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DEVELOPMENT AND APPLICATION OF APPROPRIATE TECHNOLOGY FOR THE SUGAR INDUSTRY IN AFRICA

UNIDO Contract No. 76/4
Project No. EP/RAF/76/008

FINAL REPORT

prepared

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CHAPTER IV OUTGROWER-BASED PROJECTS

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Fieldwork was also carried out in India, where the team visited the National Sugar Institute, the Planning Research and Action Institute and the Khadi & Village Industries Commission as well as several sugar and associated factories of varying technologies and scales of operation in Uttar Pradesh, Haryana, Karnataka and Maharashtra. The debt of gratitude due to the many people who assisted the team on this visit is enormous. Visits were also paid to Australia, where special thanks are due to the Queensland Sugar Cane League and to Toft Brothers, and to the United States. In the latter country assistance was willingly given by the Louisiana Sugar Cane League, the Hawaiian Cane Planters Association, the Environmental Protection Agency and the International Bank for Reconstruction and Development. The team's thanks must also be paid to three multinational sugar companies for their considerable assistance both in Europe and 'on location' at sugar estates in three of the fieldwork countries: the firms concerned are Booker Agriculture International, H.V.A. (Netherlands), and Tate & Lyle.

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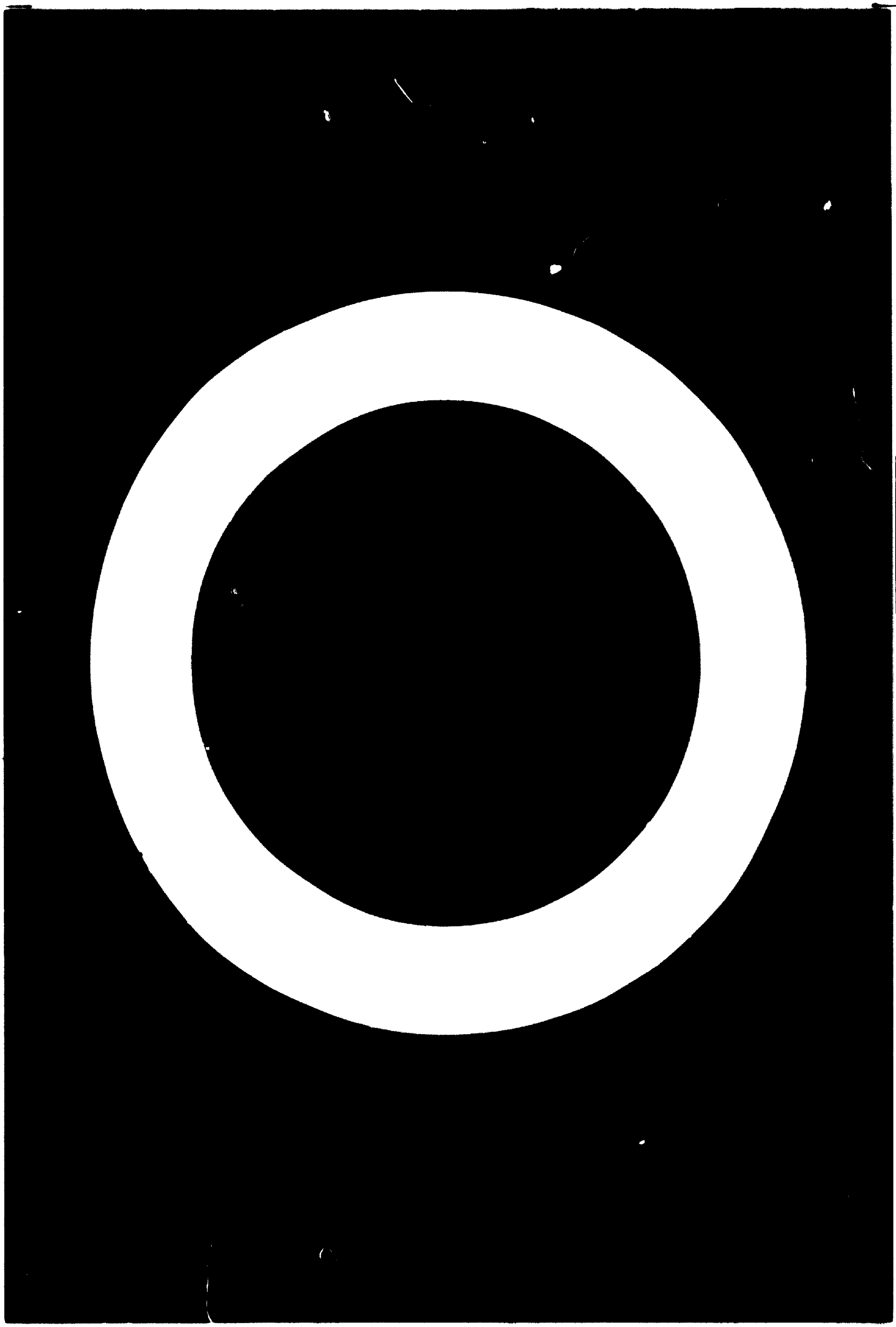


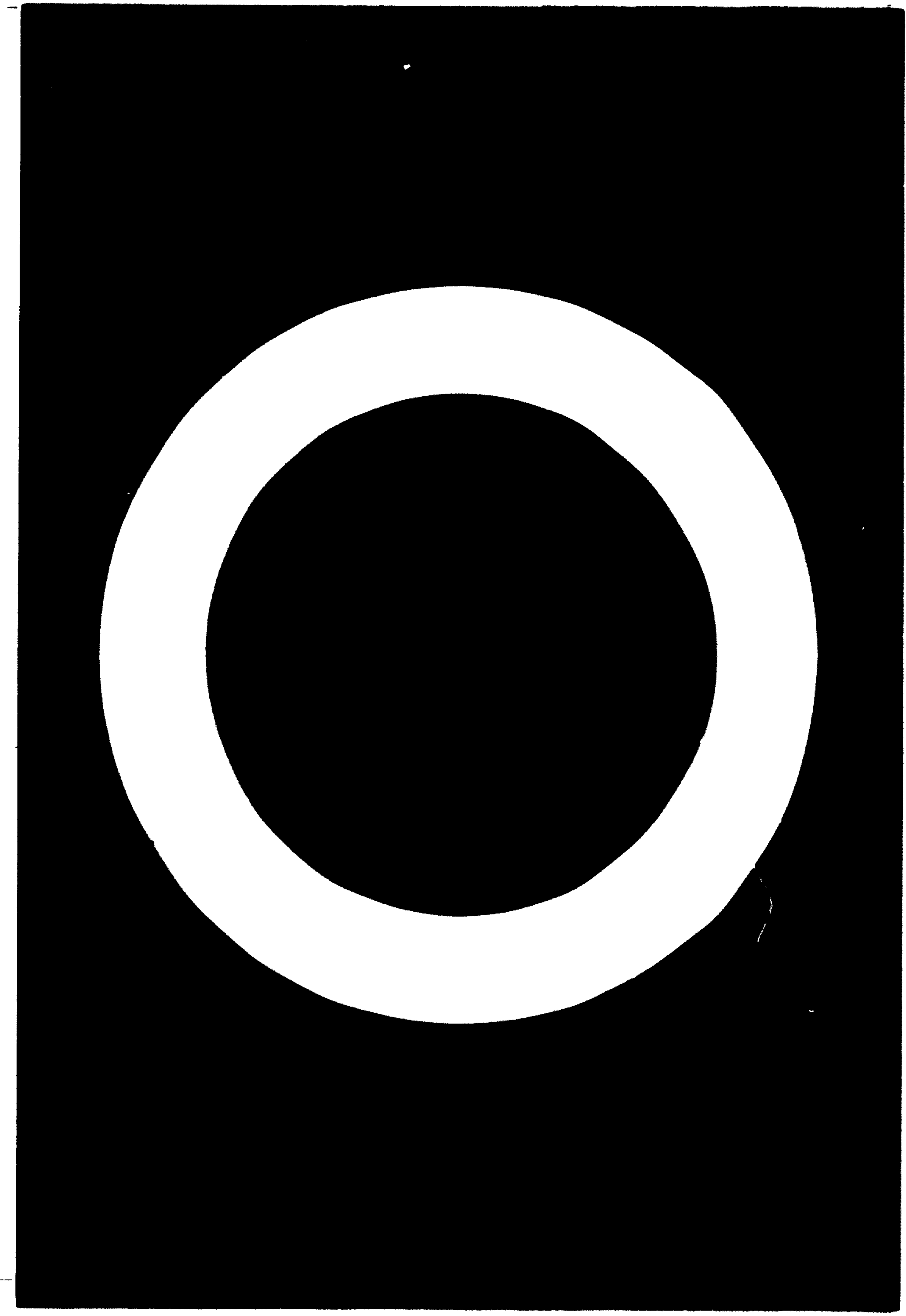
EXPLANATORY NOTES

References to 'tonnes' are to metric tonnes

References to dollars ($) are to United States dollars

Besides common abbreviations, symbols and terms, the following have been used in this Report:

VP	vacuum-pan
OPS	open-pan sulphitation
t	tonnes
tch	tonnes of cane per hour
tcd	tonnes of cane per day
tsa	tonnes of sugar per annum
ARA	annual rotation area
NPV	net present value
IRR	internal rate of return
FOB	free on board
CIF	cost, insurance and freight
kW(h)	kilowatt (hour)
hp	horsepower
MJ	megajoules
BOD	biochemical oxygen demand (5 days @ 20°C)
SS	suspended solids
rab	Indian term for massecuite



SUMMARY

This Report reviews the work conducted for the UNEP/UNIDO project entitled "Development and Application of Appropriate Technology for the Sugar Industry in Africa". The main objective of this project was to examine the environmental consequences of the development of the African sugar industry based on an evaluation of technically feasible alternative technologies. Several technological alternatives were to be specified, and an assessment made for each alternative of the potential effect on the environment of implementing a project based on that technology. These findings would then be used in the formulation of a research and development programme designed to improve the environmental impact of sugar technology.

For analytical purposes the concept of the environment has been divided into three aspects, *viz.* economic, physical and social. It should, however, be realized that these aspects are inter-related.

Much of the fieldwork carried out as part of the project was undertaken in four African countries, *viz.* Egypt, Ethiopia, Ghana and Kenya. Nearly all existing sugar estates in these countries were visited and substantial information collected on the entire range of operations involved in sugar production at these estates. In addition data were collected in other cane sugar-producing countries and from companies connected with sugar machinery supply and sugar estate management.

On the basis of the fieldwork information the technology comparisons which form the core of this Report were identified. For simplicity these are referred to as modern vacuum-pan and improved open-pan sulphitation technologies. Their environmental impact was studied by means of the establishment of a number of models designed to reflect conditions to be found in African countries. Basically the different climatic situations - which affect the growing of sugar cane - were modelled in terms of four ecosystems called long season rainfed, long season irrigated, short season rainfed and short season irrigated. Length of season refers to the number of days per annum when factories produce sugar: gross crushing days range from 270 days in the long season to 150 days in the short season. Rainfed ecosystems are those in which cane does not require irrigation. Each of the technologies was considered at two scales of production: for the large-scale vacuum-pan technology these were taken as 200 tonnes of cane per hour (factory crushing) and 100 tonnes per hour; for the small-scale open-pan technology the scales were 150 tonnes per day and 100 tonnes per day. The number of models was further extended by use of two sets of price regimes, termed low and high, reflecting price conditions observed during the course of fieldwork. Finally additional small-scale models in rainfed situations were developed on the basis of 'low-input low-output' agricultural strategies, implying lower annual production costs per tonne of cane than those derived in the other models but greater cane area requirements on account of lower cane yields.

The first set of results revealed by the models concerns financial profitability. In all four ecosystems, and at both price regimes, the rank order of the technologies was broadly similar, with the two vacuum-pan technology models yielding the higher returns per tonne of sugar per annum. Absolute profitability varies considerably, however, both across ecosystems and with price regimes. In the short season rainfed situation when the set of low prices is used no technology model earns a real financial return above 1 per cent per annum and only one model - the 200 tonne per hour one - shows a reasonable return in the short season irrigated ecosystem. In the corresponding long season situations all large-scale models would appear to earn satisfactory returns, but of the small-scale rainfed models only those based on the low-input low-output agricultural policy perform in a comparable way. When the set of high prices is used, all large-scale models become profit-making, although certain of the short season situation models earn low rates of return;

all short season small-scale models continue to show losses, but long season models perform satisfactorily.

Financial assessment is based on observed market prices for both inputs and outputs. It is, however, often the case in developing countries that certain market prices do not adequately reflect opportunity cost to society of supplying the good or service in question, and these prices are therefore adjusted for purposes of project appraisal. Two markets of particular relevance in the study being reported are those for labour (of different skill levels) and foreign exchange. Sugar projects are often sizeable users of labour; they require both unskilled labourers, particularly on the agricultural side, several categories of skilled personnel such as machine operators and mechanics, and different types of graduate. The rural siting of such projects in developing countries provides unskilled employment opportunities for people who would otherwise be underemployed so that the social cost of employing them is less than the market price. The skilled job categories on the other hand require a training input which raises the quality of the labour force and can thus be viewed as a benefit to society. It is often the case, also, in developing countries that foreign exchange is undervalued and the consequential excess demand handled by means of various controls. Projects which would be net savers of foreign exchange are themselves undervalued, therefore, when evaluation is undertaken at the official rate of exchange.

Consequently the technologies have been reassessed in terms of social cost-benefit analysis. The revised calculations of economic - as opposed to financial - profitability affect the rank order in these ecosystems for which 'low-input low-output' models have been introduced. These models compare favourably with the large-scale models when evaluated in socio-economic terms.

The physical aspect of the environment has itself been sub-divided into a number of different topics. On the question of air and water pollution it is argued that whilst there are differences between the technologies (and the direction of these varies with the criterion under consideration) in general it may be said that the sugar industry as developed in African conditions is not a particularly 'dirty' industry. The energy intensity of the technologies was separately evaluated for the agricultural, factory and distribution stages. At the agricultural stage the 'low-input low-output' models are seen to be the least energy intensive (per tonne of cane); when calculated on a per tonne of sugar basis the large-scale technology becomes less energy-intensive owing to its higher sugar/cane ratio. At the factory stage the need to purchase fuel to supplement bagasse is likely to arise in both technologies; the relative importance of supplementary fuel is greater, however, in the case of open-pan technology. Energy-intensity at the sugar distribution stage is lower for the small-scale technology than for the large-scale, but the amount of energy consumed at this stage even in the case of the largest scale unit considered is negligible.

Several important social questions are considered in the Report. Sociological issues affecting a plantation system of agriculture include the human consequences of land acquisition, the supply of labour - particularly unskilled labour - for certain agricultural jobs, and the type of human settlements established for the industry's labour force. An attempt has been made to quantify the probable costs involved. Whilst the relative importance of the three issues varies with technologies, in all of the models the net importance of social costs associated with plantation agriculture is shown to be high.

Rural development based on existing land use and social patterns may be an important objective of developing countries and in many recent sugar projects outgrowers have formed an integral part of the cane supply system. Chapter IV examines the implications of an outgrower-based cane supply and pays particular attention to the pricing of cane. On the one hand payment to outgrowers has to provide them with an adequate return to encourage replanting whilst, on the other hand, the factory has to be able to maintain an acceptable technical and financial performance.

From the viewpoint of decision-makers it would be most useful to obtain a single index ranking the sugar technologies according to their overall environment impact. Unfortunately, as is argued in Chapter V, no such index can validly be derived. A series of matrices, relating to the different ecosystems, reveals that the rank order of the technologies varies according to environmental criterion under consideration. Thus in the long season rainfed ecosystem the 200 tch vacuum-pan model earns the highest rate of financial return but only the second highest rate of social return (being overtaken by a variant of the OPS technology); in terms of water pollution effluent from a vacuum-pan factory in all ecosystems considered has a lower concentration than that from an OPS factory but a higher load factor. Integration of the rank orders into a single order requires that the criteria be weighted, and no unique system of weights exists. Weighting systems will themselves vary according to the preference of the decision-makers. It is, however, felt to be useful to show how the technologies may be ranked in respect of a wide set of criteria, even if the final decision is thrown back on the decision-maker.

In general the models of the vacuum-pan technology earn higher rates of return in financial terms than do models of the OPS technology. Broadening the economic criterion, however, changes the rank order in at least certain of the ecosystems, particularly if the fixed capital requirements of the former technology are taken into account. In terms of physical criteria the position is also confused. The large-scale technology is less energy intensive and requires less land per tonne of sugar produced, but the load factor associated with factory effluent is higher. Which of these or any other physical criteria should have the greater weight in project evaluation will depend on the particular circumstances of the location in question. In social terms the same result applies. Large-scale technology projects may require less people to be displaced - although this will not be true if plantation agriculture is being introduced - but are likely to entail higher housing costs (per tsa) than will small-scale projects.

Since both technologies have desirable environmental features as well as undesirable ones it seems fair to conclude that further work be done to improve both technologies in areas where their environmental impact is detrimental. Accordingly the Report finishes with a set of recommendations concerning future research and development. These recommendations include several suggestions to upgrade the OPS technology: in particular by improvement in the design of OPS equipment and by improvement in the fuel balance of the OPS unit. Success in these areas would enable OPS factories to achieve higher sucrose recovery, thereby attacking their main financial weakness, and to overcome an important environmental problem. Another important recommendation for work within the sugar industry relates to an investigation, aimed at increasing linkages with developing countries, of the capital goods industry supplying sugar machinery for the modern process. Also suggested is research and development in the field of biological conversion of bagasse in order to produce protein. It is felt that the opportunity to produce bagasse surplus to the requirements of the sugar factory is often lost because obvious outlets for the material (in further manufacturing industry) are not available. Conversion to protein represents one potential use which combines feasible supply requirements with a vital human need (either directly or indirectly through the creation of animal feed).

Since the sugar industry can be shown to be relatively 'clean' in terms of physical pollution, Chapter VI contains argument in favour of selecting a 'dirty' industry as a comparison study to that reported here. In this regard cement is suggested as suitable candidate from the point of view of developing countries.

CHAPTER I

INTRODUCTION

What follows comprises a report of an investigation of the likely economic and environmental impact of alternative sugar technologies in what, for the moment, may be briefly if loosely described as African conditions. As can be seen, the investigation was largely conducted at the industry and even indeed the project level; and the environment was broadly construed and taken to embrace economic, physical and social elements.1/ Project appraisal has, of course, been widely practised in developing countries, including those in Africa, for some considerable time. Insofar, however, as the present work is a variant of this it nevertheless differs from the conventional approach in that it ranges more widely in its consideration of technology options than the normal calculations of private and/or social profitability of an economic undertaking and in that it explicitly introduces the environment into the calculus of decision-making.

The fact that the main focus of the study is on an individual industry and that the methodology, as just implied, has some affinity with that of project appraisal could be explained and defended on a number of grounds, including the evident one that such a focus is hardly surprising given the substantive interests of UNIDO and UNEP, the joint sponsors of the project. Moreover even if the view were taken that questions of technology choice, adaptation and design and of the environmental consequences of industrial activity should be placed within the framework of development planning (so that explicit attention would be given to macro-economic considerations and to national development objectives), it should still be clear that plan implementation depends critically on the quality of project appraisal and industrial decision-making. In brief, a development plan should logically comprise a sequence which runs from the specification of national goals to the allocation of capital and other resources among the different sectors of the economy and thence to individual project identification and implementation. It is true that the introduction of global considerations - by, for example, making explicit the importance of capital rationing in certain circumstances - can complicate individual project appraisal. Nevertheless it is equally true that this is the level at which operational decisions are still most commonly and most appropriately taken. It is also the level at which decisions are often taken - *de facto* if not *de jure* - outside the plan framework. Thus, although global questions should be kept in mind, it is reasonable to begin what is intended to be a continuing attempt to integrate environmental questions into industrial decision-making at the level of the individual industry and project. This is particularly so since an attempt to wrestle with the problems considered at a more aggregative level with the same careful attention to detail that underlies the present study would be unmanageable.

