibility Study Projected Balance Sheet ($'000)

Year/Assets	0	1	2	3	4	5
Fixed Assets	16092	16092	16092	16092	16092	16092
Depreciation	-	(823)	(2060)	(3573)	(5086)	(6599)
Pre-startup expenditure	1144	581	436	291	146	-
	17236	15850	14468	12810	11152	9493
Working capital						
Debtors, stocks, overdraft, cash	(636)*	(988)*	(751)*	525	2024	3715
	16600	14862	13717	13335	13176	13208
Long term loans	(11600)	(10826)	(9434)	(8042)	(6650)	(5258)
Net Assets	5000	4036	4283	5293	6526	7950

Source: Feasibility Study, 1976, pg 70.

* Working capital in the Red.

The Kenya Furfural Company faced an acute dilemma over working capital and cash flows. A serious shortcoming of the feasibility study is that despite projections showing poor working capital and cash flows, nowhere did it suggest measures of financing the firm's short-term financial obligations. The working capital was in the red even after taking into consideration the overdraft facility. And if the feasibility study were to suggest that cash flow and working capital problems were to be overcome by additional short-term finance, this would have driven the company further into the mire, increasing the cost of borrowing as a result. In fact, the company did seek further financial assistance through loans and overdraft facilities. By doing so, it put itself in greater risks.

4.9 The financial structure

The financial or capital structure refers to the composition and size of long-term sources of finance, such as equity and loan capital. A sub-optimal capital structure can easily generate unmanageable problems for a company. An optimum capital structure refers to the composition of finance such that payments of principal, interest, and dividends impose the least cost to a firm. Firms that do not plan for an optimum capital structure may flourish in the short-run, but there is always the danger of failing to maximize the use of funds and show adaptability under changing conditions.

For the Kenya Furfural Company, the mode of financing included equity and loans with heavy Government participation. The composition of finance reflected a sub-optimal allocation of resources. Equity accounted for only 22 per cent; the rest of the project was financed by loans. Foreign loans accounted for 72 per cent of loan financed capital (see Appendix 4(vii)). The loans were made available in dollars and were to be serviced in dollars. Between 1976 and 1986, the dollar in the international market appreciated by nearly 100 per cent (8.4 to 16.5) against the Kenya Shilling. Since the project floundered in 1982, eighteen months after commencing production, only a small proportion of the prinicpal has been serviced. Assuming an outstanding loan of a 100 million Kenya Shillings, the appreciation of the dollar raised the principal to 200 million Kenya Shillings. In effect, the doubling in the value of the dollar has virtually doubled the amount of the principal.

Kenya will therefore have to dig deeper into its foreign exchange pocket to pay foreign loans.

In short, high gearing ratios become a source of potential trouble for a firm, much more so if the share of loan capital is foreign and therefore responsive to exchange rate fluctuations.

The fast pay-back schedules further aggravated the poor working capital and cash flow situation. The feasibility study envisaged payments as early as the second year, a time when the company was expected to consolidate itself. Servicing the principal and interest so early meant weakening the company's financial base.

The agreement between Kenya Furfural Company and Lewis & Peat (Chemicals) Limited left the company with little room for manouvre to consolidate its financial position. Firstly, a fixed fee of K1.11 million shillings was to be paid quarterly in London, with the amount payable being gradually reduced after two years to K0.74 million shillings. Secondly, a commission fee of three per cent from sales also be paid in London. Thirdly, a payment of five per cent of gross profits in US dollars was again to be made in London. Fourthly, the managers (Lewis & Peat) were to receive KShs. 0.74 million yearly in arrears as the plant construction was still under way. In the event of failure to meet these obligations, the managers could terminate the agreement on 30 days notice.

With such stringent terms of payments for a company with poor working capital and cash flows, it is not surprising that the financial status of the company worsened. The cumulative impact of these factors was to drive the firm readily into receivership.

4.10 The break-even point

Survey evidence indicates that furfural production is an extremely cost-sensitive project. Firstly, the price of furfural in the world market is relatively fixed having changed by only 6 per cent between 1976 and 1982. This being the case, any cost buildup will erode or cut deep into the sales revenue. Secondly, the break-even mark for the project occurs at 82 per cent capacity utilization (see Appendix 4(ix)). During the eighteen months of production, an estimated 1,000 tonnes were to be generated. But looking at the 1982 profit and loss account prepared by a distinguished multinational auditing firm, only 400 tonnes were produced. This constituted only five per cent capacity utilization!

In view of the evidence, it is clear that the feasibility study was not comprehensive. The furfural project was under-costed, while the projections of poor working capital and liquidity should have dissuaded the Government from too readily accepting the study's proposals.

4.11 Late deliveries

The late delivery of equipment was perhaps the single most important reason that led to delays in start-up of the plant. By the terms of the investment agreement dated 21st January 1977, the technical partners undertook to

> ... arrange completion and start-up of the plant in the shortest practicable time ... and to ensure all plant and equipemnt is new with the necessary guarantee.[2]

This ambiguous clause did not specify probable delivery dates. However, when the agreement was signed in May 1977, one of the technical partners, the Sultzer Brothers (UK), undertook to deliver equipment between 14 and 19 months after the effective date of contract. This did not materialise. The suppliers argued that industrial strikes by road transport drivers and railways in the United Kingdom in 1977/78 were responsible for the delays. The Kenya Furfural Company stated that the suppliers failed to honour their obligation and were therefore liable for damages, since late deliveries had the effect of extending the plant's commissioning period. Delays in the plant's start-up generated additional cost build-up. The management fee, according to the investment agreement, was to be five per cent of fixed capital and pre-operating costs. Hence, any cost-overuns would entail larger payments of management costs.

As such, extensions coupled with delays in start-up were beneficial to the foreign management team (see Appendix 4(xii)). The problem of covering the cost of delays was aggravated since loan repayments fell due before the factory was able to generate sufficient revenue through sales to cover these instalments. The cost of delays included: increased financial charges; increased pre-operating expenditure, including project management cost; increased site costs e.g. daily allowances to contractors; increased cost of infrastructure and raw materials.

Claims for damages by the Guiness Peat Group on behalf of the Kenya Furfural Company were countered by Sultzer Brothers who invoked the legal principle that a "force majeure" had made fulfiment of the contract impossible. Moreover, the Sultzer Brothers threatened to withdraw all future cooperation over spare parts and technical assistance unless the company was willing to appreciate the circumstances for the delays (Kenya Furfural Company, letter, 20/11/1981).

4.12 Poor designs and mis-specifications

The problem of late deliveries was further compounded by technical failings of the delivered equipment. Clause two of the investment agreement reads as follows:

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> Lewis & Peat, Foster Wheeler and Escher Wyss (the technical partners) have taken all possible steps to ensure their proposals are sound including the technical efficiency of the plant guaranteed by Escher Wyss. (emphasis mine).

The frequent breakdown of the crushing unit and related parts revealed serious technical faults of the plant's equipment caused by several factors including initial mis-specifications or poor designs (Table 4.5) e.g. single fuel boiler, pneumatic conveyors and crushing plant; insufficient supervision during repair work; and insufficient mechanical supervision.

The delays in deliveries and constant breakdowns in equipment increased the costs of supplier supervision over the extended period of commissioning (Kenya Furfural Company, letter, 13/11/1980). Extra costs were also incurred for repair and over-time work.

Technical problems such as those mentioned were not peculiar to the Kenyan plant. Escher Wyss Limited was also commissioned to install plants in Turkey and Hungary. The Hungarian plant occasionally ran into similar technical problems with the crusher (Kenya Furfural Company, letter, 13/10/1981). A Sulzer Brothers (UK) representative assured the managers that the Kenyan plant was designed to eliminate the technical problems experienced in Turkey (Kenya Furfural

Company, letter, 22/5/1980) - an obvious admission to technical failings of the Escher Wyss equipment.

TABLE 4.5

Design Errors and Equipment mis-specifications

(a) Crushing plant
(b) Fuel Handling Conveyor
(c) Secondary Steam drum
(d) Heat exchanger
(e) 5 pumps in distillation section
(f) Small bore pipes
(g) Process tower.

Source: Company file, letter 3/11/1980, pg 6.

NB Correcting errors in design and mis-specifications incurred costs in time and materials. The breakdown of critical items due to design errors prevented progress of work and delayed completion of project.

4.13 The final decision: receivership and shut down

By June 1982, the Kenya Furfural Company was a debtor in grave financial difficulties. Since operations began early in January 1981, it had sold only 400 tonnes of furfural. The sales revenue was just enough to pay the principal. Consequently, the company was declared insolvent and went into receivership in June 1982.

In retrospect, the crucial factors that drove the company into receivership are:

(1) lack of finance to run its day-to-day operations

(2) inability to service loan and interest payments.

To meet its heavy financial obligations to creditors, the plant had to break-even at 82 per cent capacity utilization. But if interest payments and depreciation were excluded, the break-even point would have been at 30 per cent capacity utilization (see Appendix 4(x) and 4(xi)). Under such circumstances, a compromise solution would have been to force the creditors into equity thereby discharging the debtor from any further liability. Only such drastic approach would have made the company's operations viable, allowing it more time to re-organize its lines of production and improve its working capital.

CHAPTER FIVE

5.0 Conclusions and Recommendations

Resource-waste recovery is crucial for mankind. Technological developments, population growth and increased industrial production have resulted in a sharp rise in waste generation. The disposal of wastes, however, has presented serious financial and management problems. Improper disposal creates health hazards, pollution of the environment, and resource waste. In this respect, waste disposal has generated widespread concern, calling for the salvaging and re-use resource-wastes by adopting economically viable waste disposal practices.