Given that the study is confined to a single industry, and that its main distinguishing feature is the attempt to incorporate more attention to technology choice and the environment than has hitherto been usual in project appraisal, it is useful to consider each of these factors briefly. Thus the remainder of this Chapter comprises three parts: an examination of some of the links among technology choice, industrialization and general development; consideration of environmental factors and development; and a brief preview and description of the contents of the remaining Chapters.

1/ This general formation notwithstanding, the distinction is sometimes made in the text between the economic and the environmental. It should, however, be clear from the context when environment is being used in its narrow or broad sense.

(1) *Technology, Industrialization and Development*

Until recently there were many who saw in modern industrial development a royal road to the attainment of economic and social objectives in the developing countries. Moreover the development strategy thus favoured largely comprised the maximum stimulation of savings and capital formation and the (uncritical) transfer of 'best-practice' technologies from developed to developing countries.

The hopes that were placed in this strategy have been sadly disappointed. In retrospect it is not surprising that the policies followed have generally led to economic, technological and social dualism. This is because, for the economy as a whole, there is very little choice of technology, at least when this is measured by the capital-labour ratio: whereas considerable choice might (explicitly or implicitly) be exercised as among and within the different sectors of the economy. Thus, although there are differences in the efficiency with which countries mobilize domestic savings and attract and use foreign funds, the flow of investible funds in a country can be expected broadly to correlate with income and income per head. It follows that the supply of such funds per head in a developed country will be a multiple of the corresponding supply in a developing one so that the former can afford to 'equip' each worker more handsomely than the latter. If this is ignored, and if in the modern industrial sector of the economy capital-labour ratios in developing countries are much closer to those of the developed countries than would be expected from the respective factor endowments, then the inevitable consequence must be that the capital-labour ratios are very low in the other - notably agricultural and urban informal - sectors of the developing economy. The result, as noted, is economic, technological and social dualism.

This has meant that many developing countries have had increasing difficulty in providing their rapidly growing labour forces with employment.2/ For this and other reasons, the importance of a critical scrutiny of the technology used both in the modern industrial sector and in the other sectors of the economy is much more widely recognized than formerly.

Present trends in development thinking and present policy emphasis aim ultimately at the removal of the economic, technological and social dualism which has resulted from previous policies. In this regard it can be argued that a logical starting point for the development of relevant policies is the modern industrial sector. This is because the application of more exacting criteria to decisions on the technology used in large-scale factories could create more employment than previously per unit of output on an economically viable basis within that sector; reveal greater economic attractiveness than hitherto of smaller, more dispersed projects in some industries when these are compared to large-scale projects; and by reducing the demands on limited investible funds by the large-scale sector, stimulate (or at least permit the stimulation of) the expansion, based on the funds so released, of employment and output in the small-scale sector. The importance of this last point, which emphasizes the benefit to the small-scale of a

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2/ Both the concept of a labour force and that of employment can be rather complex in developing countries. For pertinent discussions see A.K. Sen, *Employment, Technology and Development*, Oxford University Press, 1975, Chapter 1 and R.A. Eckhaus, *Appropriate Technologies for Developing Countries*, the National Research Council, Washington D.C., 1977, Chapter 2. For present purposes, however, it suffices to note that for most people in developing countries gainful employment or indirect access to it through kinship provide the only opportunity for securing income. For an illustration of the magnitude of the employment problem associated with dualistic patterns of development in Ethiopia see James Pickett, *A Report on a Pilot Investigation on the Choice of Technology in Developing Countries*, University of Strathclyde, 1975, Chapter 2.

comprehensive approach to the problem of technology choice could be shown by simple calculations of the magnitude of the demands on the total supply of investible funds made in many African countries by the current uncritical use of large-scale, relatively capital-intensive technology in the industrial sector.

In the light of the disappointing results that have accrued from earlier development strategy, and in the light of what has just been said concerning the importance of critical scrutiny of technology, an increasing number of studies have been made of the possibilities of making 'better' use of the resources available to developing countries. As is well known and broadly speaking, such countries, compared to developed ones, are relatively short of capital and skills and relatively well-endowed with unskilled labour. A number of studies 3/ have provided support for the following conclusions:

(i) that the range of technological choice is large at the project level, and this remains true for at least some products even when the quality of the product is specified in a fairly rigorous fashion;

(ii) that the least-cost technology is often nearer the labour-intensive than the capital-intensive end of the spectrum - at least if the technology is efficiently used so that it has to be recognized that some large questions of productivity can be raised;

(iii) that the emphasis by some economists on distorted factor prices may be overdone;

(iv) that in some industries at least substantial additional employment could be obtained, even at high levels of output, at relatively little sacrifice of economic efficiency; and

(v) that when transport costs are considered, smaller-scale projects and the labour-intensive technology normally found in them, can become more economically attractive relative to larger-scale operations than they would otherwise be.

These results, some at least of which were obtained on the basis of exacting economic evaluation of alternative technologies, are encouraging. The studies which support them, however, do not cover environmental considerations beyond the economic component of the environment. This could in part be explained by the fact that the debate on environmental questions was initially a phenomenon of the now developed countries; where the level of affluence attained made it possible for eyes to be raised, as it were, from the hard,grinding task of wringing a living from nature, and where, on some views, the affluence had been secured at the cost of increasing threat to the integrity of the environment.

3/ By the ILO, David Livingstone Institute and others. For a sample of the ILO work see A.S. Bhalla (editor) *Technology and Employment in Industry*, International Labour Office, Geneva, 1975. Convenient, brief accounts of the work of the Livingstone Institute are contained in James Pickett, *op.cit.*, and James Pickett (editor), *Choice of Technology in Developing Countries, Special Issue of World Development*,Vol.5, No.8, August 1977.

(2) *The Environment and Development*

For an individual the environment could be defined as "the whole set of surrounding conditions in which a human being lives".4/ Such a definition is useful in its implicit recognition of the complexity and comprehensiveness of the environment, less so in its failure to distinguish between the various members of the set of surrounding conditions. At present these members comprise natural and man-made phenomena which reflect a long historical process in which natural changes have been modified by human efforts to 'control' nature. The success (or failure) of these efforts has at once reflected and conditioned the forms of social organization that have developed. Although a wide variety of such forms have been and continue to be observable, a dominant belief over the last two hundred years or so has been that increasing and unending material progress is possible, so that - whatever their other differences and abstracting from differences in timing - all human societies could look forward to a time of universal plenty. Again variations in precise forms of social (and political) organization apart, the common basis for individual and social advance was seen as basically modernization - by which was mainly meant the application of the increasing powers of science and technology to the problems of production and concomitant problems of administration.

The most certain and least controversial thing that can be said of this basic view is that it is less dominant now than it was even twenty years ago. This observation could be developed into a full-scale rehearsal of optimistic and pessimistic views of the future - the former regarding present difficulties as a mere faltering on the way to ultimate success, the latter calling for recognition of irreversible limits to growth and consequent radical changes in all societies. For present purposes it is neither prudent nor necessary to adjudicate between these conflicting positions, since both are predicated on recognition of the need to reappraise in a more explicit way than hitherto the relationship between man and his environment.

To write thus is again to underline the need for a more detailed definition of the environment than that cited above, even if the call for such a definition is more easily made than answered. Among the difficulties are the complexities of the relationships among individuals, society and the environment and the fact that any serious attempt to unravel these quickly brings its author into very controversial territory indeed. Given this all that is done here is to justify the distinction between the economic and social aspects of the environment on the one hand and the natural or physical on the other. A major part of the justification for this distinction is that although natural surroundings clearly affect human behaviour - sometimes, still, to the point of making the difference between life and death - they do not do so in any purposive way. Thus the question of man and his environment is really one of how man, purposively and aware of natural limitations and of the limits to his ability prudently to 'manipulate' nature, should organize his societies to achieve as much human betterment as possible. To this end it does seem important to distinguish the physical from the social, if only in order the better to understand how the two relate to each other.

The relationship between the social and the economic are about as complex and controversial as those between man and his environment. It is nevertheless useful to distinguish between them - although, of course, the distinction is strictly artificial. It does, however, serve simultaneously to recognize the central importance of economic matters (particularly in poor countries) and to ensure that the social elements in development are not overlooked.

The current concern with the environment arose first within the developed countries and initially focused on environmental pollution. By the late 1960s many decades of very large and continuing increases in

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4/ Allen V. Kneese, *Economics and the Environment*, Penguin Books, 1977, p.13

industrial production, based largely on nature-made energy sources were beginning to affect the atmosphere and hydrosphere to a significant (and, on some views, frightening) extent. Moreover, those very advances in science that had made such industrialization possible, also permitted more exact knowledge than hitherto of its environmental and human consequences. Thus there began an increasing fear that the discharge of gaseous residuals - particularly carbon monoxide, particulates, sulphur dioxide, hydrocarbons and nitrogen oxides - were having or were likely to have life-threatening effects on the atmosphere. At the same time fears began also to be expressed that compound rates of industrial growth would, if continued, exhaust the nature-made energy supplies in such short order that chaos and a drastic disruption to the social order would ensue.

Given the origin of the contemporary concern with the environment and the quality of life many developing countries were initially suspicious of the suggestion that there was a need for national and international efforts to protect the environment. They felt that efforts to improve the 'quality of life' in developed countries would be undertaken to some extent at the expense of efforts to improve standards of living in the developing countries. Moreover they felt that the environmental problems being discussed were largely those that could be observed in the richer rather than the poorer countries of the world. From this suspicion came helpful clarification of the nature and extent of national and global 'threats' to the environment, and of the meaning of the environment itself. Thus, further discussion and reflection led to a realization that the developing countries also had their environmental problems, which they share to some extent with the developed. That there is this element of sharing is not surprising since much development that has taken place in the poorer countries of the world has consciously or otherwise been modelled on the developments of the richer countries. As a result the developing countries, it has been pointed out, suffer from the environmental problems of both medieval and modern European cities - they lack clean water and proper sewage facilities at the same time as they experience growing traffic congestion.5/ Moreover there are some environmental problems which are global in their impact - nuclear fall-out being perhaps the most graphic example.

Beyond 'shared' problems it has now been widely recognized that traditional activities in developing countries also have their environmental hazards. This is true of traditional agriculture which "in many tropical regions is characterized, particularly under stress of expansion, by a large range of environmental hazards".6/ Again when the Aswan Dam was built on the Nile it was not foreseen that "in the still waters above the Dam the snails which carried bilharzia would multiply, causing a serious spread of the disease. Nor was it foreseen that one effect of the Dam would be to stop annual discharge of nutrients into the Mediterrean, with the result that the phytoplankton would be starved. This in turn has diminished the sardine fisheries disastrously: the annual catch has fallen from about 18,000 tonnes to 5 tonnes".7/

Important as they are, it can be argued that the physical problems of the environment - whether they are similar to those of or shared with the developed countries or whether they are particular to the developing countries - are less important than the economic and social problems which are manifest in poor countries. To argue strongly in this comparative way would be to oversimplify. Nevertheless, to raise the possibility is an effective way of making the point that environmental questions have to be seen whole in developing countries, where, for most people, the single most striking and pervasive feature of the environment is stark poverty.

5/ This and many other points are made in *Development and Environment*, Mouton, Paris/The Hague, 1972.

6/ *Op.cit.*, p.15.

7/ Lord Ashby, "Background to Environmental Impact Assessment", in O'Riordan and Hay, *Environmental Impact Assessment*, Saxon House, 1976, p.7. The quotation clearly refers to the Nile Delta.

If the environment of poverty is to be replaced by a better one, then economic growth has to take place. To be sure, economic growth without development is to be avoided. There is, however, a very sharp limit on the extent to which development without economic growth is possible. This emphasis on the growth element in attempts to improve the developing country environment is extremely important. At the very least it makes it clear that the status quo is not acceptable; and that, when all due regard is paid to tradition, distributional requirements and a strong emphasis on the basic needs (however these are defined) of the mass of the population, it is still necessary that economic activity should be so organized as to produce year in and year out a surplus available to add to the size and sophistication of the capital stock, the skills of the labour force and the arability of the land. The consequent need to combine economic progress with environmental prudence greatly increases the challenge posed by development to developing and developed countries alike.

(3) *Brief Preview*

Against this daunting background the purpose of the project which is now being reported on has been to study in detail the interrelationship between alternative technologies, economic viability and the environmental impact. The investigation has been based on extremely detailed fieldwork in a number of countries in Africa and elsewhere, and covers the entire operation from the planting of the seed cane to the despatch of the sugar from the factory. The results of the study are presented below. Some of these, it is hoped, will directly provide guidelines for the decision-maker involved in considering the expansion of the sugar industry in Africa. Moreover on the basis of the fieldwork and consideration of the results, the Report identifies areas in which further investigation promises substantial economic and environmental benefit.

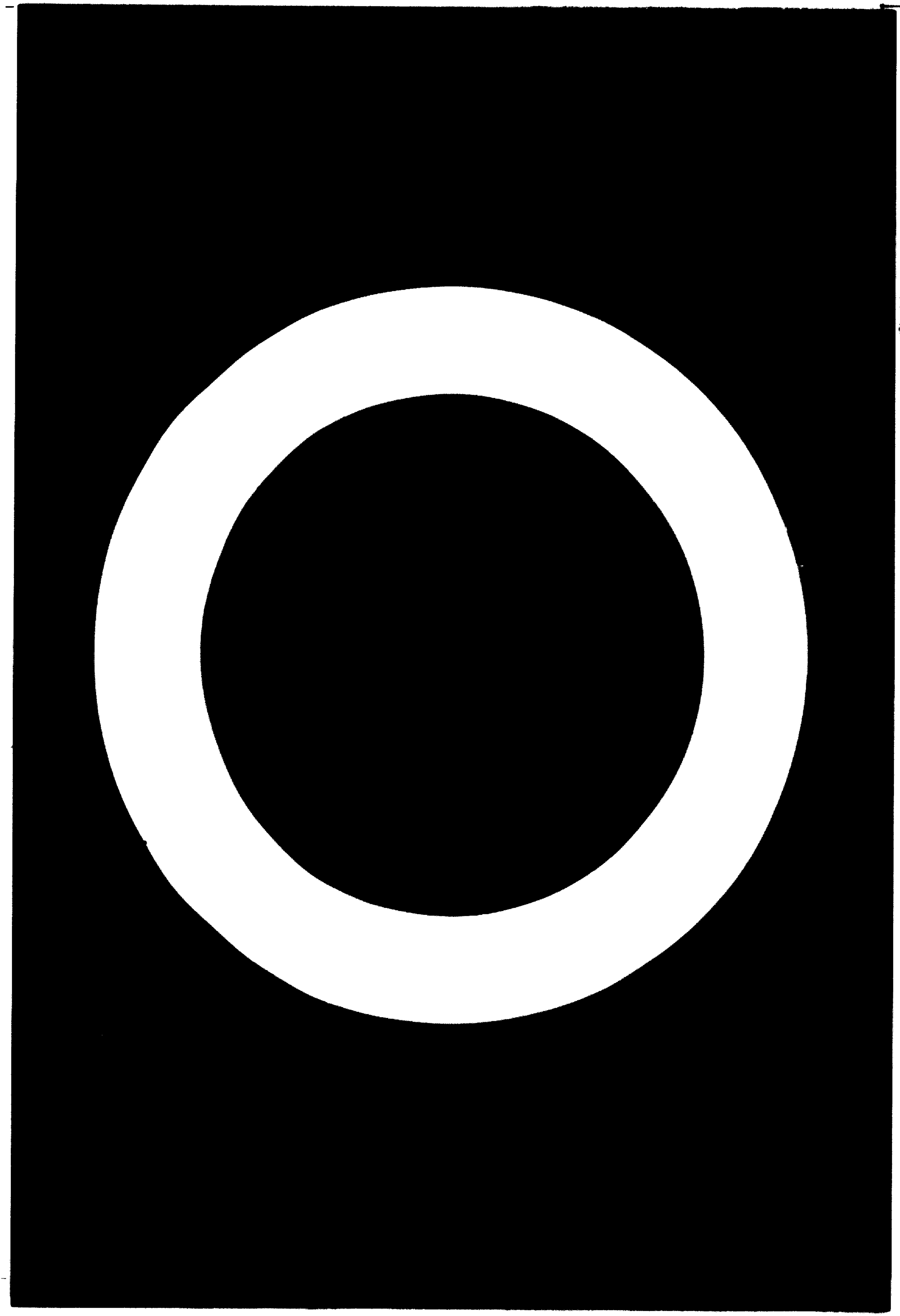
In considering the technology options available to African countries wishing to produce sugar attention was given to two essentially different processes - the open-pan sulphitation technique and the modern vacuum-pan system. These were each considered at two different levels of scale (and uniformity imposed by making comparisons per tonne of sugar produced) and in relation to four climatic/agricultural regimes - long and short season, rainfed and irrigated. Distinctions were also drawn between plantation and outgrower agricultural activities and it was recognized that there were technology choices in the field operations.

As is made clear subsequently, all economic and environmental factors considered the choice of technology is neither an easy nor an unambiguous matter. As a consequence it is not possible to say dogmatically that either technology is superior to the other in all circumstances. Which is preferable depends on the policy objectives (including the weight given to environmental matters) and the climatic and other conditions of particular countries. In the circumstances examined in this Report the vacuum-pan process would be generally superior if the only criterion were the private (market) financial one. This position changes, however, even in the move from private to social costing - when in some circumstances the open-pan technology looks more attractive.

The calculation of net present values at either market or social prices is still a fairly narrow base on which to make a choice; and as the base is widened grounds for dogmatism are correspondingly reduced. This said, it is worth noting that the present study finds in favour of further work on both technologies: research and development to improve the economic efficiency of the open-pan process; and adaptation and possibly some design work to increase the number and 'appropriateness' of the technologies in the modern spectrum.

The remainder of this Report comprises a further five Chapters. The first (i.e. Chapter II) describes the methodology used in the work and includes a pertinent discussion of the treatment of the environment; Chapters III and IV present and discuss the results relating to the various alternatives considered; Chapter V, drawing *inter alia* on the earlier Chapters, takes a broader view; and Chapter VI is given over to a discussion of further work.

In keeping with the Terms of Reference a seminar on the subject matter of the project was held under the auspices of UNEP and UNIDO in Nairobi in April 1977. For this the Livingstone Institute prepared a number of papers (which are listed together with the other papers prepared for the Seminar in Annex I). These, which naturally incorporated the results of the investigation, are to be published in revised form with the other papers written for the Seminar. In order to minimize duplication between the present Report and these technical papers (and thus to effect a convenient compromise between brevity and comprehensiveness which some readers might find useful), only the main results from the relevant papers, suitably revised, are reproduced in the present document. The reader interested in greater detail should find the revised Seminar papers when published of considerable interest and help.



CHAPTER II

GENERAL METHODOLOGY

While cultivation of sugar cane is confined to the tropics and sub-tropics, agronomically cane is a very tolerant crop, being reasonably high-yielding under a wide range of soil and climatic conditions. Traditionally it has been associated with a hot and wet environment, but it is in fact grown in countries near the equator where a high altitude results in a more temperate climate than is normal for the latitude and also in low-rainfall areas. The principal effects of the temperature difference is to vary the length of the growing season, so that in certain areas a crop can be harvested inside one year whilst in other areas mature cane is harvested at about two years. The growing of sugar cane in low-rainfall areas depends on the feasibility of establishing an irrigation system and thus involves the introduction of an important project cost.