This has been the focus of the present study. It emphasizes the need to recycle wastes rather than to treat them. In this respect,the pollution control institutions must establish laws that emphasize recycling rather than treatment. If rationally conceived, recycling activities can provide many jobs and conserve Kenya's resources.

Resource conservation and environmental protection require a powerful enforcing agency. Since indiscriminate disposal of waste products leads to wastage of resources and environmental pollution, the Kenyan government should lead in stimulating interest and effecting programmes for waste product utilization. The case studies provide insights on how this can be done.

Unfair business practices by multinational oil companies have frustrated the growth of the waste-oil recyclers. The oil companies have used their dominant economic and market power to deny re-refiners access to the principal distribution points e.g. petrol stations and garages. Recognizing the social, economic and environmental benefits, the government ought to formulate policies to counter undesirable commercial practices such as unfair pricing and misleading information to consumers.

Fortunately, the government has realised that, in many cases, the Kenyan markets are not competitive, and that monopolistic and unfair practices constitute part of market distortion. Though no comprehensive legislation exists to curb such practices, the government is proposing the formation of a Prices and Monopolies Commission responsible for the promotion of a competitive environment and prohibition of such commercial restraints (Kenya Government Sessional Paper No. 1, 1986:100). Its early establishment is urgent.

The four main types of waste-oil recycling technologies have different recovery rates and consequently, varying pollution implications. Technological choice is therefore crucial in minimizing pollution. The two technologies used in Kenya are not among the best; the decision to recycle waste-oil was private, and not public. In the choice of technology therefore, we need to consider the environmental impacts.

The furfural project shows that fast payback schedulcles with short grace periods can easily erode the financial base of a firm. Stringent terms of payments further aggravate poor working capital and cash flows. Arrangements to delay payments must always be considered to give new investments time to mature.

A good financial structure allows adaptability during changing conditions. High gearing ratios may become a source of potential difficulties, especially if a large proportion of the loan is foreign financed which implies heavy risk of exchange-rate fluctuations.

The Covernment should bargain strongly against foreign financed projects with high gearing ratios. The Government must provide more equity participation in joint ventures. These incur less interest costs.

Government intervention to secure foreign finance on behalf of private investors has generated big difficulties. For a number of privately-owned enterprises, the Government has served as a guarantor to facilitate the procurement of loans. But when the projects collapse, the foreign financiers have held the Government accountable. The failure of private projects transfer the burden of servicing foreign loans to the public. Presently, the Government is servicing loans of at least two other dead private investments: the Mollasses Complex in Kisumu (capital invested KShs. 1.2 billion) and the Polyster Fibre Staple and Filament Project in

Nanyuki (capital invested KShs. 400 million). The Government has to be more careful in its dealings with foreign private investors.

The furfural case study reveals a lack of a broad-based sectoral investment planning to establish and expand industrial complexes. The establishment of complexes may generate substantial economies of scale through the sharing of utility inputs .e.g. electrical power, steam; common ancillary processes; and overheads. Moreover, the Government should ensure an independent evaluation of feasibility studies to avoid serious problems arising from deficiencies as happened in the furfural case. The Government must ascertain that the contents reflect reality.

A major cost in the production of furfural is steam. Yet, instead of integrating the plant to an existing sugar mill, the furfural project was conceived in isolation from existing industrial complexes. An opportunity to cut overheads and reduce operating costs was missed. This is a common error in the design of industrial projects in Kenya, where new investments are not linked to existing facilities.

More generally, to overcome the problems associated with waste-product utilization in Kenya, the Government should:

(a) develop an incentive structure to accelerate the development of waste-oil recycling industry and overcome the frustrating marketing tactics of multinational oil companies.

(b) increase its involvement in the independent evaluation of feasibility studies to avoid serious shortcomings and deficiencies in state-sponsored projects.

(c) enter agreements with private foreign investors to share risks and accountability in the event of projects collapsing.

Finally, further research should be conducted on all aspects of resource wastes: collection, storage, processing, salvaging and utilization.

Technological and industrial progress have generated immense benefits and economic opportunities for mankind. But these have been accompanied by growth of wastes and an increase in environmental pollution. As Winston Churchill said many years ago:

> "It would be a tragedy if the sunrise of technology were to be the sunset of mankind".

END-NOTES

Chapter 2

1. The following reactions summarize the production of chemical substances through the leblanc leblanc and Weldon processes:

   (a) Sodium Chloride + Sulphuric acid → Sodium Sulphate + Hydrogen Chloride (gas).

   (b) Hydrogen Chloride (acid) + Manganese dioxide → Manganese Chloride + Chlorine (gas) + water.

   (c) Slaked lime + Chlorine → Bleaching powder.