Sugar cane can be used in a number of ways, ranging from the chewing of stalks and juice extraction for drinking, through its use as a high-yielding source of cattle-feed, to the production of sweetening agents, which themselves may be classified according to sucrose purity and physical appearance. The traditional sweetener in various parts of the world is *gur* or jaggery, which is a brown solid material of 70-75 per cent sucrose and containing most of the constituents of molasses. A simple form of crystalline sugar is the Indian *khandsari* which tends to be brownish in colour with a sucrose content of around 95 per cent. The open-pan process has been considerably improved over recent years, with the introduction of sulphitation for clarification. The product, known as OPS sugar, can be of 98-99 per cent sucrose and comparable in colour to the output of mill-white sugar from vacuum-pan factories. Mill-white or plantation-white sugar is the most common product from vacuum-pan factories in developing countries, and is used for direct consumption and certain industrial purposes. It has a sucrose content of about 99.5 per cent (as compared to 99.9 per cent for refined sugar) but tends to be more variable in terms of grain size and colour than the more highly processed product. Raw sugar is produced in some countries for export and further refining, hence there is considerable duplication in plant and equipment across countries to achieve an increase in sugar purity which is essential for only a few industrial purposes.

Production of these sweetening agents may be related to a spectrum of technologies,at one end of which - in the production of *gur* - the cane stalks are squeezed in a small, bullock-powered crusher handling less (often considerably less) than one tonne of cane per hour. The juice is subsequently boiled in open pans until a certain degree of concentration is achieved, whereupon it is allowed to cool and solidify. Further along the technological spectrum diesel (or electric) power is introduced at the crushing stage - thus raising the cane handling capacity - and sugar is separated from molasses in small centrifugals once the concentrated juice has been sufficiently cooled in crystallizers. Further sophistication may be introduced at the crushing stage (to increase juice extraction) and at the juice clarification stage (to improve the colour and purity of the final product).

A major technological jump occurs once steam is used instead of direct heat at the juice concentration stage; the heating pans are now closed and under vacuum in order to economize on fuel and lower the boiling point of the magma. Historically,this technological change has been associated with a substantial increase in the scale of operation, a trend which is still continuing. Current conventional thinking in the industry is that crushing capacity of around 2000 to 3000 tonnes of cane per day (tcd) is the minimum financially viable scale of operation (using vacuum-pan technology) in most developing country situations.

(1) *Product Choice*

Since the work being reported here was envisaged as an initial phase intended to lead to a successor project and since the time available for the study was relatively short it was felt more fruitful to study specific segments of the technology spectrum in depth than to attempt to cover the whole field, particularly since the range of alternative technologies can be large. The major use of sugar cane in African countries is in the production of mill-white sugar, almost all for direct consumption. Furthermore present interest in most countries lies in the expansion of cane cultivation in order to increase production of this type of sugar. Hence attention in this study has concentrated on the technological alternatives available for the production of sugar of mill-white quality, *viz.* the vacuum-pan technology and the improved version of the open-pan sulphitation (OPS) technology.

Within each of these technologies there is scope for variation at the individual work station level, so that variants of each (factory) technology exist.[1] The interests of the present work extend beyond the factory stage, however, and the study is concerned to compare sugar production situations which comprise an agricultural stage (up to the point where cane reaches the factory gate), a factory stage (processing cane into sugar) and a distribution stage (transporting sugar to final users). In order for the study to encompass all these stages it was decided to compare, at the factory stage, the versions of each of the two selected technologies currently favoured by machinery suppliers. Details of each technology are given in Chapter III. As can be seen below, the present study also touches upon other aspects of cane production and utilization, including - for example - alternative uses of by-products.

Within the main area of concern some attention has been paid to options within the agricultural stage (in particular manual versus mechanical harvesting) because a change in current practice appears here to be more imminent. In summary at this point the technologies being compared may for simplicity be denoted as large-scale vacuum-pan and small-scale open-pan; more precise quantification is given later in this Chapter.

(2) *Environmental Questions*

Having specified the technologies to be considered, it is appropriate to discuss the central environmental questions posed (at least potentially) by them. For convenience of exposition the concept of the environment is classified in terms of three areas of interest, *viz.* economic, physical and social, and a fuller discussion of the issues under each heading is given below. It should, of course, be noted that many of the questions involve an interrelationship between at least two of the areas: nevertheless it is felt that the classification proposed is methodologically useful.

(a) Economic environment

Preliminary comparison of the two technologies is performed in financial terms, in order to establish the profitability (or otherwise) of the technologies in a variety of settings. There are, however,

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[1] See Pickett, J., *op.cit.*

economic questions of interest, to economic planners and others concerned with the development of national sugar industries, which go beyond the narrow measures of financial profitability.2/

(i) Resource availability: Factor endowments, and the possibility of augmenting these through international assistance, vary considerably across developing countries. Nevertheless certain resources are commonly in short supply (or over-supply) and thus warrant particular consideration of the requirements of each per tonne of sugar per annum produced. In this category comes total employment, skilled labour, initial capital investment, land and net foreign exchange requirements (or savings).

The technology options are initially compared in terms of their respective aggregate requirements of capital and labour. Further comparison is based on the relative intensity with which the technologies require more specific resources, including several which are analysed in detail under other headings, including energy and land occupied by human populations;3/

(ii) Linkages: Establishment of conventional vacuum-pan sugar factories for many developing countries represents investment of very considerable magnitude in relation to their total industrial investment. It is therefore appropriate to enquire into the linkages that might be expected to develop between a sugar project and other sectors of the economy.

Potential linkages might arise on both the input and output sides. In the former case two particularly important possibilities may be singled out. The need for trained manpower - at various levels of skill - requires training programmes which can contribute to the supply of labour within the economy with particular abilities. What appears solely as a cost to the individual firm provides a benefit when seen from the viewpoint of society. Similarly the origin of machinery including spare parts required by the different technologies may be considered in conjunction with information about the capacity of the domestic engineering industry.

Linkages on the output side fall more naturally into the section on the physical environment, within a framework specifying the totality of outputs obtained from sugar production, in part because of the recycling possibilities that exist;

(iii) Shadow pricing: In any assessment of a specific project an important task is the analysis of the potential return offered to society compared with the financial return offered to the investor(s). Although, as explained in Section (3) below, the present study does not seek to be entirely country specific, it is worthwhile to consider (by means of sensitivity analysis) how the technologies perform when assumptions are made regarding the relationship between certain market prices and hypothetical shadow prices.

(b) Physical environment

As a convenient form of classification it is useful to take a definition of 'physical' as the solid, liquid and gaseous phases of the environment.

2/ The most widely used and understood economic measures - e.g. of costs and profits - are based on market prices. As is obvious from the text these are not the only basis of economic valuation. It is convenient to distinguish between the broad and narrow economic view by describing market price calculations as financial.

3/ The link between this stark presentation of capital, energy, labour and other requirements of technologies and economic appraisal in the broad sense is found, of course, in shadow pricing discussed subsequently.

(i) Air: The gaseous environment, air, tends to be taken for granted until its quality deteriorates by the emission of various pollutants. The two main problem areas with regard to the sugar industry are the factory furnace emissions and the open burning of the cane crop before harvest;

(ii) Water: This is the most important component of the liquid environment and is quantitatively and qualitatively a requirement for life. Sometimes this requirement has to be met by the discharges of factory effluent and agricultural run-off. One of the greatest environmental problems arises when the liquid discharge is of such a quality as adversely to affect or prevent life. A major influence on the natural habitat of an area is the introduction of irrigation, often involving large-scale river control and diversion;

(iii) Land: In an agro-industry, land is of major importance and usually undergoes considerable change whether in its shape or in the vegetation it supports. Manual and agricultural operations also affect local soil conditions and possibly the future ability of the land to support the crop at economic levels;

(iv) By-product utilization: Bagasse, molasses and filter mud can be regarded as useful by-products or as waste disposal problems. In the latter case they could have been incorporated in the previous categories but as valuable potential raw materials they are treated individually;

(v) Energy: The energy intensity of a technology is becoming an increasingly important consideration particularly in developing countries. In this regard in the present Report the main comparative focus is on manual versus mechanical agricultural technologies and the vacuum-pan versus open-pan processing technologies.

(c) Social environment

Several areas of socio-environmental impact may be distinguished in the operation of a cane sugar industry. Among them some are directly associated with the scale and content of the technology being employed; the remainder are indirect and depend on interaction between each technology and the institutional setting of the society in which it is established. The direct social policy issues are more clearly defined and are also usually more susceptible to quantification. In the analysis that follows quantitative indices are used where possible to compare the social consequences of technology in the African sugar industry. These comparisons relate to a set of criteria which give operational meaning to the concept of social appropriateness.

(i) Human settlements: Within this area two related issues arise: the magnitude and character of the disruption of existing settlements (and the consequent displacement of human populations) caused by land acquisition for a given project; and, in newly created settlements required for agro-industrial projects, the provision for collective and individual needs and for demographic balance;

(ii) Employment generation: The main components of this criterion are as follows: the extension of productive employment to those most in need (the poorest, least educated and least skilled members of rural populations); maximization of access to employment for the population most directly affected by the implementation of a project; and creation of a working environment which minimizes regimentation, promotes creativity, and - in this and other ways - encourages skilled people to stay in rural areas;

(iii) Development impact: This criterion comprises three broad elements: equitability in the distribution of income-earning opportunities, supported by geographical dispersion; improvement of food supply and nutritional standards; and diversification of the rural economy resulting from strengthened linkages between sugar production and other activities.

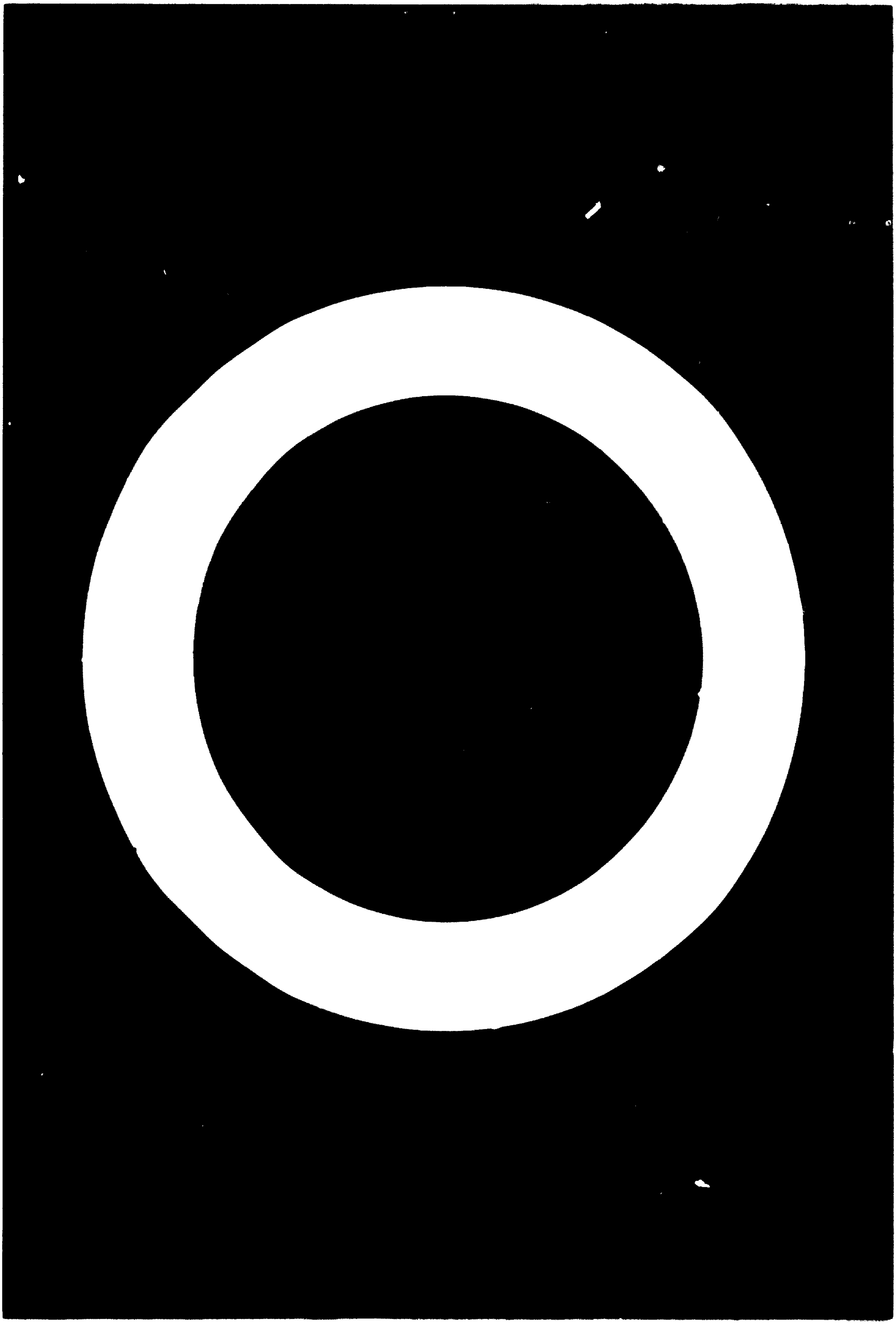
(3) *Conduct of the Investigation*

During the course of the study fieldwork was carried out in four African countries, Egypt, Ethiopia, Ghana and Kenya. Visits were paid to almost all the sugar factories currently operating and additional information was obtained from Government Ministries and other bodies connected with sugar production and utilization. However, the data collected have been deliberately synthesised - via the construction of a number of models - so that the study may relate to a wider spectrum of African countries than those mentioned. Fieldwork was also carried out in several other major countries associated with cane sugar production including Australia, India and the U.S.A. Detailed information was obtained from equipment manufacturers, research institutes and sugar estates concerning both agricultural and processing aspects of sugar technology.

The analyses contained in this Report are based on a number of models, so devised as to represent a variety of scenarios which differ in terms of climatic conditions as depicted by two major parameters, length of crushing season and the absence or presence of the need to irrigate cane. The overall (gross) number of days per annum available for sugar production is taken as 270 (long season) and 150 (short season): each of these is considered in terms of rainfed and irrigated cane cultivation, thus yielding four typical African eco-systems.

The performance of the large-scale vacuum-pan technology is considered in all four situations at two levels of operation, *viz.* 100 tch (tonnes of cane per hour) and 200 tch, implying a total of eight basic models. Analysis in Chapter III is based on a plantation system of cane cultivation, but further possibilities - an outgrower system and a mixed system combining a nucleus estate with outgrowers - are analysed in Chapter IV.

The small-scale OPS technology is also considered at two scales of operation *viz.* 100 tcd (tonnes of cane per day) and 150 tcd. Analysis in Chapter III presupposes a factory farm system of agriculture, but as with the large-scale models alternative systems of cane supply are considered in Chapter IV.



CHAPTER III

PLANTATION-BASED PROJECTS

This Chapter contains an assessment of the respective environmental impacts of the vacuum-pan and improved OPS technologies in the production of mill-white sugar. As described in Section (3) of Chapter II, each technology is analysed at two scales of operation in four different climatic settings. The term 'model' is used to describe the characterization of one technology at a particular scale of operation within a given climatic setting. In this Chapter each model is assumed to draw cane from a plantation or factory farm.

Analysis of the performance of each model utilizes values assigned to a set of parameters, some of which reflect technical efficiency, others economic conditions. These values have been based on observations made during the fieldwork visits outlined in Chapter II. Prices of materials, equipment and labour were seen to vary between countries both absolutely and relatively. This variation is handled in this Report through the use of two price regimes, termed 'low' and 'high'. The low price regime is based on the minimum prices observed in the fieldwork countries. The high price regime is based on wage and salary rates double those of the low price regime, material and equipment prices 50 per cent higher than in the low price regime, and a sales price (ex-factory) for sugar double that of the low price regime. In the high price regime the relative price of labour and sugar is thus higher than in the low price regime. Broadly speaking price conditions in the East African countries may be approximated by the low price set of models, whereas price conditions in Ghana are reflected by the high price set.

The values selected for the more important technical and economic parameters are included in an outline of the methodology described in Section (1) below. Further values and methodological details are given in Annex II of the Report. In Annex III some detail is given on alternative agricultural technologies.

(1) *Methodology*

Section (2) of this Chapter compares the financial performance of the two technologies as evaluated in a variety of climatic and economic settings. The purpose of this section is to provide information on the basis of the calculations of the underlying cost and revenue data.

(a) Large-scale vacuum pan technology models

Capital and operating costs associated with VP models have been estimated from a separate consideration of agricultural operations (ending with the supply of cane at the factory) and factory operations with additional allowance for administrative overheads (financial and general management, personnel and welfare) which cover the entire operation. The technical parameters have been based on what is currently in use in well-managed African projects. On the agricultural side, for example, cultivation activities are largely mechanized, with the exception of weeding, and harvesting comprises manual cutting of burnt cane with mechanized trailer loading. Sugar factory technology is based on conventional milling with processes thereafter subject to a moderate degree of instrumentation. Sugar bagging and handling is assumed to be largely manual in operation.

(i) Agricultural operations: Agricultural activities were classified into land preparation, cane cultivation and harvesting, civil engineering and administrative overheads (including agricultural research). Costing these activities in the case of a specified location would depend greatly on many particular features peculiar to that location. The figures used in this Report are meant to serve as averages, being based on data relating to several recently commenced and currently planned projects. It should be noted that the cost of land - including all forms of compensation - is omitted from the cost calculations at this point: this omission is common to many financial appraisals of such projects, and the significance of this item is assessed in Section (5) below.

The starting point for the specification of agricultural costs is the determination of the required cane area. This depends on the length of growing season for cane and the yield obtained per hectare, and is described in Table 1. Costs associated with the determined cane area are divided into capital costs (land development) and operating costs. The former include purchase of agricultural equipment and use of that equipment in land clearance, road and drainage construction, and irrigation system installation if necessary. Both sets of costs are shown in Table 2 in terms of $ per hectare for both long and short season situations. Calculation of costs at high prices is based on observed weightings of labour and material costs within the various activities. The latter include the cost of land preparation and planting, cultivation of plant and ratoon crops, and civil engineering (maintenance of roads etc).

Annual operating costs also include cane harvesting and administrative costs. The former are based on a 24-hour cane delivery system to the factory, with manual cutting of burnt cane at a rate of 4-5 tonnes per-man day (long season) and 2-5 tonnes per man-day (short season). The system analysed assumes that cane is loaded into trailers (4.5 tonnes capacity) by grab loader, trailers being moved in and out of fields by crawler tractor and hauled to and from the factory in sets of four by wheel tractor. Table 3 gives information on the cane harvesting equipment requirements and on annual operating unit costs.

Most of the agricultural administrative cost comprises staff salaries relating to agronomy, agricultural engineering and administration sections: this item appears to increase only slightly as the size of the operation increases, and has been taken as $500,000 for cane estates of around 5000 hectares, rising to $700,000 for estates of around 10000 hectares and $1,000,000 for estates of around 20000 hectares (at low prices). In the high price models these costs are increased by 85 per cent, reflecting the assumption of 100 per cent increase in rates of pay.