2. There was, indeed, much public hue and cry. The obnoxious gases were responsible for devastation of the countryside. Note the following observation:

   > . . .A great cloud of smoke hangs continually over the town, and choking fumes assail the nose from various works. In the face of such an atmosphere it is not to be wondered at that trees and other green things refuse to grow (Campbell, 1971:39).

3. The reactions showing sulphur recovery are as follows:

   (a) Calcium Sulphide + water + Carbon dioxide → Calcium Carbonate + Hydrogen sulphide.

   (b) Hydrogen sulphide + Oxygen → water + sulphur

4. Manganese was recovered in the form of Manganese dioxide.

   (a) Manganese chloride + Calcium Hydroxide → Manganese Hydroxide + Calcium chloride.

   (b) Manganese Hydroxide + Oxygen → Manganese dioxide + water.

5. Fixer solutions are homogeneous mixtures containing either sodium thiosulphate or ammonium thiosulphate in water. They are used to wash away the unaffected silver halide (the photo-sensitive layer) remaining after development, leaving the latent image on the negative intact.

Chapter 3

1. The clay can be recovered by heating the waste-clay to temperatures above 1000^{oC} This apparently is not being done in Kenya.

2. Confidentiality requested. Interviewed Esso, Shell, Caltex and Agip.

3. Some foul play was discovered. Drums with waste-oil contained huge amounts of water as well. Since water sinks in oil, a 'thieving tube' is used to ascertain whether water was at the bottom. This is a long capillary tube immersed in the drum with a finger tight on the upper orifice. On touching the bottom, the

finger is released for a few minutes, then placed again and capillary removed. Any water present shows in the thieving tube.

4. A UNIDO expert, Dr. S.P. Maltezou, explained to me in a letter that auto manufacturers in the U.S.A. have no objections as to the use of re-refined oil.
Dr. Maltezou is the Industrial Development Officer, Chemical Industries Branch, Division of Industrial Operations. His doctoral thesis was on Waste-oil Recycling in New York Metropolitan Area, United States.

5. See for instance, Quality Certificate for the company dated 3/6/1985. An independent quality analysis which passed was carried out by Kenya Industrial Development Institute (KIRDI). See laboratory report number 7772, dated 6/6/1985.

6. This approach had a limited impact in the United States. L.O. Bowman writes in <u>Hydrocarbon Processing</u> "Used Oil Management Update" February, 1982, Vol. 61, No. 2 that it is "premature to discount the potential long-range value of this concept" (pg. 87).

Chapter 4

1. The Kenya Furfural Company later faced severe problems of cobs procurement resulting from untimely payments to farmers. It was then compelled to rely on its own transport system, which was limited. A decision was passed to purchase tractors and trailers, which seriously affected the company's liquidity position.

2. This is the clause 9 of the Investment Agreement. The agreement is reproduced in *Report on Project and Current Financing*, for the Kenya Furfural Company Limited, 1979, pg. 5(A).

APPENDIX 3(i)

Availability of Waste-Oil for Collection - '000 Litres: Performance and Prospects

Year	Sales of Lubricants	Available for Collection 40%	Collected 24%
1980	29159	11663	6998
1981	29743	11897	7138
1982	30338	12135	7281
1983	30945	12378	7427
1984	31563	12625	7575
1985	32195	12878	7227
1986	32839	13136	7881
1987	33495	13398	8039
1988	34165	13666	8199
1989	34849	13940	8364
1990	35546	14218	8531

Source: U.S. Environmental Agency, Waste Lubricating Oil Research: An Investigation of Several Re-refining Methods, 1974, Annex IV.

APPENDIX 3(ii)

Break-even Points and Capacity Utilization Rates.

Optimum Lubricants

Annual production capacity = 2500 tons

Break-even point (annual) = 1080 tons

Capacity utilization $= \frac{1080}{2500} = 43.2\%$

Actual annual production = 624 tons

Actual capacity utilization $= \frac{624}{2500} = 24.96$

$= 25\%$

Refanoil Manufacturing Company Limited

Annual production capacity = 1500 tons

Break even point (annual) = 660 tons

Capacity utilization at break-even $= \frac{660}{1500} = 44\%$

Actual annual production = 360 tons

Actual capacity utilization $= \frac{360}{1500} = 24\%$

---

1. The break-even points emerged in interviews with the respective firms.

APPENDIX 3(iii)

Capacity Production as a Proportion to Total Imports of Lubricating Oil

---

Average annual imports of lubricating oil 34,405,680 litre

Density of lube oil = 0.88 Kg/litre

In terms of weight,

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad \begin{matrix}\text{(Kg)}\\ \text{(litres)}\end{matrix}$$

∴ Mass = Density x volume

= 0.88 x 34,405,680

= 30,277,000

This equals 30,277 tons

At full production capacity,

Optimum (2500 tons) plus Refanoil (1500 tons)