The unit cost figures for cultivation activities, shown in Table 2, are based on the cost data obtained from fieldwork country sugar estates. Since an activity such as land preparation or ratoon cultivation itself comprises a number of individual operations (like ploughing, weeding etc) a cross check was performed on the cost data shown in Table 2: on the basis of information collected at the estates a list of operations was drawn up and the required labour, machine and (where relevant) material inputs specified and priced. The unit costs for all activities were then re-costed. Whilst some variation was noted between the revised costs and the unit cost figures given in Table 2 the net impact on financial profitability was small. The original agricultural employment estimates were, however, shown to be uniformly conservative and the revised figures, shown in Table 4, have therefore been used in this Report. It has been assumed that virtually all cane harvesting daily paid employees would be seasonal.

TABLE 1

Agricultural Parameters for Large-Scale Plantation Models

	Long season		Short season	
	rainfed	irrigated	rainfed	irrigated
Cane cycle[a]	P + 2R	P + 4R	P + 4R	P + 4R
Growing season (months)				
plant cane	22	20	13	13
ratoon cane	18	15.5[b]	11	11
Average cane yields[c]	5	10	4	8
Area required (hectares)[d]				
cane	9058	4453	6527	3221
total[e]	12681	6680	9138	4832
Cane zone radius (kilometres)				
200 tch	9.0	6.6	7.7	5.6
100 tch	6.4	4.7	5.4	3.9
Annual cane requirements[f] (thousand tonnes)	518.4	518.4	288.0	288.0

[a] P represents plant crop, R ratoon crop

[b] 2 ratoons of 16 months each followed by 2 ratoons of 15 months each.

[c] Yield is given in tonnes per hectare per month

[d] Area is shown for the 100 tch models: the required areas for the 200 tch models are twice the respective areas shown

[e] Total area required by each project is assumed to be 140 per cent cane area in rainfed situations and 150 per cent cane area in irrigated situations

[f] Cane requirement is given for the 100 tch models: required cane for the 200 tch models are twice the respective quantities shown

TABLE 2

Agricultural Unit Costs

	Low price $/ha	High price $/ha	Area applicable
A. Initial capital expenditure			
1. Land clearance/preparation/drainage	250	425	
Road construction	250	390	
Irrigation plus additional preparation/drainage	1000	1635	
total: rainfed situation	500	815	
irrigated situation	1500	2450	
2. Cultivation equipment			
100 tch rainfed situation	400	600	
irrigated situation	500	750	
200 tch rainfed situation	360	540	
irrigated situation	450	675	
3. Tractor workshop	10 per cent of expenditure on cultivation and cane harvesting equipment		
B. Annual operating cost excluding depreciation			
1. Land preparation/planting	240	384	ARA
2. Plant crop cultivation:			area under plant crop
long season	300	480	
short season	480	768	
3. Ratoon crop cultivation:			area under ratoon crop
long season	250	400	
short season	375	600	
4. Civil engineering:			
rainfed situation	15	24	total under cane
irrigated situation	75	120	

TABLE 3

Cane Harvesting Costs

A. Capital requirements

		Grab loaders	Crawler tractors	Wheel tractors	Cane trailers
1. Long season rainfed: (number)	100 tch	5	10	23	144
	200 tch	9	18	46	372
2. Long season irrigated: (number)	100 tch	4	9	18	120
	200 tch	8	19	37	300
3. Short season rainfed: (number)	100 tch	5	10	20	132
	200 tch	9	18	41	336
4. Short season irrigated: (number)	100 tch	4	10	17	108
	200 tch	8	19	29	264
5. Unit price: ($ thousand)	low	40	27	10	3
	high	60	40.5	15	4.5

B. Operating costs

		Grab loaders	Crawler tractors	Wheel tractors	Cane trailers
1. Running costs ($/machine hour) excluding depreciation	low	12.4	7.3	5.0	0.5
	high	20.2	11.9	8.1	0.8

2. Rates of pay

(a) Permanent employees		Foreman	Field assistant	Headman
($/month)	low	120	80	48
	high	240	160	96

(b) Seasonal employees		Loader/ crawler operator	Tractor driver	Cane cutter	Clerk	Other labourer
($/day)	low	2.20	1.85	1.35	1.30	1.00
	high	4.40	3.70	2.70	2.60	2.00

TABLE 4

Agricultural Employment

	Long season rainfed		Long season irrigated	
	200 tch	100 tch	200 tch	100 tch
1. Senior management	5	5	5	5
2. Other managerial staff	17	16	18	17
3. Supervisory staff	40	25	29	20
4. Skilled workers	100	56	72	40
5. Semi-skilled workers				
permanent	291	156	191	103
seasonal	197	98	171	84
6. Unskilled workers				
permanent	4005	2003	2668	1332
seasonal	1559	813	1307	680
Total	6214	3172	4461	2281

	Short season rainfed		Short season irrigated	
	200 tch	100 tch	200 tch	100 tch
1. Senior management	5	5	5	5
2. Other managerial staff	17	16	18	17
3. Supervisory staff	36	25	27	18
4. Skilled workers	85	50	59	33
5. Semi-skilled workers				
permanent	274	147	164	89
seasonal	218	111	189	93
6. Unskilled workers				
permanent	3575	1787	2080	1042
seasonal	2819	1443	2313	1184
Total	7029	3584	4855	2481

(ii) Factory operations: Two scales of operation, *viz.* 100 tch and 200 tch are analyeed in this Report. The capacity of machinery required at the various work stations is estimated on the basis of material flow calculations designed to produce mill-white sugar of 99.6 pol by means of a double-sulphitation process. The characteristics assumed for cane and the various by-products are shown in Table 5.

TABLE 5

Input-Output Characteristics

	Water %	Sucrose %	Fibre %	Other Solids %	As % Cane
Cane	69.6	13.0	15.0	2.4	100
Bagasse	48.0	3.0	48.33	0.67	30
Filter mud	77.5	1.5	12.0	9.0	5
Molasses	20.0	32.0	-	48.0	3.5

In addition the following assumptions have been made: imbibition 200 per cent on fibre; milk of lime 1 per cent on cane (15° Beaume); waeh water 116 per cent on wet filter mud; clear juice 85 per cent of sulphited juice on average; bagacillo as filter aid 2kg/tonne cane.

On the basis of these assumptions it is estimated that sulphited juice will amount to 120 per cent on cane and clear juice 102 per cent on cane, with syrup at 64° Brix 20.75 per cent on cane. An undetermined sucrose loss of 1.9 per cent is also assumed.

The boiling system adopted for the purpose of the calculations requires C (or third) sugar to be remelted with clear juice. In the case of 200 tch, it is estimated that A massecuite of 27.3 tonnes per hour (92° Brix, 87.4 per cent purity) will be produced from 75 per cent of the available syrup plus the remelt, which in turn yields 15.0 tonnes A sugar (99° Brix, 99.6 per cent purity) and 12.3 tonnes A molasees (83° Brix, 69.7 per cent purity). B massecuite of 15.2 tonnes per hour (93.5° Brix, 74.5 per cent purity) is produced from A molasses plus 15 per cent of the available syrup, to yield 6.7 tonnes B sugar (98° Brix, 99.5 per cent purity) and 8.5 tonnes B molasses (90° Brix, 53.2 per cent purity). C massecuite of 10.8 tonnes per hour (95° Brix, 62 per cent purity) produced from B molassee plus the remaining syrup yields 4.9 tonnes C sugar (96° Brix, 88 per cent purity) and 5.9 tonnes C molasses (94.3° Brix, 40 per cent purity) which is diluted to 7 tonnes final molasses at 80° Brix.

The sucrose balance, given the assumptions listed, is as follows:

Sucrose in cane		100
in bagasse	6.9	
mud	0.6	
molasses	8.7	
undetermined	1.9	18.1
Sucrose recovery		81.9

These figures are consistent with a milling efficiency of 93 per cent and a cane : sugar ratio of 9.34 (10.7 tonnes sugar at 0.05 per cent moisture per 100 tonnes cane). Estimates of factory capital cost, for both 100 tch and 200 tch, at low and high prices are shown in Table 6. In practice a sugar factory is nearly always supplied at present on a turn-key basis, so that an exact price for a hypothetical factory would depend on a detailed specification of many more parameters than those quoted. The figures given in Table 6 are meant to cover the likely price range applicable to most situations.

The data in Table 6 are based on those supplied by particular manufacturers of equipment. Such quotations can obviously vary with, for example, different phases of the trade cycle, random imperfection in the market perceptions of the supplier, including a failure fully to anticipate exchange rate fluctuations. In this regard the figures in Table 6 are possibly on the low side. If - as could be reasonable - the capital costs of the VP factories were increased by 20 per cent then although the rank ordering of the technologies would not be altered, the profitability of the modern factories and the absolute gap between this and that of the small-scale factories would. Thus in the case of 200 tch models NPV (at low prices) discounted at 10 per cent per annum would be reduced by between $7.5 million and $8 million, whilst the corresponding figures for 100 tch models would be $4.5 million to $5 million.

Factory operating costs have been evaluated in terms of expenditure on staff, chemicals, bagging materials, other process materials, repairs and replacement materials, fuel and miscellaneous expenditure. Information on consumption and unit prices of various materials is given in Table 7. Electricity consumption is calculated at 600 kw per hour (100 tch) and 900 kW per hour (200 tch) for each day the factory is not operating.1/ The estimate of supplementary fuel requirements (the major fuel material being the bagasse, or cane residue, produced as a by-product of the factory operation) is on the low side when compared with existing needs of many factories in African countries: it may be expected, however, that plans for new projects will pay more attention to ways of increasing fuel economy.

Miscellaneous expenditure is calculated at a rate (low price regime) of $0.6 per tonne cane for the 100 tch long season and 200 tch short season factories, with corresponding amounts of $0.5 per tonne and $0.75 per tonne for the 200 tch long season and 100 tch short season factories respectively. This relationship reflects economies coming partly from the length of crushing season and partly from scale of operation.

Estimates of machinery requirements are used to build up factory manpower requirements, technical and processing, shown in Table 8. These are based on a 4 crew 3 shift system, which increases the number of jobs required but substantially eliminates overtime payments. The number of seasonal workers, included in the labour force total, is calculated separately for the long and short season situations. In the former case it is taken as semi- and unskilled workers on the processing side only, whereas in the latter case half of the unskilled workers on the technical side are also counted as seasonal.

(iii) Administrative overheads: This item covers the running of general management, financial and personnel departments plus the provision of transport services (cars, land rovers etc.) and housing.

Capital expenditure comprises housing, vehicles and miscellaneous. The provision of housing - even the extent to which it should be regarded as a charge on the project - is variable. It is assumed here that all managerial staff including supervisory grades

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1/ This part of the factory electricity consumption refers to external purchases of electricity.

TABLE 6

Factory Capital Cost

	Low price ($ million) 100 tch	 200 tch	High Price ($ million) 100 tch	 200 tch
Plant and equipment (FOB Europe)	15.00	25.00	21.00	35.00
Spares	0.60	1.00	0.84	1.40
Freight and insurance	1.56	2.60	2.18	3.64
Port charges and internal transportation	0.78	1.30	1.31	2.18
Installation	3.90	6.50	6.55	10.92
Civil works	3.90	6.50	6.55	10.92
Supervision	0.47	0.78	0.66	1.09
Total (rounded)	26.2	43.7	39.1	65.2

TABLE 7

Vacuum-Pan Factory Operating Costs

(excluding salaries & wages)

	Consumption per tonne cane		Price $		
	100 tch	200 tch	Unit	Low	High
1. Fuel					
furnace oil:					
long season	0.8	0.6	litre	0.12	0.18
short season	1.0	0.8	litre	0.12	0.18
lubricants	0.15	0.1	litre	0.8	1.2
electricity: (see text)					
long season	4.15	3.10	kWh	0.02	0.03
short season	12.25	9.20	kWh	0.02	0.03
2. Process materials					
lime[a]	2.0 Kg	2.0 kg	tonne	60	90
sulphur[a]	0.4 Kg	0.4 kg	tonne	300	450
sugar bags	1.1	1.1	each	0.9	1.35
other process materials	..	..	per tonne cane	0.3	0.45
3. Repairs and replacement materials:					
long season		5% installed factory cost			
short season		3% installed factory cost			
4. Miscellaneous expenditure		See text			

a/ Expenditure on other factory chemicals is assumed to be 60 per cent that on lime and sulphur

TABLE 8

Factory Employment

		Number of people		Average monthly employment cost ($)	
		100 tch	200 tch	low	high
1.	Senior management	3	3	2920	5840
2.	Other managerial staff	15	18	980	1960
3.	Supervisory staff	39	42	250	500
4.	Clerical staff	11	11	90	180
5.	Skilled workers	78	105	125	250
6.	Semi-skilled workers	114	130	45	90
7.	Unskilled workers	204	300	28.5	57
	Total	464	609		
	including seasonal:				
	long season	136	206		
	short season	191	276		

broad elements: equitability in the distribution of income-earning opportunities, supported by geographical dispersion; improvement of food supply and nutritional standards; and diversification of the rural

plus skilled workers would be accommodated. Details are given in Table 9. An additional 10 per cent is added to the total for welfare buildings. Required expenditure on vehicles is taken as $450,000 for the 100 tch long season rainfed situatic (at low prices). Calculations for other situations are based on the assumption that the requirements for irrigated situations would be 67 per cent that of rainfed, and for short season 80 per cent that of long season, reflecting (though not proportionately) the reduction in cane area being served. Similarly it is assumed that expenditure for the 200 tch situation would be 150 per cent that of 100 tch. Miscellaneous capital expenditure is taken to be $250,000 irrespective of situation (at low prices). Calculations at high prices assume a 50 per cent increase in equipment prices and 75 per cent increase in housing costs (reflecting the assumed doubling of wage rates).

Annual operating costs largely comprise staff salaries which may be expected not to vary much on account of change in situation. A figure of $4 per tonne cane has been used for the 100 tch long season situation (at low prices): short season expenditure is taken as 90 per cent that of long season, and 200 tch 20 per cent higher than the corresponding 100 tch situation. High price figures are 75 per cent higher than the low price equivalents.

(iv) Working capital: It is assumed that one week's production of sugar would be on hand at any one time, and that payment for sugar is received three months in arrears. An estimate was made of agricultural, factory and administrative stores requirements: it was assumed that one year's consumption of factory repairs and replacement materials would be needed as stores, together with six months' consumption of all other materials. Payment for stores would be three months in arrears.

(v) Revenue: This is based on ex-factory prices for sugar and molasses. It is assumed that sugar sells ex-factory at $300 per tonne (low price) and $600 per tonne (high price). The corresponding prices for molasses are $15 and $30 per tonne respectively. The low price for sugar reflects currently observed prices in East Africa. The high price is in fact below that to be found in West Africa. Even the low price, however, is slightly above the present world market price (FOB London) for refined sugar.

It is assumed that sugar production is carried on over 25 years, and that sugar recovery will be lower than normal in the first few years. To allow for a small amount of wastage a figure of 10.6 per cent is used as normal (equivalent to 81.5 per cent recovery). Table 10 provides details of sugar recovery estimated for the early years of operation (years 1 and 2 being, of course, devoted to agricultural preparation etc).

(b) Small-scale OPS technology models

The OPS technology has also been analyzed for two scales of operation, although in this case only one size of factory is specified. The variation is introduced by means of a difference in the number of eight-hour factory shifts worked per day: 100 tcd requires two shifts whereas 150 tcd requires three-shift working, in both cases equivalent to 7 tch.

Assessment of profitability, as depicted by these models, is based as in the large-scale situations on a comparison of revenues and costs over 25 years of sugar production. Much of the basic data used to construct the models have, however, been drawn from that used in the large-scale technology models or from small-scale experience in India since as yet in the African countries at the time fieldwork was undertaken, only three OPS units existed and none had been operating for more than a few months.

TABLE 9

Housing Provision

		Senior management	Other managerial	Supervisory staff	Skilled workers
1. Long season rainfed: (number)	100 tch	14	41	65	161
	200 tch	14	48	80	235
2. Long season irrigated: (number)	100 tch	14	42	60	145
	200 tch	14	49	69	207
3. Short season rainfed: (number)	100 tch	14	41	65	155
	200 tch	14	48	76	220
4. Short season irrigated (number)	100 tch	14	42	58	138
	200 tch	14	49	67	194
5. Unit cost ($ thousand)	low	40	25	10	4
	high	70	43.8	17.5	7

TABLE 10

Sugar Recovery

			Year		
	3	4	5	6	7
1. Long season rainfed:					
cane % normal		33	75	95	100
sugar % cane		9	10	10.3	10.6
molasses % cane		3	3.3	3.4	3.5
sugar recovery %		69.2	76.9	79.2	81.5
2. Long season irrigated:					
cane % normal	10	35	70	90	100
sugar % cane	8	9	10	10.3	10.6
molasses % cane	2.7	3	3.3	3.4	3.5
sugar recovery	61.5	69.2	76.9	79.2	81.5
3. Short season:					
cane % normal	30	65	90	100	100
sugar % cane	8.5	9.5	10.2	10.6	10.6
molasses % cane	2.9	3.2	3.4	3.5	3.5
sugar recovery	65.4	73.1	78.5	81.5	81.5

TABLE 11

Agricultural Parameters for Factory Farm Models[a]

	Area required (hectares)		Cane zone radius	Annual cane requirements
	Cane	Total[b]	(km)	(thousand tonnes)
Long season rainfed				
150 tcd	529	744	1.5	30.3
100 tcd	353	496	1.3	20.2
Long season irrigated				
150 tcd	261	390	1.1	30.3
100 tcd	173	260	0.9	20.2
Short season rainfed				
150 tcd	380	534	1.3	16.8
100 tcd	254	356	1.1	11.2
Short season irrigated				
150 tcd	188	285	1.0	16.8
100 tcd	126	190	0.8	11.2

[a] Cane yields are assumed to be equal to those shown in Table 1 for the corresponding large-scale situation

[b] Total area required by each project is assumed to be 140 per cent cane area in rainfed situations and 150 per cent cane area in irrigated situations

(i) Agricultural operations: These have been costed on the basis of two different sets of assumptions. Primary analysis has been based on the expectation that cultivation inputs and associated cane yields per hectare will be the same as in the corresponding large-scale situations.2/ Where irrigation is required this expectation is tentative since very little information is available on small-scale irrigation, so that the formal financial analysis of the performance of OPS technology under these conditions should be regarded as being particularly conditional on the attainment of similar cane yields for the same unit irrigation cost as those incurred in large-scale projects. Table 11 contains information on cane requirements for the various models.

The costing of cane harvesting and transportation has been calculated on similar lines to that used in the large-scale models: in particular rates of productivity for cane cutting, rates of pay and running costs per machine hour are identical to those used the costing of harvesting operations on large-scale plantations.3/ Cane loading has, however, been assumed to be a manual operation at the small-scale level. The cane transportation equipment requirements are shown in Table 12. Agricultural administrative costs are based on three items of expenditure: a fixed employment cost of $20,000 per annum ($40,000 at high prices) covering the cost of an agricultural manager, three supervisors and two clerical assistants; land rent of $10 per hectare ($15 at high prices); and staff transport running costs of $5,000 per annum ($7,500 at high prices). Table 13 summarizes agricultural employment data.

TABLE 12

Cane Transportation Requirements

	62 hp tractors	3 tonne trailers
150 tcd models	5	13
100 tcd models	3	9

In the rainfed situations the implications of an alternative policy are considered. This policy may be described as 'low-input low-output' in comparison with the main hypothesis (same input-output as in the corresponding large-scale situations), depending to a greater extent on unskilled labour with reduced use of equipment. The technical and economic parameter values underlying this alternative policy are based on limited observation relating to one fieldwork country (Ghana); nevertheless they suggest that, for OPS models in situations where it is feasible to consider utilizing an increased land area in order to supply a given quantity of cane, it is possible to produce cane at a lower cost per tonne. The unit cultivation costs and associated cane yields are shown in Table 14. Cane harvesting operating costs are based on the same unit running costs and rates of pay as under the main hypothesis. Capital expenditure on cane transport equipment is taken as equal to that shown in Table 12. Similarly agricultural administrative costs are based on calculations outlined above under the main hypothesis.