= 4,000 tons a year

Proportion of capacity to total lubricating oil imports:

$$\frac{4000}{30277} = 13.21\%$$

APPENDIX 3(iv)

Waste-Oil Availability

Waste oil generated	15,000 tons
Available for collection 65%*	9,750 tons
Conversion rate (waste-oil to lube) 65%*	6,338 tons
To produce 4,000 tons (Industry's production capacity) we require waste-oil.	6,153 tons

Therefore,

Potential amount available
substract collected waste-oil

$$15{,}000 - 6{,}153 = 8{,}847$$

Assume only half of this can be recovered. So

$\frac{8847}{2}$ Approximately 4,424 tons.

---

* UNIDO estimates of collection and conversion rates, 1985.

APPENDIX 3(v)

Potential Foreign Exchange Savings

Price of base-oil = KShs. 7.00 a litre*

Capacity production = 4,000 tons

Density = 0.88 Kg/litre

Equivalent to $\frac{4000 \times 1000}{0.88}$ = 5 million litres

Amount saved in KShs. = 5,000,000 x 7

= KShs. 35 m. annually

Current Savings

Current production 984 tons

Equivalent to $\frac{984 \times 1000}{0.88}$ = 1.2 million litres

Amount saved in KShs. = 8.4 million annually

---

* Refanoil estimate of lube price.

APPENDIX 4(i)

Description of the Escher Wyss process*

The raw material is brought from the crusher and into a cyclone where a dust extractor is connected. By gravity, the pre-treated cobs fall into a pre-steaming de-aerator. The material is then led to a silo through a rotary valve and into a reactor (R). Primary steam is fed into the reactor which is under pressure (12 kg cm^2) and at a temperature of 200°C. The reaction vapours leave at the top with excess steam, while the reaction residues leave the reactor at the base assisted by an agitator.

The reaction vapours contain a mixture of furfural, acetic acid, and steam. These are allowed to pass through a filter (F) to a secondary boiler (B). The vapours then leave the boiler with steam to condensers (D), where the condensate is stored in an intermadiate storage tank. The furfural condensate is heated again in the azeotrope column (Z) with secondary steam where the furfural-water mixture boils off at 100°C. leaving the acids, which boil at 123°C.

The by-products, methanol and acetone, boil off at 58°C.

The furfural-water mixture is then separated (S). Furfural is neutralized with sodium hydroxide (N), passed through another separator and the final rich layer is stored in a tank.

The acetic acid recovery unit can be summarized as follows:

Acid Extraction P

The acids which boil off at 123°C. are now mixed with ethylacetate and heated. They are extracted from the top of column P.

Ester Stripper Q

An ester is a product resulting from a chemical reaction between an acid and an alcohol.

From the acid extraction unit P, an ester-water mixture is left behind; this mixture is heated. The ester vapours enter the recovery unit (T). Heating separates ester (boils at 93°C.), from the acids, which remain behind in the recovery unit (T). These are transferred to Acid stripper column (W) where pure acids are extracted. The acids are then piped to separation column (X). Here, formic acids boils off at 94°C., while acetic acid which boils at 123°C. is recovered from the base of the column, cooled and stored (F).