2/ For information of yields and cultivation costs per hectare see Tables 1 and 2 above.

3/ Details of productivity are given in Annex II. Rates of pay and machine running costs are shown in Table 3 above. Cane is cut green at a rate half of that of the corresponding large-scale model.

TABLE 13

Agricultural Employment in Small-Scale Models

	Long season rainfed		Long season irrigated	
	150 tod	100 tod	150 tod	100 tod
1. Managerial	4	4	4	4
2. Skilled workers	4	4	4	4
3. Semi-skilled workers				
permanent	14	12	11	10
seasonal	12	10	12	9
4. Unskilled workers				
permanent	116	78	77	52
seasonal	119	84	109	77
Total	269	192	217	156

	Short season rainfed		Short season irrigated	
	150 tod	100 tod	150 tod	100 tod
1. Managerial	4	4	4	4
2. Skilled workers	4	4	4	4
3. Semi-skilled workers				
permanent	13	11	10	9
seasonal	14	11	13	10
4. Unskilled workers				
permanent	104	69	60	41
seasonal	198	136	171	119
Total	337	235	262	187

TABLE 14

Agricultural Unit Costs and Yields Under 'Low-Input Low-Output' Policy

A. Initial capital expenditure		Low price $/ha	High price $/ha	As % of large-scale
1. Land clearance/preparation/drainage		125	212	50
Road construction		83	130	33
2. Agricultural equipment		175	263	45
3. Tractor workshop		10% agricultural equipment + cane transport equipment		
B. Annual operating cost excluding depreciation	**Area applicable**			
1. Land preparation/planting	ARA	200	320	83
2. Plant crop cultivation:	area under plant crop			
long season		150	240	50
short season		240	385	50
3. Ratoon crop cultivation:	area under ratoon crop			
long season		62.5	100	25
short season		93.8	150	25
4. Civil engineering	total	5	8	33
C. Cane yields per hectare per month				
long season: small-scale 4 tonnes				80
short season: small-scale 2.5 tonnes				63

Agricultural employment generated under the 'low-input low-output' policy is shown in Table 15. The required cane areas to provide 150 tcd are 661 hectares (long season) and 608 hectares (short season), whilst the corresponding 100 tcd figures are 441 and 406 hectares respectively.

(ii) Factory operations: Since OPS technology is relatively less well-known a brief description is given here of the factory specification and performance assumed in this Report. The basic factory specification is fairly similar to that outlined in a booklet published by the Planning Research and Action Institute, India.4/ Specifications of complete units currently offered by Indian machinery manufacturers are closely modelled on this. The major differences relate to the increased crushing capacity of the plant considered in this Report compared with that detailed by P.R.A.I. (60 tcd). Table 16 provides a list of the principal plant and equipment required by a 7 tch factory.

It is assumed that downtime will amount to 25 per cent of available cane crushing time, reducing the net crushing days to 202 (long season) and 112 (short season). Unplanned stoppage would appear to be more frequent with OPS technology and this is reflected in a higher percentage downtime. Annual cane requirements associated with the four models are thus 20,200 tonnes (100 tcd long season); 30,300 tonnes (150 tcd long season); 11,200 tonnes (100 tcd short season) and 16,800 tonnes (150 tcd short season).

Sugar recovery is estimated on the basis of the following parameters: cane contains 15 per cent fibre; raw juice % cane 65 (no imbibition); clear juice % cane 61.5; 1st rab (massecuite) % clear juice 20 with rab at 86° Brix; 1st sugar % 1st rab 37.5; 2nd rab % 1st molasses 90 and 2nd sugar % 2nd rab 22.5; 3rd rab % 2nd molasses 90 and 3rd sugar % 3rd rab 17.5. 5/

By-products in relation to cane comprise bagasse 35 per cent, filter mud 4 per cent and final molasses (at 80° Brix) 4.25 per cent. Sucrose losses may be shown from the above parameters to be bagasse 19.2 per cent, filter mud 2.3 per cent, molasses 14.5 per cent and undetermined 14.0 per cent giving an approximate recovery of 50 per cent. These assumptions regarding losses are not particularly demanding, when translated into implications for factory efficiency, in Indian conditions, where *modern* OPS units are expected to achieve 60 per cent recovery. However, technology transferred to a different environment cannot be automatically assumed to give equal results.

With an assumed cane sucrose content of 13 per cent (as in the large-scale models), the sugar % cane ratio works out at 6.5 per cent, broken down into 4.25 per cent first sugar, 1.5 per cent second sugar and 0.75 per cent third sugar.

A breakdown of the factory capital cost is given in Table 17. The smaller than usual percentage mark up from low to high prices for factory plant and equipment reflects the much higher number of potential suppliers of small-scale sugar machinery. It is assumed here that this equipment would be imported - on a turnkey basis as in the large-scale case - though it is now feasible for developing African countries to manufacture some part of this themselves.

4/ P.R.A.I., *Open-Pan Sulphitation Process of Khandsari Sugar Manufacture: General Description, Capital Cost and Detailed Economics*, Publication 226, Lucknow, India, 1965.

5/ For further information see P.R.A.I., *Open-Pan Sulphitation Process of Khandsari Sugar Manufacture : General Instructions on Process Techniques*, Publication 260, Lucknow, India, 1969, and P.R.A.I., *Report of the Fourth Technical Seminar on the Open-Pan Sugar Manufacture, September 1968*, Lucknow, India, 1968.

TABLE 15

Agricultural Employment Under 'Low-Input Low-Output' Policy

		Long season rainfed		Short season rainfed	
		150 tcd	100 tcd	150 tcd	100 tcd
1.	Managerial	4	4	4	4
2.	Skilled workers	4	4	4	4
3.	Semi-skilled workers				
	permanent	8	6	8	6
	seasonal	15	15	17	16
4.	Unskilled workers				
	permanent	119	80	122	81
	seasonal	119	109	198	171
	Total	269	218	353	282

TABLE 16

Specification of Plant and Equipment Required by a 7 tch OPS Factory

1. Cart weighbridge - 5 tonne capacity

2. 2 x 3 roller hydraulic crusher (355mm x 530mm) with cane carrier and two sets of knives

3. 100 hp electric motor for the crusher, 15 hp and 10 hp electric motors for knives

4. 2 raw juice tanks

5. 0.6 cubic meter capacity air compressor, sulphur oven and scrubber for gas filtration

6. 4 sulphitation tanks

7. 2 sulphited juice heating bels (each of 4 pans) fired by wet bagasse furnaces

8. 24 settling tanks

9. 3 filter presses (760mm x 760mm)

10. 6 clear juice heating bels (each of 5 pans) individually fired by a wet bagasse furnace

11. 36 U-shaped crystallizers

12. 3 centrifugals (305mm x 610mm)

13. 5 molasses heating bels (each of 3 pans) individually fired by a firewood fuelled furnace

14. Sugar drier with hopper and elevator

15. Pumps, small electric motors, pipes and fittings, sugar bagging and weighing equipment and other miscellaneous small items

TABLE 17

OPS Factory Capital Cost

		Low price ($000)	High price ($000)
1.	Plant and equipment (FOB India)	100.0	120.0
	Freight and insurance	10.0	12.0
	Port charges and internal transportation	5.0	6.0
	Installation including supervision	25.0	36.0
	Civil works	40.0	60.0
	Sub-total	180.0	240.0
2.	Generator sets	50.0	75.0
3.	Vehicles	20.0	30.0
4.	Office/laboratory equipment	5.0	7.5
5.	Initial training	6.0	10.5
	Total	261.0	363.0

A large element in the overall capital cost is provision for a 200 KVA generator set (plus a small standby unit) to supply power for the crusher unit and other electric motors. This cost could be considerably reduced if direct access to electricity is available. On the other hand, water availability has been assumed (with consumption estimated at up to 20,000 litres per day). Estimation of the initial training cost has been based on the assumption that three key factory employees would attend a six month training course in India.

Labour requirements are shown in Table 18. The managerial and skilled labour requirements are estimated to be the following:

managerial: factory manager, 3 production superintendents (1 per shift), accountant/secretary;

skilled labour: head pan boiler (1 per shift), mechanic and electrician per shift plus day mechanic and day carpenter/mason.

The majority of those classified as semi-skilled are employed at the heating bels and centrifugal stations. Basic rates of pay for daily rated staff are taken as equal to those offered in the large-scale factories, with overhead costs around half. Semi-skilled and unskilled production staff have been classified as seasonal.

The managerial input seems high compared with Indian practice and certainly is so compared with Indian specification 6/ but is in line with East African intentions for small-scale units and would appear to be advisable if units are to have any chance of success.

Consumption and prices of material inputs are given in Table 19. Fuel consumption depends partly on the efficiency of the bagasse furnaces to satisfy all process heating needs. In addition to supplementary fuel to fire furnaces, diesel oil (or electricity) will be required to power the mills and cutters and electricity needed to run the crystallizers, centrifugals, sugar drier and the various pumps. The supplementary process heating fuel requirement is based on a material flow calculation utilizing Indian data.7/ Some of the required parameters have been given in page 33 above; in addition it is expected that 4 kg water is evaporated per 1 kg of dry bagasse fuel consumption. On the basis of these parameters it can be shown that in a factory of 100 tonnes of cane crushed per day approximately 48 tonnes of water will require to be evaporated at the clear juice heating bel stage in order to raise the rab to 86° Brix (from 19° to 20° Brix clear juice), implying a fuel requirement of 12 tonnes of dry bagasse. In addition, 5 tonnes of dry bagasse are required daily for the heating of the sulphitation and molasses bels. With the bagasse : cane ratio estimated to be 35 per cent (at around 51 per cent moisture) it would appear that around 17 tonnes of bagasse (on a dry basis) could be available per day under optimal conditions. However to allow for possible shortfall, a requirement of 1 tonne firewood per 100 tonnes cane has been allowed for, to be used in the molasses bels' furnaces.

Miscellaneous expenditure is based primarily on the (maintenance) cost of running two vehicles (saloon and pick-up truck) at $0.1 per km (at low prices). The total figure is taken as $6,000 long season and $4,800 short season at low prices, with the high price figures 50 per cent more.

6/ As contained for example in P.R.A.I., Publication 226, *op.cit.*

7/ See P.R.A.I., *Report on the Fourth Technical Seminar on the Open-Pan Sugar Manufacture, op.cit.*

TABLE 18

OPS Factory Employment

	Number of people		Average monthly employment cost $	
	100 tcd	150 tcd	low	high
1. Administration				
Management	2	2	600	1200
Clerical/storekeepers	4	4	82.5	175
Drivers	2	2	58.5	117
Unskilled	5	5	27.3	54.6
2. Production				
Management	3	3	345	690
Skilled workers	2	3	114.4	228.8
Semi-skilled workers	29	43	41.9	83.8
Unskilled workers	137	205	27.3	54.6
3. Maintenance				
Skilled workers	6	8	114.4	228.8
Total	190	275		

TABLE 19

OPS Factory Operating Costs

(excluding salaries and wages)

	Consumption per 100 tonnes cane	Unit	Price $ low	Price $ high
1. Fuel:				
heavy diesel oil	500	litre	0.16	0.24
firewood	1	tonne	12	18
lubricants	(10% of diesel oil expenditure)			
2. Process materials:				
lime	200 kg	tonne	60	90
sulphur	50 kg	tonne	300	450
castor seed	0.2 kg	kg	7	10.5
sugar bags (100 kg)	(1% wastage)	each	0.9	1.35
filter cloths	2 cloths	each	8	12
3. Repairs & maintenance materials:				
150 tcd long season		5% installed factory cost		
100 tcd long season/ 150 tcd short season		4% installed factory cost		
100 tcd short season		3% installed factory cost		
4. Miscellaneous expenditure	See text			

Estimation of capital replacement expenditure has been evaluated on the observation that certain pieces of equipment, particularly pans and crystallizers, have a much shorter life than the 25 years taken for factory production. In the long season situation it is estimated that 45 per cent of the value of plant and equipment requires replacement after every six years of operation, with a further 15 per cent requiring replacement once (after thirteen years). In the short season situation it is estimated that 45 per cent of plant and equipment requires replacement after every eight years of operation. In addition it is assumed that the factory vehicles require replacement after six years (long season) or eight years (short season).

As mentioned above OPS factories produce up to three (sometimes four) grades of sugar, of differing qualities. These sugars have been priced on the basis that first sugar is of comparable quality to large-scale factory mill-white sugar (certainly in India modern OPS units are capable of producing sugar of at least 'D29' standard, a common grade of Indian vacuum-pan sugar); that second sugar is slightly 'inferior' in terms of colour and grain size; and that third sugar is distinctly darker in colour than the other two grades. The respective prices used (per tonne) are $300, $270 and $225 in the low price models with high prices being double the corresponding low price. Molasses is priced at $15 per tonne ($30 per tonne high price) as in the large-scale factory models.

(iii) Production parameters in the early years of operation: The date of commencement of sugar production depends on the length of time required to obtain the first harvesting of cane. It is assumed, for convenience, that land clearance takes one year - as in the large-scale situations - so that sugar production commences at the same time as in the corresponding large-scale models. A new project cannot commence at or even near the full production rate if the plant crop/ratoon crop distribution is to remain within reasonable proportion, though planting over the first few years exceeds the normal (equilibrium) level to some extent in order to bring the factory into full production more quickly. It is assumed that the long season factory commences production in year 4 at a rate of 33 per cent of normal, building up to 100 per cent by year 7: in the short season model production commences one year earlier. The required operating cost expenditures in the early years (expressed as a percentage of normal) and the corresponding required distribution of expenditure on capital items are shown in Annex II.

Finally, it is assumed that sugar recovery will be lower than normal in the first two years, as shown in Table 20.

TABLE 20

Outputs in Early Years as Percentage of Cane

Year of operation	First sugar	Second sugar	Third sugar	Molasses
First	2.0	1.0	1.5	5.0
Second	3.0	1.25	1.25	4.5
Third	4.25	1.5	0.75	4.25

(2) *Technology Comparison based on Financial Profitability*

The basic financial results for each model are presented in terms of net present value (NPV), discounted at 5 per cent and 10 per cent 8/ per annum, and internal rate of return (IRR). The values obtained are given in Table 21. It will be noted that very few of the short season models manage to show a positive real rate of return greater than 2 per cent per annum. The long season large-scale models all perform reasonably well, as does the 150 tcd model in the irrigated situation (though the caveat expressed in Section (1) (b) (i) should be kept in mind).

Direct comparison of the technologies is, however, facilitated if the results are based on a per tonne of sugar per annum (tsa) basis, and the outcome is illustrated in Table 22. It can be seen that, on the basis of the assumptions used, in all situations, irrespective of discount rate or price regime, a ranking of the technologies in terms of NPV per tsa coincides with the ranking by scale of operation.

(a) <u>Sensitivity analysis</u>

An investigation was made into the sensitivity of the results contained in Tables 21 and 22 to the values attached to certain of the technical and economic parameters. Three sets of alternatives were (separately) considered. The first investigates how overall project returns (in rainfed situations) are affected when lower cane yields are obtained through the utilization of less mechanization and reduced fertilizer applications in cane cultivation (i.e. excluding cane transportation, which is left unaltered). The data available suggests that, in certain cane-growing areas a 'low-input low-output' policy (reflecting more reliance on manual labour and obtaining lower yield per hectare) can result in a lower unit cost of cane (per tonne). The detailed (alternative) parameter values are given in Table 14 above: in both long season and short season situations the operating cost per tonne of cane works out at 75 per cent of the corresponding figure used in the calculations underlying the results shown in Tables 21 and 22. The impact that this alternative set of values has on the NPV figures may be seen by comparing Table 23 with these Tables. Despite the cost reduction no overall project in a short season (rainfed) situation is able to earn a positive return; the impact on OPS technology viability in long season situations appears to be more dramatic, since potentially loss-making projects - in the more commonly observed low price regime - now become not only profitable but capable of earning a rate of return comparable to that earned by at least the 100 tch large-scale technology project.

During the course of fieldwork it was observed that average cane yields (for broad cane areas rather than individual smallholdings) varied more in rainfed than in irrigated ecosystems. The yields used in the models representing the rainfed situations are intended to be median values, and a second use of sensitivity analysis considers how the technology performances are affected by a 50 per cent increase 9/ in cane yields per hectare in rainfed models. The results are given in Table 24: as is to be expected the technology ranking order shown in Table 22 is unaffected; despite the increase in agricultural productivity only one of the short season OPS models becomes profit-making even at high prices, 10/ and the 100 tch large-scale technology model also remains loss-making (at low prices). In the long season situation all OPS models now earn a positive return even at low prices.

8/ The analysis is based on cash flows given in real terms.

9/ The yields used in the basic models are shown in Table 1: the higher yields used here are thus 7.5 tonnes and 6 tonnes per hectare per month in the long and short seasons respectively.

10/ The 150 tcd low-input low-output model earns around 4 per cent per annum at high prices.

TABLE 21

Net Present Values and Internal Rates of Return for Plantation Models

	Annual sugar production 000 tonnes	NPV[a] ($ million) @ low prices	NPV[b]	IRR (%)	NPV[a] ($ million) @ high prices	NPV[b]	IRR (%)
Large-scale vacuum-pan							
1. 100 tch							
long season rainfed	55.0	22.2	-5.0	8.7	110.7	30.6	15.0
irrigated	55.0	45.9	7.2	11.7	148.9	53.8	17.3
short season rainfed	30.5	-42.5	-41.5	<0	-28.0	-40.3	1.9
irrigated	30.5	-18.6	-26.3	0.9	12.1	-18.1	6.5
2. 200 tch							
long season rainfed	110.0	96.2	23.7	13.4	308.4	124.0	20.2
irrigated	110.0	142.0	48.0	16.1	384.1	164.9	22.2
short season rainfed	61.0	-34.4	-48.5	0.7	31.0	-26.8	7.1
irrigated	61.0	11.5	-20.2	6.4	105.8	19.1	12.0
Small-scale open-pan[c]							
1. 100 tcd							
long season rainfed	1.31	-0.83	-0.81	<0	0.13	-0.46	5.8
irrigated	1.31	-0.15	-0.44	3.7	1.24	0.14	11.1
short season rainfed	0.73	-2.23	-1.60	<0	-2.86	-2.14	<0
irrigated	0.73	-1.38	-1.08	<0	-1.49	-1.30	<0
2. 150 tcd							
long season rainfed	1.97	-0.63	-0.82	0.4	1.29	-0.02	9.9
irrigated	1.97	0.43	-0.23	7.7	2.96	0.90	14.9
short season rainfed	1.09	-2.77	-2.02	<0	-3.30	-2.57	<0
irrigated	1.09	-1.53	-1.26	<0	-1.28	-1.32	<0

a/ Discounted at 5 per cent per annum

b/ Discounted at 10 per cent per annum

c/ The results shown in this Table are based on agricultural policy relating to inputs and cane yields similar to that applied in the large-scale models

TABLE 22

Net Present Values for Plantation Models

($ per tonne of sugar per annum)

	@ low prices		@ high prices	
Discounted at	5%	10%	5%	10%
1. Long season rainfed				
200 tch	875	215	2804	1127
100 tch	404	-91	2013	556
150 tcd	-320	-416	655	-10
100 tcd	-634	-618	99	-351
2. Long season irrigated				
200 tch	1291	436	3492	1499
100 tch	835	131	2707	978
150 tcd	218	-117	1503	457
100 tcd	-115	-336	947	107
3. Short season rainfed				
200 tch	-564	-795	508	-439
100 tch	-1393	-1361	-918	-1321
150 tcd	-2541	-1853	-3028	-2358
100 tcd	-3055	-2192	-3918	-2932
4. Short season irrigated				
200 tch	189	-331	1734	313
100 tch	-610	-862	397	-593
150 tcd	-1404	-1156	-1174	-1211
100 tcd	-1890	-1479	-2041	-1781

TABLE 23

Impact of Using Lower Costs and Yields in Small-Scale Models[a]

	Long season rainfed		Short season rainfed	
	100 tcd	150 tcd	100 tcd	150 tcd
1. Low price regime				
Revised NPV @ 5%	0.13	0.57	-1.16	-1.34
NPV ÷ tsa	99	289	-1589	-1229
Revised NPV @ 10%	-0.19	-0.02	-0.93	-1.12
NPV ÷ tsa	-141	-11	-1274	-1028
Revised IRR	6.5	9.5	<0	<0
2. High price regime				
Revised NPV @ 5%	1.63	3.09	-1.18	-1.08
NPV ÷ tsa	1244	1569	-1616	-991
Revised NPV @ 10%	0.52	1.20	-1.07	-1.15
NPV ÷ tsa	396	610	-1466	-1085
Revised IRR	15.4	18.9	<0	<0

[a] NPV's measured in $ million, NPV ÷ tsa in $, IRR as %

TABLE 24

Effect of Increasing Cane Yields per Hectare by 50 per cent in Rainfed Situations

	Annual sugar production (000 tonnes)	low price Revised NPV @ 5% ($ million)	low price Revised NPV @ 10% ($ million)	high price Revised NPV @ 5% ($ million)	high price Revised NPV @ 10% ($ million)
1. Long season					
200 tch	110.0	134.72	48.40	370.01	163.40
100 tch	55.0	41.09	7.10	140.57	49.85
150 tcd	1.97	0.43	-0.14	2.97	1.06
100 tcd	1.31	-0.12	-0.36	1.25	0.26
150 tcd[a]	1.97	1.16	0.37	4.02	1.83
100 tcd[a]	1.31	0.52	0.08	2.26	0.94
2. Short season					
200 tch	61.0	2.42	-24.65	88.51	10.96
100 tch	30.5	-24.26	-29.67	0.52	-24.08
150 tcd	1.09	-1.78	-1.37	-1.72	-1.53
100 tcd	0.73	-1.57	-1.17	-1.81	-1.45
150 tcd[a]	1.09	-0.71	-0.66	-0.07	-0.42
100 tcd[a]	0.73	-0.73	-0.63	-0.50	-0.60

[a] 'low-input low-output' models

A key parameter representing factory operation is sugar recovery, often shown as a percentage of cane input though a superior measure is the percentage of sucrose in the cane recovered as sugar since cane sucrose content is itself variable. A figure of 13 per cent has been used - in all models - for sucrose content of cane with recovery assumed to be 81.5 per cent in the large-scale technology models and 50 per cent in the OPS models. The impact on NPV of a given change in recovery may be readily determined. Table 25 shows the change in NPV (at low prices) associated with a 10 per cent variation in the recovery figures quoted above; the change at high prices is double that shown at low prices. A fall in recovery reduces NPV, and vice-versa.11/

TABLE 25

Affect on NPV of Varying Sugar Recovery by 10 Per Cent

(low prices)

	Change in NPV		Change in NPV ÷ tsa	
	@ 5%	@ 10%	@ 5%	@ 10%
	($ million)		($)	
Long season				
100 tcd	0.46	0.26	351	198
150 tcd	0.69	0.39	351	198
100 tch	20.0	11.2	364	203
200 tch	40.0	22.3	364	203
Short season				
100 tcd	0.27	0.16	370	219
150 tcd	0.40	0.24	370	219
100 tch	11.5	6.70	377	220
200 tch	23.0	13.4	377	220

The effect of a given variation in sugar recovery on NPV per tonne of sugar per annum may be seen to be remarkably constant across technologies and season lengths. What is important in specific climatic situations, however, is what variation in recovery is needed in order to enable a particular technology to earn a reasonable return.

Comparison of Table 25 with Table 21 shows for example that in the long season rainfed situations a 20 per cent increase in the recovery achieved by OPS units would be required to allow a 100 tcd project to earn 5 per cent and a 150 tcd project to earn 10 per cent approximately 12/: in the irrigated situations the required increase in recovery to achieve these returns would be only around 3 per cent to 5 per cent. Similarly a 10 per cent reduction in recovery achieved by large-scale projects in the long season rainfed situation would lower their rates to around

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11/ The figures shown in Table 25 for the OPS units apply to both sets of small-scale models since they relate to variations in *factory* efficiency.

12/ The situations illustrated are, of course, the main hypothesis OPS models. Comparison of Tables 25 and 23 enable one to calculate the impact on profitability that variations in factory recovery would have on 'low-input low-output' models.

5 per cent (100 tch) and 10 per cent (200 tch). Sugar recovery may thus be seen to play an important role in the determination of project profitability and in certain situations - especially the long season rainfed case discussed above - the small-scale technology appears the more vulnerable.

(b) Summary of financial profitability results

On the basis of the mainstream set of assumptions the rank order for profitability remains constant across all climatic situations, being perfectly correlated with scale of operation (and hence with technology). Indeed most OPS models fail to achieve a satisfactory rate of return.

Alternative values were selected for certain important parameters in order to examine the sensitivity of the financial results. The cane yields selected for the rainfed situations represented, in the fieldwork countries, a reasonable level of achievement, but improvement of up to 50 per cent was demonstrably seen to be possible. The yields selected for the irrigated situations on the other hand, whilst reflecting current achievement in fieldwork countries were felt to be high by world standards. Hence alternative, higher, cane yields were considered for rainfed situations only. On the basis of cane yield increases of 50 per cent, the rise in profitability in the case of long season models was such as to enable them all to show positive rates of return; alternatively for small-scale models, a 'low-input low-output' policy can be shown to improve the rank order to the 150 tcd model in terms of financial profitability, at the cost of an increased need for cane land.

Higher factory productivity - expressed in terms of increased sugar recovery - even more dramatically increases project returns. Thus, whilst it requires - on the mainstream agricultural assumptions - a rise in cane yields of more than 50 per cent for the 150 tcd long season rainfed model to earn a 10 per cent per annum return, the corresponding increase needed in sugar recovery is only 20 per cent (i.e. 60 per cent recovery). In Indian conditions such an achievement would certainly be expected of the improved OPS technology considered in this Report. How easily it can be achieved when the technology is transferred elsewhere is something that will only be known for certain after relevant experience has been acquired. In principle, however, financial success for this technology in African conditions must certainly be considered feasible.

(3) *Economic Impact of the Technologies*

The calculations presented in Section (1) are based on market prices as observed in a number of African countries. It is well known that such prices can differ, sometimes substantially, from the prices that would correctly reflect a country's supply of resources and social preferences. Use of market prices in project evaluation is necessary, at least as a first step, in order to examine the profitability of the project for the firm or firms which undertake it, but consideration of the contribution which the project can make to the country's social welfare requires that evaluation is carried out in social (or shadow) prices.

In essence shadow prices should be such that input prices reflect the social opportunity cost of using the inputs for the particular purpose , and output prices reflect the utility which the user of the output receives. Measurement of shadow prices is in practice often difficult, requiring substantial information beyond that pertaining to the project. Later in this Section ths performance of the two technologies is compared based on a simplified set of shadow prices, principally investigating their respective dependence on unskilled labour and inputs from abroad. Prior to this analysis their requirements of capital, labour and land are compared and potential linkages with the domestic economy considered.

(a) Technology resource requirements

A commonly used device in comparing large- and small-scale technologies is to calculate the number of small-scale units that are equivalent (in terms of either output or capital input) to one large-scale project. The comparison made below is given in terms of the combined agricultural and factory stages, for the long season rainfed ecosystem. Further data covering both long season situations is given in Table 26.

The sugar output from 56 150 tcd factories would exactly equal that of a single 200 tch factory. The total (i.e. agricultural plus factory) discounted fixed capital cost of these units (at low prices) would amount to $40.0 million, discounting at 10 per cent, compared with $54.5 million for the 200 tch factory. Factory employment would be 14,952 (compared with 633) excluding administrative employees. The required cane area to support these small units would amount to 29736 hectares, compared with 18115 hectares; and agricultural employment would be 14,896 as compared with 6,214 for the 200 tch project. Finally, 504 people would be employed in administration - at 9 per OPS unit - against 223 in the large factory complex. Thus total employment in the 56 OPS units would equal 30,352 compared with 7,070 required to serve a

TABLE 26

Resource Requirements in the Long Season Situations

	Fixed capital[a]		Total employment		Area under cane	
	$ million	$ per tsa	Thousands	Persons per tsa	Hectares	Hectares per tsa
Rainfed						
200 tch	54.5	496	7.07	64	18115	0.16
100 tch	31.9	581	3.83	70	9058	0.16
150 tcd[b]	0.71	360	0.54	275	529	0.27
100 tcd	0.55	420	0.38	289	353	0.27
Irrigated						
200 tch	59.1	537	5.32	48	8905	0.08
100 tch	34.4	625	2.94	53	4453	0.08
150 tcd[b]	0.78	396	0.49	249	261	0.13
100 tcd	0.60	457	0.34	262	173	0.13

[a] Discounted at 10 per cent per annum (low prices)

[b] The OPS models shown here are based on the mainstream agricultural assumptions

single 200 tch factory.13/ Comparison of requirements, expressed on a per tonne of sugar per annum basis, for all four scales of production considered, is shown in Table 26.

Assuming that sufficient resources are available to operate the larger size of project (for either technology) at the same unit prices as paid by the smaller size (for example that 18115 hectares of suitable land can be put under cane at the same cost per hectare as 9058 hectares), the financial superiority of increased size (within each technology) is shown to be unsurprising. Basically the larger scale of operation uses less of each resource per unit of output, both in the VP and in the OPS technologies.

A comparison of the two technologies - on a per tonne of sugar per annum basis - reveals that compared with the 200 tch model 56 150 tcd projects would use 27 per cent less capital, provide 329 per cent more employment and require 63 per cent more cane land in order to produce the same quantity of sugar per annum.

Small-scale projects in the long season rainfed situation, which are based on the less mechanized agricultural system (Table 14) would use still less capital (only 52 per cent that of the 200 tch model), provide 425 per cent more employment and require 106 per cent more cane land.

(b) Sugar technology linkages

There are two major areas where a sugar project might yield external benefits to an economy resulting from its input requirements. Firstly an indigenous engineering industry might develop in order to produce pieces of equipment and spare parts. Secondly the project's needs for skilled manpower are likely to be such, in relation to available supply, that a considerable training effort will be undertaken.

Given the relatively low level of industrialization in many developing countries it is worth considering whether or not a new industrial (or agro-industrial) project will further the process of industrialization or have to import all the required equipment throughout the project life. Even when the benefit from the project in terms of foreign exchange savings outweigh the additional import requirement for replacement capital the latter course means that a stage in the development process has not been reinforced.

Vacuum-pan factory plant and equipment in developing African countries is almost entirely imported; similarly spare parts are very largely purchased from developed countries. A change in this situation would seem to require either the emergence of an indigenous engineering industry with proven quality control standards or the creation of suitably large workshop facilities within the sugar industry itself. This latter option does seem potentially possible (technically) at present in certain countries: it may be commercially attractive in countries where spare parts are highly taxed or subject to considerable delay in transit, but usually the scale of production of individual parts to serve a few factories is insufficiently high for economies of scale to be enjoyed - and this may be an important factor in determining outside suppliers too.

In the case of OPS units the proportion of equipment which may be potentially manufactured domestically seems promising. Expenditure

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13/ It may be argued that comparison of employment generated by the two technologies should consider multiplier effects, and in particular the additional employment arising from input and output linkages. As is argued in Section (b), supported by fieldwork observation, little such benefit may be shown to have accrued as yet in most developing African countries from the establishment of large-scale (vacuum-pan technology) sugar factories beyond the training benefit which is explicitly valued in Section (b).

on tanks, heating bels and furnaces comprises about 25 per cent of the FOB value of plant and equipment, whilst filter presses and crystallizers account for a further 25 per cent. Given the relatively low value to bulk density of these items - and hence the relative importance of transport cost - it ought to be practical for domestic manufacturers to produce them at or below their CIF price. Hence it can be expected, depending on the status of the engineering industry, that up to 35 per cent of the equipment (allowing for imported materials) might be manufactured locally, at least within a few years of the introduction of such plants.

In well-managed vacuum-pan factories it is customary to find training programmes organized within the factory, both to upgrade employees (from unskilled to semi-skilled, for example) and to produce supervisory staff. The opportunity cost of employees trained within the project is the rate they were previously earning (as unskilled labour for example).

Instead of reducing the market wage now being paid to a shadow wage rate reflecting opportunity cost internally trained employees can be priced at the market wage rates paid to them and the value of training appear as an additional benefit. This latter approach is adopted here in order to illustrate the benefit which training can yield.

The internal benefit of training is based on the following assumptions: that semi-skilled employees, trained on the job, have a social opportunity cost equal to that of unskilled employees; that skilled workers have a social opportunity cost 25 per cent below the market cost of employing them; and that supervisory staff also have a social opportunity cost equal to 75 per cent of the market cost of skilled workers. The estimate of the social benefit of training is thus the difference between the market cost and the social opportunity cost, and this is calculated (on a discounted cash flow basis) over the project life. The present value of training, discounted at 10 per cent per annum, is estimated to be $4.4 million ($3.0 million) in the 200 tch long season rainfed situation (100 tch figure in brackets) and $3.7 million ($2.7 million) in the 200 tch long season irrigated situation.

A sugar project can also introduce linkages on the output side, when one of its by-products is used in further processing. The scope for such utilization is discussed in Section (4).

(c) Shadow pricing

The variables for which alternative, shadow prices are used have been selected to reflect the more common price distortions to be found in many developing countries.

Labour requirements are sub-divided into unskilled labour, which receives a basic minimum wage (often set by government statute), and other labour which receives a premium reflecting at least to some extent the relative scarcity of skilled people. As discussed above, the payment to the latter category of employee has not been adjusted (downwards) in the social cost-benefit calculation; instead the value of training is used as a measure of the additional benefit which training provides. The shadow wage for unskilled labour is taken as 50 per cent of the market wage. 14/

14/ This is close to the figure derived in several studies. See, for example, Roemer M. & Stern J.J., *The Appraisal of Development Projects*, Praeger, New York, 1975 (for data relating to Ghana) and Stern N.H., *An Appraisal of Tea Production on Small Holdings in Kenya*, Development Centre Studies, OECD Paris, 1972.

Taxation of inputs used by sugar factories varies considerably from country to country, but for most industrial inputs except those associated with road transport vehicles (cars, pick-ups etc) tax levied is not large. For simplicity it is assumed here that tax is levied on only three items, *viz.* vehicles as defined above, fuel consumed by these vehicles and housing equipment.

It is not uncommon in developing countries for foreign exchange to be undervalued with the consequent excess demand for it blocked by use of controls of various kinds. Such a situation is not surprising, especially if many of the capital goods and a number of important raw materials/intermediate goods have to be imported whereas export earnings are based on a narrow range of commodities. It is assumed here that the shadow exchange rate (if tariffs, import controls etc were abolished) would be 25 per cent greater than the official rate (i.e. the shadow price of imported goods is 25 per cent higher than the market price).

The other major area where consideration of price correction is important is in the calculation of revenue. In the financial calculations sugar is priced at $300 per tonne (low price) and $600 per tonne (high price). At present (May 1977) the world market price for refined sugar, CIF African ports, is around $260 per tonne. Most long-term sugar transactions are settled at prices above the prevailing world market price and even without allowing for the possibility that the present world price is below its equilibrium trend price it would seem reasonable to take $300 per tonne as the CIF price for sugar in Africa; since sugar is an import-substituting product the social value of sugar production is raised by 25 per cent over commercial value, *viz.* $375 per tonne ex-factory, if it is assumed that internal distribution cost from the factory is the same as that from the port. This price for sugar is used in both low and high price models.

The shadow price for molasses is increased by 25 per cent to represent the effect of the shadow exchange rate. In the financial calculations the molasses price was already based on world market price.

Application of the shadow prices and resulting conversion factors to the calculations undertaken to measure private profitability shows a considerable change in the results for the various models. Firstly, because the shadow price for sugar is 38 per cent below the high price of $600 per tonne, all short season models evaluated at high prices now show considerable losses, whilst the higher shadow price is insufficient to make the low price models profit-making. Attention is therefore focused on a comparison of large-scale and small-scale units in the long season situations, given in Table 27 below. Comparison with the corresponding results for private profitability in Table 21 show that social returns are higher, given the shadow price conversion factors, than private returns. Furthermore, in the case of the basic models, the profitability gap between the technologies narrows. Social returns from the less formal (rainfed) agricultural models in fact are higher than those from large-scale factories, which suggests that even a partial realization of the cost reduction per tonne of cane would enable OPS units to obtain comparable social returns to those yielded by large-scale projects.

As a final comment, it is worth noting that at the lower rate of discount, the 200 tch model yields a higher NPV per tsa than does the 150 tcd model,whereas at the higher rate this ranking is reversed.

TABLE 27

Measures of Social Profitability
(low prices)

	IRR %	NPV[a] $ million	NPV ÷ tsa $	NPV[b] $ million	NPV ÷ tsa $
Long season rainfed					
200 tch	17.6	173.7	1579	63.4	576
100 tch	12.9	59.9	1089	14.2	258
150 tcd	10.1	1.04	528	0.06	31
100 tcd	7.4	0.25	191	-0.24	-183
150 tcd[c]	23.7	2.79	1420	1.23	626
100 tcd[c]	19.5	1.57	1198	0.62	473
Long season irrigated					
200 tch	19.9	207.1	1883	86.6	787
100 tch	15.2	79.0	1436	26.4	480
150 tcd	15.6	1.94	983	0.70	354
100 tcd	11.7	0.84	642	0.14	104

[a] Discounted at 5 per cent

[b] Discounted at 10 per cent

[c] Low-input low-output agriculture models

(4) *Effects on the Physical Environment*

This section of the discussion on the all-plantation models is sub-divided into five categories, as detailed in Chapter II. The first three categories, namely air, water and land, are in fact components of a strict definition of the physical environment. The remaining two topics, energy and by-product utilization can be considered as 'physical' aspects especially with regard to inputs, but may have considerable economic significance to the sugar industry and to individual developing countries.

(a) Air

In most developing countries the question of air pollution has probably not been examined very closely. The process of environmental lobbying tends to begin with cities and rivers 15/ while sugar production is an agri-based, industrial activity. Air pollution by the industry has two principal sources: cane burning and fuel combustion in the factory.

The open field burning of cane represents a comparatively recent strategy, involving a sacrifice in sugar output so as to improve harvesting productivity.16/ Cane is normally burned a few hours before harvesting but in order to reduce the fire hazard and to improve the efficiency of the burn, the operation is usually carried out in blocks of less than 10 ha, and whenever possible in dry and calm conditions. Visually a cane fire produces large clouds of black smoke. The composition of these clouds, however, is basically steam and partially burned vegetation (particulate matter). Particulate matter has been found to have potential environmental effect in relation to human health, materials deterioration and visibility reduction. The first two of these, however, depend on a high concentration of particulate matter in conjunction with high sulphur dioxide and moisture contents. In rural African situations such high levels of sulphurous gases are unlikely to be found.