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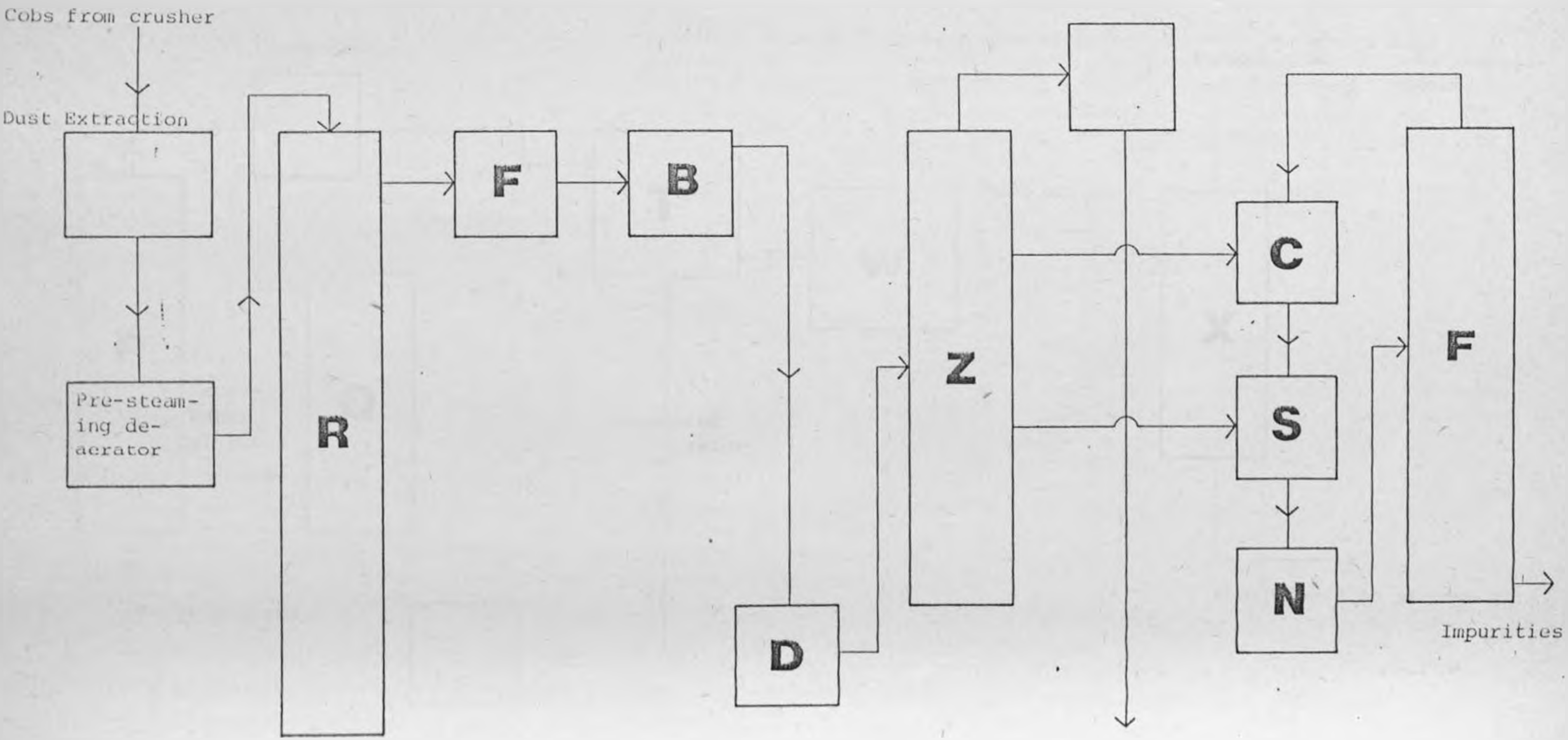
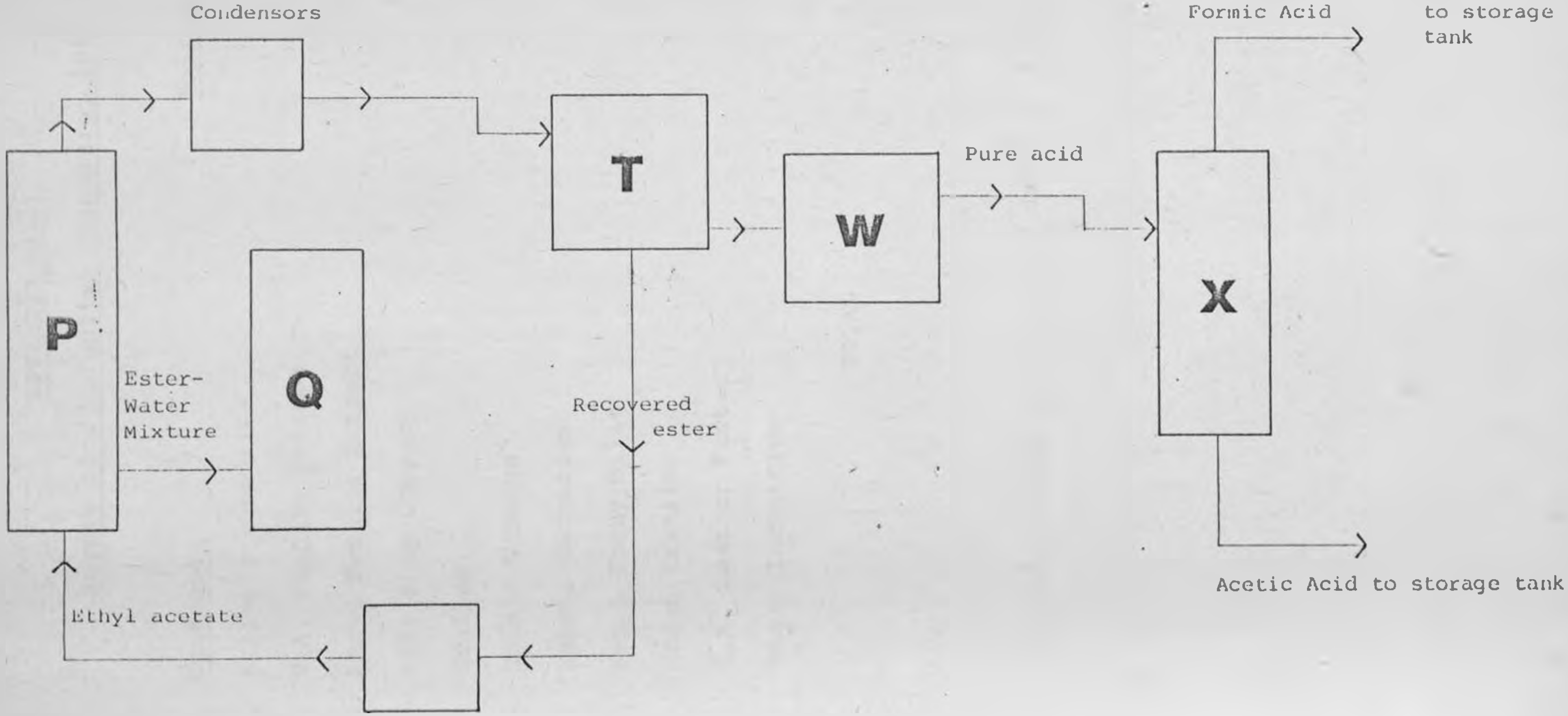
* Please refer to flow charts in Appendix 4(ii) and 4(iii) as you read the production process.