A study carried out in Florida, on behalf of the U.S. Environmental Protection Agency has shown that air quality does not change significantly between the harvest and non-harvest seasons although in certain local situations nuisance levels of particulate matter may be reached.17 / It may be assumed that the nuisance created by a cane fire is directly related to the population density within the fall-out area. Emissions from cane burning per tonne of material burned have been estimated at 4kg particulates, 35kg carbon monoxide and 5kg hydrocarbons.18/ This is well within the normal emissions from agricultural burning, with for example 8kg, 50kg and 10kg respectively from a grass fire. The relevant unit for determining the nuisance level of emissions, however, is not per tonne but per hectare. In this respect cane burning is much less favourable due to the physical quantity of material involved; a high yielding cane crop can produce combustible trash of the order of 25t/ha whereas most field crops fall into the range of 2-5t/ha.

15/ See "Air Pollution in the Developing Country" by M.G. McGarry in *New Concepts in Air Pollution Research* edited by J.O. Willums, Birkhauser Verlag, 1974.

16/ See Section (c) of this Chapter.

17/ E.R. Hendrickson, *Status of Air Quality in the Sugar Cane Area of Florida*, presented at the Annual Meeting of the American Society of Sugar Cane Technologists, Palm Beach, Florida, U.S.A., October 1970.

18/ E.F. Darley and S.L. Lerman, *Air Pollution Emissions from Burning Sugar Cane and Pineapple Residues from Hawaii*, EPA-450/3-75-071, North Carolina, U.S.A., July 1975.

Current legislation in the U.S.A. allows cane burning only under licence and only at times when climatic criteria, particularly related to wind and thermal inversion, are met.

The pollutants emitted by the factory furnaces are potentially more hazardous. In the case of the major source of fuel - bagasse - the main problem is one of particulate matter, *viz.* flyash. Due however, to the variability of bagasse in quantity and composition throughout the crushing season and its low fuel value, supplementary fuel is usually required. This may take the form of electricity, heavy oil or firewood and other agricultural residues. It is the use of fossil fuels that poses the greatest environmental questions. However, apart from the global problem of increasing levels of sulphur dioxide in the atmosphere, the immediate local impact is determined by prevailing climatic conditions, particularly wind patterns, and the proximity of other industrial emissions.

A contrast between the vacuum-pan and OPS technologies lies in the efficiency of combustion. The former employs sophisticated bagasse boilers which produce steam for electricity generation and proces heating; supplementation usually by oil is kept to a minimum. The OPS units using simple wet bagasse furnaces require a greater proportion of supplementary fuel, but mainly firewood and electricity. Although the technology exists to control factory stack emissions, it is expensive (say $100,000 for the installation of a wet scrubber) and yields no financial return to the project. This is unlike, for example, chemical recovery as part of water pollution control and may explain the tendency for air pollution control to be neglected until water has been dealt with. The process of industrialization has shown, however, that if air is treated as a free good air quality deteriorates; the resulting processes of declining health standards and deteriorating materials quality may be very difficult to reverse.

(b) Water

It is logical to begin a discussion of water with its use as a primary input and hence a comparison of the rainfed and irrigated models. The historical development of modern rainfed agriculture has had marked, but generally anticipated ecological consequences (for example the weakening of a system by a reduction in its diversity). The introduction of water to an arid region or a change in seasonality however, can have and indeed has had physical, social and economic consequences reaching far beyond the boundaries of a specific project; to cite one example, the impact of the regulation of the River Nile has been well documented.19/

In the establishment of an irrigation system a guaranteed supply of water is fundamental. This may involve the flooding of fertile valleys or, possibly on a smaller scale, the tapping of groundwater resources. The regulation and diversion of a river system abruptly changes the eco-climatic conditions and inevitably the flora and fauna supported by a particular area. The utilization of groundwater, assuming it is chemically suitable for the purpose, may proceed with a more localized impact, but its uncontrolled use can lead to a lowering of the water-table over a wide area. In fact, in any planned irrigation system the maintenance of the ground watertable or its controlled adjustment by the integration of a drainage programme is of prime importance in determining the success or failure of the enterprise in both the short and long terms; the critical events are drought, water-logging and accumulation of salts.

As an output from agricultural operations, whether rainfed or irrigated, agricultural run-off can lead to several problems. The risk

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19/ See for example papers by George, Kassas and Worthington. pp.159 *et seq* and Van der Schalie pp.116 in *The Careless Technology: Ecology and Economic Development*, New York 1972 edited by M.T. Farvar and J.P. Milton.

of soil erosion is likely to be greater in the rainfed conditions where cane may be grown on sloping land and where rainfall is typically seasonal and of high intensity. In the irrigated situation areas tend to be selected which are relatively flat or easily shaped but on the micro-scale furrow erosion and silting up of canals can be significant in financial terms.

In plantation agriculture where consolidated land units can be surveyed and field layouts planned at the outset, erosion control techniques ranging from contour ploughing to terracing can be incorporated. The cost of soil erosion control, at varying degrees of sophistication, could be calculated for a given project site. However, the long-term benefit to cane cultivation, and the benefit of a reduction in the sediment load of the river system are much more difficult to assess.

The run-off of plant nutrients, mainly from the application of artificial fertilizers, is influenced by soil type, recent rainfall or irrigation, and the frequency and rates of application. The impact of run-off depends on the area of the plantation and the individual areas being treated at one time; the resultant eutrophication of waterways is likely to be more severe in the larger cane growing units, particularly if the drainage layout directs run-off towards a limited section of a river system. Eutrophication is most often discussed in connection with developed countries where fertilizer application rates and other industrial discharges are considerably greater than in present African conditions. It should be borne in mind, however, that the drainage of plant nutrients is a waste of a very useful and expensive commodity. Major components of agricultural research, particularly in large-scale factory/plantation complexes, are the assessment of optimum fertilizer application rates; determination of the time of application for maximum utilization by the cane crop and minimum loss in field drainage; and the identification of the most appropriate types of fertilizer for local soil conditions.

As an output from the industry, sugar factory effluent tends to vary between factories of basically similar proces but would also appear to be markedly different qualitatively and quantitatively between the vacuum-pan and open-pan technologies. The absence of analytical data from OPS units prevents the presentation of the numerical differences between the two.

In vacuum-pan factories the volume of water used, mainly in the form of steam, is of the order of 20,000 litres per tonne of cane. Most of this is condenser water which, up to a point, is cooled and re-circulated. During the boiling process, sucrose becomes entrained in the vapour and so with re-circulation condenser water is gradually contaminated and has to be discharged. Modern vacuum-pan factories should be able to keep entrainment (and sugar losses) to a minimum. Basic factory hygiene can have a marked influence on the quantity and quality of effluent. Two examples are the prevention or reduction of material spillages (juice, syrup, oil etc.) and a minimum of 'hosing down' as a means of floor washing.

In the OPS technology the reliance on direct heating as opposed to the use of steam greatly reduces the volume of water required for the production of sugar. It would seem a reasonable assumption, however, that factory hygiene would be of lower standard, particularly with regard to spillages of juice and syrup carried between various stages of the process.

Two analytical components of water pollution of major interest in the sugar industry as Biochemical Oxygen Demand (BOD) and Suspended Solids (SS). BOD represents a measure of the substances present in the effluent which, on decomposition, use up oxygen. In polluted water severe deoxygenation kills or stunts the growth of fish, aquatic micro-organisms and vegetation. The major contributor to BOD in sugar mill effluent is sucrose from spillages and entrainment.20/ Suspended solids, consisting of fine bagasse fibres, floor washings etc can have the effect of silting up waterways and of weakening aquatic life, for example, by coating the river bed or clogging fish gills. The chemical composition of factory effluent is not a serious concern, with a minimal use of chemicals for the control of bacterial growth in pipes and for de-scaling. The main chemicals are sodium hydroxide and hydrochloric acid and these are discharged together to keep pH around neutral.

It is evident that factory efficiency is intimately associated with environmental protection as for example a high BOD value suggests high sugar losses. 'Good housekeeping' is a useful catch phrase when trying to bring industrialist and environmentalist together. It is simply a first step in pollution control with an economic benefit to the industry. It is conceivable that in many cases the achieved reduction in BOD and SS would be adequate, without the need for substantial capital investment in water treatment.21/

Conventionally BOD and SS are expressed on a concentration basis and a national standard is commonly set for all industrial discharges. It is preferable although more complex, however, to consider BOD and SS in terms of load (i.e. concentration times volume expressed in kg/day) and to relate the standard for a specific outlet to relevant characteristics of the receiving waters; 22/ these include rate and volume of flow, ambient temperature, other discharges upstream, and consumption requirements of the water downstream. Choosing one standard rather than the other i.e. concentration versus load, alters the relative significance of effluents from the two sugar technologies: the large-scale vacuum-pan unit has lower concentration but enormous volume, while the small-scale OPS unit probably has a higher concentration but significantly lower volume. This is illustrated in Chapter V where both measures are presented in the matrices (Tables 1-8).

The question of effluent quality appears to be less important in the irrigated as opposed to the rainfed situations. The impact of BOD and SS levels is removed by the application of effluent to the cane crop rather than to the local river system. This is only valid, of course as sugar mill effluent contains no substances likely to be toxic to the crop. Agricultural run-off should not be affected as quantities of dissolved nutrients are negligible when compared to fertilizer application.

An interesting comparison arises between the long and short season, rainfed situations, if it is assumed that relatively strict environmental standards are imposed. In the long season, a water treatment plant would have to be installed to deal with the daily discharge of effluent. In the short season situation, the standards could be met by a simpler technology which is land-intensive, rather than capital-intensive *viz.* only one third of the daily discharge need

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20/ Although in some parts of the world, filter mud is discharged as part of the effluent hence contributing significantly to BOD and SS, it is assumed in this Report that mud is partially dried. As a solid it is considered as a factory by-product. See Section (d) of Chapter III.

21/ A figure of 10 per cent of the capital cost of a new sugar mill for pollution (air and water) control in U.S.A. has been estimated. Personal communication, F.C. Schaffer & Associates Inc., Baton Rouge, Louisiana, U.S.A., July 1977.

22/ B.S. Meadows discusses the transfer of effluent standards from U.K. to Kenya and the research underway to enable the setting up of more realistic standards for local conditions in *Effluent Standards in Kenya*, a paper presented at the Seminar on Sewage Treatment, Dept. of Civil Engineering, University of Nairobi, November 1973.

be passed to the river each day. In this way primary treatment by lagooning (anaerobic digestion, settling of solids and overflow of clear surface water) would probably be adequate.

(c) Land

The creation of a plantation, whether rainfed or irrigated involves either the extensive clearance of natural vegetation or the consolidation of previously cleared smallholdings. As a generalization an area suitable for the rainfed cultivation of cane would be found in a zone with forest as the climax vegetation, while a typical area requiring irrigation would be a fairly level river valley site with a climax vegetation of grass or scrub. In the establishment of a plantation, the inputs (manual and mechanical) for initial land clearance are considerably greater in the former situation. In environmental terms, clearance in either of these ecological zones has local impact but also contributes to global processes. In the rainfed case, deforestation often leads to rapid soil erosion - which is directly related to the area involved - and depletion of soil fertility at the local level. On the global level, it is possible that deforestation influences weather patterns in particular precipitation and its distribution; it follows that the greatest impact would be on marginally dry regions, already feeling the effects of desertification. In the more arid areas, clearance of the sparse vegetation can cause problems of soil erosion (by wind, for example), but when part of a well-planned development project, a fertile oasis may result. Moving from rainfed agriculture to a zone where crop production is only feasible with irrigation, the risk factor increases sharply and consequently greater emphasis is placed on high levels of pre-planning and site management.

In the set of plantation models, a common sequence of agricultural operations is assumed. The principal factors in the maintenance of high cane yields on a continuous cropping basis are timeliness of operation and good soil management. In the first of these large-scale plantation agriculture would appear to have an advantage over the small-scale having a high standard of skilled management and the numbers and types of equipment required to carry out the necessary cultivation operations near the optimum time.

On the question of soil management, the large-scale may also have the advantage but the case is not so clear- cut. On the one hand a large-scale project's agronomy department may rightly place priority on surveys of plantation soils and the determination of, for example, cane cycles, fertilizer requirements, and optimum irrigation intervals, for each category of soil. In small-scale projects individual units are unlikely to have the financial or manpower resources to carry out this type of work, although it may be worthwhile to operate a central extension service between a number of small units.

As a counter to this argument, however, the cost and logistics of closing down the vacuum-pan factory for want of cane, caused by wet weather is very much greater than for the OPS units. For this reason harvesting, and the movement of machinery on the soil may continue on occasions when the physical condition of the soil makes this inadvisable. At this point it is convenient to return to the question of burning of cane. The litter remaining after green cane harvesting acts as a surface mulch. In certain soils and climatic conditions this mulch can protect the soil from capping by torrential rain; conserve moisture; suppress weeds; and have a slight fertilizing effect. Surface litter, however, can also carry over pests and diseases and without windrowing the litter would inhibit ratooning in the same way as it suppresses weed growth. For the sake of harvesting productivity, however, cane is normally burned before harvesting, and the loss of the advantagesof a surface mulch is relatively easily remedied by modern agricultural practices - such as by the judicious application of fertilizer, deep ploughing and scientific weed control.

As a general rule, soil deterioration, for example by compaction, is greater the more mechanization involved. A discussion of a highly mechanized cane production system is given in Annex III of this Report. The most damaging operation is probably mechanical harvesting in wet weather; a harvester travels along the furrow bottom while cutting cane stalks at or just below ground level. The effect on the soil is compaction in the furrow, surface capping and a general loss of structure in the topsoil. More visible effects are the condition of the cane supplied to the factory, particularly the content of extraneous matter; and at a later date the condition of the ratoon crop. The degree of damage, however, depends on the soil type. Tropical black clay soils (*vertisols*) become very plastic and sticky after rain and are generally very difficult soils to work either by traditional or modern means. Their main advantage is the inherent high fertility. Tropical red soils (*oxisols*), on the other hand, are well drained with a strong granular structure and thus are particularly suited to mechanized operations. Inherent fertility, however, is low and fertilizer requirements high. It is interesting to note that the addition of organic matter - in the form of surface litter, filter mud etc. can improve considerably the condition of both these soil types. In the first case permeability and workability in wet conditions would be improved and in the second case the effect would be greater moisture retention for the benefit of the growing crop in dry conditions.

The use of mechanization in a fully irrigated regime would not, under normal circumstances, be faced with the same problems as the normal practice is to stop giving water for 1½-2 times the irrigation interval before harvest. This is to encourage ripening of the cane but also to allow the soil to dry out before heavy equipment is put on the land.

(d) By-product utilization

As the major by-products of the sugar industry - bagasse, molasses and filter mud - are produced in the factory processing stage, this discussion is confined to a comparison of the outputs of the vacuum-pan and OPS technologies. Table 28 shows the output in tonnes for each scale of operation and season length.

TABLE 28

Output (tonnes) of Cane Sugar By-Products at Various Scales of Operation

	Bagasse (wet)[a]	Molasses[b]	Filter Mud[c]
Long season			
200 tch	311,040	36,288	51,840
100 tch	155,520	18,144	25,920
150 tch	10,605	1,288	1,212
100 tcd	7,070	858	808
Short season			
200 tch	172,800	20,160	28,800
100 tch	86,400	10,080	14,400
150 tcd	5,880	714	672
100 tcd	3,920	476	448

[a] 30 per cent on cane in 200 and 100 tch models and 35 per cent in 150 and 100 tcd models

[b] 3.5 per cent on cane in 200 and 100 tch models and 4.25 per cent in 150 and 100 tcd models

[c] 5 per cent on cane in 200 and 100 tch models and 4 per cent in 150 and 100 tcd models

Bagasse is the cane fibre remaining after the extraction of juice, with a composition of 43-52 per cent fibre, 46-52 per cent moisture and 2-6 per cent soluble solids. The composition is affected by efficiency of milling, cane variety and maturity and cane deterioration since harvesting. Production of wet bagasse is assumed to be 30 per cent in the vacuum-pan technology from a cane of 15 per cent fibre. In the OPS technology, largely due to the difference in milling efficiency, production is taken to be 35 per cent on cane.

The most natural use for bagasse is as boiler fuel to power the sugar factory, or to burn in the furnaces in the case of an OPS unit. Unless the cane fibre content is very low an efficient vacuum-pan factory should be virtually self-sufficient in fuel, and discussion of potential uses for bagasse implies that either an alternative fuel can be provided or that the quantity of bagasse available is surplus to factory requirements. In a situation where there is a demand for fibre and where an economic alternative source of fuel is available (and is environmentally acceptable), bagasse can successfully be used, for example, as a raw material in the production of paper and board. In this type of industry where economies of scale appear to exist, the factory situation with the largest annual output of bagasse would be the most attractive. The much smaller output of OPS unit or a number of scattered units is unlikely to be of interest to a producer, particularly as the low bulk density and the inflammable nature of bagasse makes it very costly to transport and store. The problem of transport and storage is also the main aspect of a comparison between long and short seasons, with the long season production being most suited to supplying a year-round secondary industry.

This substitution, however, assumes that an alternative fuel source is available at low cost. In practical terms this assumption is not valid except perhaps where cheap hydroelectric power is available. In any case, with the present plights of developing countriss facing rapidly increasing fuel import costs, and the global problem of the depletion of non-renewable resources, it is unlikely that a valid case could be made for complete substitution of a material which represents a valuable and annually renewable source of energy.

Of course, the demand for fibre-based products such as paper or packaging board is increasing, although still relatively small in most developing countries. The most common source of fibre is wood and as a locally produced commodity or as an import, wood pulp is expensive in monetary terms and its production or over-production from a given area can be very damaging to the physical environment. Therefore an environmentally preferred situation could be one of a compromise between increased oil use and deforestation. This can be achieved, in the case of the vacuum-pan technology, by the utilization of a bagasse surplus; the actual amount is determined by the local fibre % cane and the factory design (steam balance). This is also discussed in Section (e) below.

The OPS technology already has a heavy dependence on supplementary fuels with the bagasse (at 35 per cent on cane) being sufficient only to fire the furnaces below the boiling bels, even then with the addition of other agricultural residues and firewoods is necessary. Potential improvements in this area are discussed in Chapter VI of this Report.

Molasses is the viscous liquid remaining after repeated crystallization and centrifugal separation of sugar. It commonly contains 30-40 per cent sucrose and other non-crystallizable sugars, and is produced at a rate of about 3.5 per cent on cane in the vacuum-pan technology and 4.25 per cent on cane in the OPS technology. As with bagasse, potential buyers of molasses as a raw material would tend to deal with the larger producers and by-pass the OPS units. This is particularly true where molasses is to be used for fermentation and distillation, either in domestic distilleries or after exportation to Europe or North America. The most common product is industrial alcohol, for which the domestic markets in Africa are normally quite small. There is, however, an increasing interest in the production of power alcohol for blending with petrol (as in Brazil).23/ This would appear to be a relatively large-scale enterprise, taking molasses from several large factories to a central distillery. The feasibility of pooling the production of OPS units would depend on distance and accessibility. Molasses from OPS units has a higher sugar content, due to lower sucrose recovery, hence should of slightly more value to a fermentation-based industry. Fermentation and distillation can cause severe pollution problems if the spent mash is discharged to a river system. As with factory effluent, discharge to an irrigation system relieves the problem somewhat. Spent mash, however, has a high potash content which can be recovered by incineration; alternatively the mash can be further processed to cattle feed yeast. In this way the cost of reducing the pollution caused by the disposal of spent mash can be recovered to some extent.