APPENDIX 4(ii) - Flow Chart: Escher Wyss process for extracting furfural from maize cobs



Source: Flow Chart of a continuous furfural and acetic acid plant. Reproduced from J.K. Muiruri, Joint Receiver and Manager, Chemical plant for sale. 1983, pp 9 -.12.

APPENDIX 4(iii) - Flow Chart: Escher Wyss process for extracting Acetic and Formic acids



Source: Acid Recovery Unit flow chart. Reproduced from J.K. Muiruri, Joint Receiver and Manager, *Chemical plant for sale*, 1983, pp 14 – 15.

APPENDIX 4(iv)

Formic Acid Potential Consumers, 1981

Customers	Tons per year
Bulley's tanneries	60
E.A. Tanning Extract	32
Kenya Tanning Extract	17
Bata Shoe Company	15
Sunflag	10
Double Diamond	6
Sagana Tanneries	5
Kenya Toray Mills	3
Midco Textiles	3
E.A. Leather Factory	2
Kemyn Industries	2
TOTAL	155

Source: Company file, letter dated 4/11/81.

APPENDIX 4(v)

Acetic Acid targeted consumers

Customer	Tons per year
Rivatex	26
Raymonds Woolen Mills	20
Elliots Bakeries	20
Kicomi	12
Sunflag	10
Thika Cloth Mills	7
Pan African Paper Mills	6
Kenya Rayon Mills	6
Mt. Kenya Textiles	5
Kenya Sunshine	5
Ken Wool	5
Double Diamond Tanneries	4
African Synthetic Fibres	4
Lords Cosmetics	4
Trufoods	3
Kenya Orchards	3
E.A. Fine Spinners	2
Kenya Toray Mills	2
Njoro Canning Factory	2
Fast Foods	2
Tinus Industries	1.5
Londra Industries	1.3
United Textiles Industries	0.2
Kemyn Industries Ltd.	1.2
Endi Textiles	0.6
Simbarite	0.6
Total (tons)	153.3

Source: Company file, letter dated 4/11/81.

APPENDIX 4(vi)

Estimates of Expenditure, Kenya Furfural Company, October 1977.

	KSHS '000
Foster Wheeler Engineering Services	16,305
Foster Wheeler Erection Services	4,396
Foster Wheeler Start-up Supervision	459
Foster Wheeler re-imbursables	34,100
Sulzer Equipment (F.O.B.)	68,897
Sulzer Services	2,779
Local sub-contracts	
Site development	3,133
Painting	1,300
Civils	8,006
Buildings	2,392
Erection (Electrical/Mechanical/ Insulation)	12,080
Foster Wheeler travel/living/transport costs	2,818
Import duty/sales tax	22,558
Additional items	
Cob depots	3,748
Railway siding	138
Cranes	1,100
Workshop	1,460
Spare/consumables	1,460
Effluent	2,027
Cars/office and housing equipment	2,135
Electrical access cost	2,400

APPENDIX 4(vi) CONTD.

	KSHS. '000
Pre-operating expenditure	23,701
Working capital, raw materials	2,337
Finished goods/debtors/W.I.P.	16,758
Residue Processing	2,960
	239,457

Source: Kenya Furfural Company, Company file, October 1977.

APPENDIX 4 (vii)

The Financial Structure

Equity

Local Participation	KSHS.
Kenya Government - Treasury	20,000,000
Industrial Development Bank	5,500,000
Development Finance Company of Kenya	2,000,000
Agricultural Development Corporation	5,250,000
Kale Agro Industrial Limited	371,700
Sub total	33,121,700

Overseas Participation	
Lewis and Peat Limited	12,678,300
Escher Wyss GmBH	2,100,000
Foster Wheeler (Process Plants) Ltd.	2,100,000
European Investment Bank	10,000,000
Sub total	26,878,300
TOTAL	60,000,000

Loans	
European Investment Bank	57,771,000
Bank of Scotland (ECGB)	71,598,000
Industrial Development Bank	9,043,000
Kenya Commercial Bank (loan)	20,000,000
Development Finance Company of Kenya	6,000,000
Kenya Commercial Bank (overdraft facility)	15,000,000
TOTAL	179,412,000

Source: Kenya Furfural Company: Company report on Project and Current Financing., 1979.

APPENDIX 4 (viii)

Unbudgeted Capital Expenditure

Additional Capital Expenditure	KSHS. '000
Cob depots	5,714
Cranes for furfural equipment	1,646
Workshop equipment	1,660
Plant spares and consumables	2,218
Effluent plant	4,200
Railway siding	138
Residue processing	3,730
Front End loaders	95
Laboratory equipment and spares	450
Motor vehicles, housing and office equipment	870
Sub total	20,668
Additional Construction costs not related directly to time delays	
Design changes because of extra piping required	1,651
Extra mechanical erection costs	4,606
Extra insulation and installation costs	1,925
Unanticipated increased civil costs	1,150
Raw materials holding room	100
Sub total	9,432
Total additional costs KShs. '000	30,100

Source: Kenya Furfural Company, company file,
November 1979.

APPENDIX 4 (ix)

The Break-even point

The break-even point for furfural, acetic acid and formic acid production is computed from data prepared by the Kenya Furfural Company in 1979. The sales and cost estimates took into account the unexpected contigencies of the time.

From theory, the break-even point (B/E) is given by the following formula:

$$\text{B/E} = \frac{\text{Fixed Costs}}{\text{Price per unit} - \text{variable cost per unit}}$$

Projected estimates for 1982* KShillings

Total sales = 74,500,000

Sales per unit = 8602.7

Variable costs = 16,465,510

Variable cost per unit = 1901.3

Fixed costs = 47,761,000

$$\text{The B/E point} = \frac{47{,}761{,}000}{8602.7 - 1901.3}$$

$$= \frac{47{,}761{,}000}{6700.7}$$

$$= 7127.7 \text{ units}$$

As percentage of capacity

$$\frac{7127.7}{8660} = 82.3\%$$

The figure appears very unrealistic! But it is computed from estimates prepared by the company itself.

*The exchange rate of the Kenyan shilling against the dollar was 8.06:1 in 1982. The price of furfural in the world market was K8060 shillings per ton; acetic and formic acids sold for K8500 shillings and K7500 shillings per ton respectively. At full production, 5000 tons of furfural, 3000 tons of acetic acid and 300 tons of formic acid are generated. Their prices are so close that we assume 8660 tons of furfural are produced. This enables us to calculate the per unit sales and per unit variable costs without serious difficulties.

APPENDIX 4 (x)

Break-even point on exclusion of interest payments and depreciation

	KSHS.
Loan interest	9,788,000
Overdraft interest	1,500,000
Additional funds interest	3,000,000
Depreciation plant, machinery	16,069,000
Total	30,357,000
Fixed costs	47,761,000
Less depreciation and interest payments	30,357,000
Modified fixed costs	17,404,000

$$\text{Break-even point} = \frac{\text{Fixed costs (modified)}}{\text{Price per unit - variable cost per unit}}$$

$$= \frac{17,404,000}{6700.7}$$

$$= 2597 \text{ units}$$

$$\text{Capacity utilization at Break-even} = \frac{2597}{8660}$$

$$= 29.9\%$$

Approximately 30%

APPENDIX 4(xi)

Break-even point on exclusion of interest payments only

	KSHS
Loan interest	9,788,000
Overdraft interest	1,500,000
Additional funds interest	3,000,000
Total	14,288,000
Fixed costs	47,761,000
Less interest payments	14,288,000
Modified fixed costs	33,473,000

$$\text{Break-even} = \frac{\text{Fixed costs (modified)}}{\text{Price per unit - variable cost per unit}}$$

$$= \frac{33,473,000}{6700.7}$$

$$= 4995.5$$

$$\text{Capital utilization at break-even} = \frac{4995.5}{8660}$$

$$= 57.68$$

Approximately 58%

APPENDIX 4(xii)

Management Fees as a proportion of Fixed Capital and Pre-operating Costs

Initial (Planned) cost of fixed investment & pre-operating costs = KShs. 130,000,000

Management Fee per year (5% of fixed capital and pre-operating costs) $= \frac{5}{100} \times 130{,}000{,}000$

= KShs. 6,500,000 million

Actual cost of fixed investment and pre-operating costs = KShs. 350,000,000

Management fee per year $= \frac{5}{100} \times 350{,}000{,}000$

= KShs. 17,500,000

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