There is, however, an alternative use of molasses which has greater flexibility in terms of scale of production, namely as a constituent of cattle feed. The process of mixing molasses - a high energy feed - with water and small amounts of supplementary vitamins, minerals and non-protein nitrogen can be carried out in large vats with rotary agitators, or in simple vessels of a few litres capacity. The former would tend to be associated with a larger output of raw material and possibily with a sophisticated market such as a feedlot, feeding high but controlled rations. The latter can obviously be done on a very small scale with the customers more likely to be local farmers, possibly cane outgrowers, who wish to feed low levels (say 2kg/head/day) of the concentrated feed in times of fodder shortage or as an appetite stimulant which helps to increase the intake of poor quality fodder. A market of this kind may be more difficult to establish, as traditional farmers may take time to accept the product and realize its advantages. The problem of carrying a liquid feed in containers which may be more costly than the feed itself can be overcome by the use of an absorbent material such as agricultural waste, sawdust or bagasse.

Filter mud is produced in the settling process after juice clarification amounting to 4-5 per cent on cane, of which 60-80 per cent is moisture. As a fertilizer/soil conditioner it contains 1-4 per cent CaO, 1-3 per cent P_2O_5 and 0.5-1.5 per cent MgO and a benefit accrues, particularly as regards phosphate, from the application of large quantities such as 15 tonnes per hectare. Filter mud may also be up to 30 per cent fibre, a useful addition of organic matter.

If it is assumed that the output of filter mud is evenly spread over the plantation at a rate of 15 t/ha the proportion so treated each year would be almost 20 per cent in the 200 tch, long season; 15 per cent in the 200 tch, short season; 15 per cent in the 100 tcd long season; and 12 per cent in the 100 tcd short season. This suggests that the large-scale plantations would reap potentially greater benefits from filter mud than the small-scale ones. However, in practice the reverse is probably true. On a large-scale plantation, the question of distance and transport costs comes into play. Filter mud is a very high-bulk, low-value material and the normal practice is to dump it in end-of-cycle cane fields close to the factory, basically as a means of disposal rather than as part of the cultural operations. On the small-scale plantations it should be simpler and more beneficial to have a systematic distribution of filter mud throughout the cane area.

(e) Energy

Energy production and consumption are subjects of ever increasing importance as the depletion of non-renewable resources becomes

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23/ See A.L. Hammond, "Alcohol: A Brazilian Answer to the Energy Crisis", *Science*, Vol.195, p.564, February 11, 1977.

apparent. In this connection the sugar industry is particularly interesting, with a marked contrast between the vacuum-pan and open-pan technologies and also with current trends in the field and factory operations which have opposite consequences.

An analysis has been made of the energy intensity of the two technologies, each at two scales of operation and set in four climatic regimes. Account has been taken of the establishment of the plantation and factory. Annual operations include inputs of fuel, equipment, chemicals and labour. Sugar distribution has been added using a theoretical model of an evenly distributed population around a central sugar producing unit. The results, in terms of MJ per tsa, in agriculture, factory and distribution categories are presented in Table 29. The Table also shows the results on an index basis with 100 representing the lowest energy consumption in each climatic regime.

In the agricultural stage the specific operations necessary to supply the required quantity of cane to the factory gate have been held constant with the exception of cane loading; it is by grab loader in the 200 and 100 tch models and by hand in the 150 and 100 tcd models. In general, therefore, the energy input per hectare or per tonne of cane is similar, but as illustrated by Table 29, the conversion to a per tsa basis puts the large-scale models at a considerable advantage - of the order of 70 per cent.

In the world's sugar industry, the current trend is towards mechanization of agricultural operations and, in particular, of cane harvesting.[24] The energy consumption of a more capital-intensive agricultural system has been calculated. The system involves mechanical planting and fertilizing and a greater dependence on chemicals and inter-row cultivation for weed control; harvesting is by chopper harvester with direct loading to infield haulers.

Although greater mechanization is potentially applicable to the small-scale plantations mechanization of harvesting would be impractical as one harvester can cut up to 60 tch. It seems more realistic to compare the small-scale models with the 'low-input low-output' strategy making more use of labour and less of artificial inputs. The consequent reduction in yield and hence increased area has been taken into account. Table 30 shows the energy intensity of the labour-intensive and capital-intensive agricultural strategies compared to a semi-mechanized system or standard practice used throughout this Report the results of which are given in Table 29.

In the factory stage the basic difference between the technologies, namely vacuum- and open-boiling pans, gives a major contrast in the operating energy pattern. Unlike the agricultural trend, the modernization process in the factory has made the vacuum-pan factory virtually self-sufficient in its fuel requirements. In fact, with carefully designed steam economy, the vacuum-pan factory can be a net producer of electricity (see below).

The supplementary fuel requirement of the OPS unit amounts to two times more energy per tsa than the 100 tch, short season and six times more than the 200 tch, long season factory. However, as Table 29 shows, the factory energy total, allowing for all other inputs and factory establishment, the relative positions are much closer and in the short season the OPS unit appears considerably less energy using than the vacuum-pan factory. This seems to suggest that the less sophisticated equipment reduces the overall energy intensity of the OPS system and there is also considerable scope for improvement in the supplementary fuel requirement without, perhaps, going as far as closing the boiling pans. (See Chapter VI of this Report for a discussion of possible research and development work.)

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[24] For a fuller discussion of a highly mechanized agricultural system see Annex III of this Report.

TABLE 29

Energy Consumption (MJ per tsa)

	Agriculture		Factory		Distribution		Total	
	MJ	Index	MJ	Index	MJ	Index	MJ	Index
Long season rainfed								
200 tch	4,598	102	4,458	100	547	927	9,603	100
100 tch	4,520	100	5,244	118	385	653	10,149	106
150 tcd	7,463	165	4,759	107	72	122	12,294	128
100 tcd	7,609	168	5,069	114	59	100	12,737	133
Long season irrigated								
200 tch	4,457	100	4,458	100	547	927	9,462	100
100 tch	4,578	103	5,244	118	385	653	10,207	108
150 tcd	7,707	173	4,759	107	72	122	12,538	133
100 tcd	7,871	177	5,069	114	59	100	12,999	137
Short season rainfed								
200 tch	7,157	101	6,908	130	407	925	14,472	100
100 tch	7,073	100	8,252	155	289	657	15,614	108
150 tcd	12,007	170	5,327	100	54	123	17,388	120
100 tcd	12,118	171	5,804	109	44	100	17,966	124
Short season irrigated								
200 tch	6,345	100	6,908	130	407	925	13,660	100
100 tch	6,416	101	8,252	155	289	657	14,957	109
150 tcd	10,954	173	5,327	100	54	123	16,335	120
100 tcd	11,302	178	5,804	109	44	100	17,150	126

TABLE 30

Energy Consumption in Alternative Agricultural Technologies

	Labour-intensive	Standard[a/]	Capital-intensive
Long season rainfed			
200 tch		100	121
100 tch		100	113
150 tcd	82	100	
100 tcd	83	100	
Long season irrigated			
200 tch		100	118
100 tch		100	112
Short season rainfed			
200 tch		100	138
100 tch		100	136
150 tcd	77	100	
100 tcd	77	100	
Short season irrigated			
200 tch		100	140
100 tch		100	129

[a/] 'Standard' refers to the semi-mechanised system of cane production used throughout the Report and the figures presented in Table 29

The energy involved in the distribution of sugar to the consumer illustrates the advantage of the small, decentralized units over the larger units when the population is evenly distributed around them. In reality, however, the location of the producing units in relation to the centres of population and the characteristics of a country's population distribution and consumption patterns may significantly alter the rankings.

As mentioned above, a vacuum-pan factory can be designed in such a way as to generate a surplus of electricity during the crushing season for sale to the National Grid or for the benefit of local communities. In the past, disposal of bagasse was only a nuisance and so factories were designed for a steam balance. Increased interest in by-product utilization, however, has led to greater steam economy leaving a surplus of bagasse.

The potential bagasse surplus from a 200 tch factory is estimated as follows: 25/

Bagasse:Cane = 0.3 (based on cane of 15 per cent fibre)
Steam:Bagasse = 2.1 (range 2.0-2.5)
Hence Available Steam:Cane = 0.63, say 0.6
Factory steam:cane = 0.55 (range 0.5-0.6)
Hence Potential Surplus = 0.05/0.6 = 8 per cent bagasse
= 5 tonnes per hour

A surplus of 5t bagasse per hour could generate a further 10.5 tonnes steam. A back pressure turbo-alternator requires 12 kg steam per kW. Electricity generation is, therefore:

$$\frac{10{,}500}{12} = 875 \text{ kW per hour}$$

This is equivalent to 21,000 kWh per day or about 4.5 million kWh in the long season situation.

Another form of fuel which can be generated by the sugar industry is bio-gas (50-60 per cent methane). The main advantage of this is that it can be produced on a very small scale, within the capability of an OPS unit, unlike the generation of electricity. The process involves anaerobic digestion of organic matter, including agricultural residues and animal wastes. The gas is produced at a rate of about 200m^3 per tonne of organic matter and can be used for cooking, heating and lighting. The residual solid material is a valuable compost with a greater fertilizing and soil conditioning effect than animal manure. Prospects for improving the open-pan boiling system by heating with gas instead of bagasse furnaces are discussed in Chapter VI.

(5) *Effects on the Social Environment*

The first set of sugar technology models has assumed that all cane is supplied from a plantation managed, and either owned or leased, by the

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25/ Chatterjee, A.C., "Cane Sugar Factories Can Add to Energy Resources", *Indian Sugar*, January 1974.
Also *By-Product Power from Sugar Factories*, All Indian Expert Group Meeting of the Sugar Technologists' Association of India, April 1975, New Delhi.

factory. In this respect each is an integrated project, representing a conventional solution to the problem of raw material supply.

The main concern in this section of the Report is to compare models within the set in relation to the socio-environmental issues raised in Chapter II. A more extensive discussion of the factory-plantation complex and certain social characteristics commonly associated with this system of production, is contained in a paper prepared for the Nairobi Seminar.26/

As already indicated, there are major difficulties in quantifying the full range of potential social consequences arising from the establishment of a sugar industry. Plantations involve dependence on single-crop agriculture over extensive areas: the implications of this pattern are complex, varying from one set of circumstances (climatic, social and economic) to another. The supply of food for the project's labour force, to cite one example, may emerge as a serious problem; major changes are also likely to occur outside the boundaries of the plantation itself, potentially affecting not only the surrounding rural population but even the operation of the sugar project. Careful and systematic study of both primary and secondary impacts is essential to determine the social soundness of a specific project proposal. Thus the results of the following analysis of the models should not be taken as definitive, but as a guide to how such study should be developed in concrete situations.

In Table 31, the data on displacement for each of the models are presented. Three population densities are considered, *viz.* 20, 100 and 250 persons/km^2. No difference is assumed to occur in the cane yields from plantations of OPS units and vacuum-pan units operating in the same ecosystem. Two critical contrasts emerge: the irrigated models require only 53 per cent of the land area needed for plantations in the corresponding rainfed models; and each short season model requires 72 per cent of the land area of its long season counterpart. If population density is held constant, proportionate numbers of people would be displaced by land acquisition in the different model situations.

The magnitude of impact, as reflected in the Table, demonstrates certain constraints that are likely to impinge on project design. All of the 200 tch models, for example, would displace more than 24,000 people at a population density of 250/km^2. At this density even the smallest of the 100 tch factory plantations would displace 12,080 people. By comparison, displacement caused by one OPS factory farm would be 473 in the lowest (100 tcd, short season, irrigated) case and 1,858 in the highest (150 tcd, long season, rainfed) case at the density of 250/km^2.

It will be apparent that particular ecosystems tend to be associated with different magnitudes of population density: thus an agricultural environment capable of supporting 250 persons/km^2 without pre-existing irrigation would in most cases not require irrigation in a new sugar project. The density of 100/km^2 has been taken here as an intermediate case, yet even at this density the opportunity cost of land might be sufficiently high to discourage the additional investment needed for irrigation works. Of the three densities considered, that of 20/km^2 corresponds most closely to a usual irrigation situation and the likely magnitude of displacement can be judged on this basis.

A comparison between the VP and OPS models can be made within a framework measuring the magnitude of displacement against two types of benefit arising from sugar production: sugar output (tsa) and employment creation. The results of these calculations are contained in Tables 32 and 33. Output (tsa) is achieved at a higher direct social cost (measured in numbers of persons displaced) in the OPS units with factory farms as shown in Table 32. The displacement effect in relation

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26/ A.H. Barclay: "Sociological Issues in the Design of Cane Growing Systems".

TABLE 31

Number of Persons Displaced by Plantation Establishment

	Population density		
	20/km^2	100/km^2	250/km^2
Large-scale models (100 tch)[a]			
long season			
rainfed[b]	2,536	12,681	31,703
irrigated[c]	1,336	6,680	16,700
short season			
rainfed[b]	1,828	9,138	22,845
irrigated[c]	966	4,832	12,080
Small-scale models (100 tcd)[a]			
long season			
rainfed[b]	99	496	1,240
irrigated[c]	52	260	650
short season			
rainfed[b]	71	356	890
irrigated[c]	38	190	475

a/ Numbers displaced by 200 tch model are 100 per cent larger; numbers displaced by 150 tch model are 50 per cent larger

b/ Rainfed plantations require total land area equal to 140 per cent of cane area

c/ Irrigated plantations require total land area equal to 150 per cent of cane area to tsa is 64 per cent greater for the OPS units than for the corresponding vacuum-pan units (which require less cane per tsa and therefore less land).

TABLE 32

Ratio of Displacement Effect[a] to Sugar Output (tsa)

		VP[b]	OPS[c]
long season	rainfed	0.23	0.38
	irrigated	0.12	0.20
short season	rainfed	0.30	0.49
	irrigated	0.16	0.26

[a] Number of people displaced by plantation establishment where population density = 100/km^2. Ratios for 20/km^2 and 250/km^2 can be computed by multiplying by 0.2 and 2.5, respectively

[b] Identical ratios exist for the 100 tch and 200 tch vacuum-pan models

[c] Identical ratios exist for the 100 tcd and 150 tcd open-pan models

The relationship is reversed, however, when the displacement affects of the models are related to employment creation. As shown in Section (3) above, the OPS models are more labour-intensive both in the factory stage, and in the agricultural stage as well, to the extent that more labour is needed to produce the additional amount of cane required per tsa. In a given ecosystem and population density the ratio of a a particular benefit (employment) to a particular cost (displacement) is higher for the OPS units than for the vacuum-pan units, as Table 33 indicates.

TABLE 33

Employment Creation Measured Against Displacement[a] Due to Plantation Establishment[b]

		100 tch	200 tch	100 tcd	150 tcd
Long season	rainfed	0.30	0.28	0.77	0.73
	irrigated	0.44	0.40	1.32	1.26
Short season	rainfed	0.46	0.43	1.19	1.14
	irrigated	0.64	0.58	1.97	1.88

[a] At a density of 100/km^2

[b] The ratios shown in the Table are obtained by dividing total employment (factory plus agricultural) by the number of persons displaced

A major difference exists with regard to the place of employment: the plantation sector accounts for between 78 and 89 per cent of total employment for each of the vacuum-pan models in the set; in the OPS models agricultural employment is only between 42 and 56 per cent of the total. As already suggested, however, comparisons within the set are most easily standardized on a per tsa basis. From this standpoint a network of OPS units producing a sugar output equivalent to that of a single vacuum-pan plant would distribute both costs (displacement) and benefits (jobs) over a wider geographical area.

A brief caution should be inserted regarding the limitations of the measures employed in this procedure. It is possible to calculate the *number* of people displaced when a plantation is established for each model in the set, at varying population densities. But determining the true *cost* of the land being acquired is a vexed question: what is the proper basis for compensation when removal is involuntary, as it must be for consolidated land units? Should the price be computed on a per hectare basis, reflecting current market values (if a market actually exists), or should it anticipate the ease or difficulty of resettlement and adjustment to a new environment? Conventionally land is treated as a free good (purchased by government and made available to the project) in sugar industry project studies. On this basis its cost is usually excluded from commercial analyses, and is rarely given adequate treatment in cost-benefit analyses.

As an alternative to this conventional view, we may consider the consequences of assigning financial costs for plantation land to the set of models being examined in this Report. As a crude measure of social costs, the value of land and the property on it could be based directly on population density. If this method is used, opportunity cost of land will be five times greater at a density of 100/km^2 than at a density of 20/km^2. Put differently, the cost is assessed on a per capita basis for the population being displaced. This procedure has the advantage of emphasizing the function of compensation payments in assisting people who must resettle elsewhere following acquisition of their land.

In Table 34, results are shown for an exercise in which a provisional 'resettlement award' has been made to each person displaced by land acquisition. The per capita payment was set at $500 within a low price regime, and $800 within a high price regime. As the Table indicates, the resultant increases in fixed capital are substantial in all cases, but as expected, they are higher for the OPS than for the vacuum-pan models.

A second area of analysis for the 100 per cent plantation models concerns the relationship between the labour requirements and new human settlements arising from each project. Here the social criteria listed in Chapter II overlap to a significant degree. If, as assumed in the financial and economic environmental analyses above (Sections (2) and (3) of this Chapter), unskilled and semi-skilled workers do not receive housing from the project, by implication they are assumed to have residences of their own locally, from which they can travel to work every day, or to be able to find rented accommodation in the locality. On closer examination this assumption does not seem equally satisfactory for all of the situations being considered in this Report. The distance involved in daily travel between home and place of work may be expected to vary considerably. For purposes of modelling we may consider a radius of 10 km from the sugar factory as defining the area from which locally housed labourers may be drawn. The potential demand for new housing is then dependent on the number of unskilled and semi-skilled labourers recruited from beyond this radius. Their number can be computed by matching the labour requirements of a particular model in a given ecosystem against two factors: population density within the 10 km radius, and the rate of recruitment for unskilled and semi-skilled jobs within that local population.

TABLE 34

Cost of Land Acquired for Plantation: Resettlement Awards to Persons Displaced[a]

		Low price[b]		High price[b]	
		Cost ($m)	Cost/K[c] (%)	Cost ($m)	Cost/K[c] (%)
Large-scale models (100 tch)[d]					
long season	rainfed	6.34	19.8	10.14	20.8
	irrigated	3.34	10.3	5.34	10.7
short season	rainfed	4.57	14.3	7.31	15.0
	irrigated	2.42	7.4	3.87	7.8
Small-scale models (100 tcd)[d]					
long season	rainfed	0.25	61.0	0.40	66.7
	irrigated	0.13	31.0	0.21	34.4
short season	rainfed	0.18	42.9	0.28	45.9
	irrigated	0.10	23.3	0.15	24.2

[a] Population density = 100/km^2. Costs at population densities of 20/km^2 and 250/km^2 will be 20 per cent and 250 per cent, respectively of the figures shown in the Table

[b] Resettlement award of $500 per person displaced, at low prices, and $800 at high prices

[c] Percentage increment in fixed capital of land costs included in project budget

[d] Costs for 200 tch and 150 tcd are 100 per cent and 50 per cent greater

Table 35 presents the results of this analysis for the set of models at six combinations of population density and local recruitment rate. The densities are 20, 100 and 250 persons/km^2, and the recruitment rates are 5 per cent and 10 per cent. Of the latter two, the 10 per cent rate is probably on the optimistic side, being equivalent to about 40 per cent of the male population over age 16.27/ (The 10 km radius gives a circle whose area is 314.2 km^2, some of which will of course have been acquired for the establishment of a sugar cane plantation. If a proportionate number - say 10 per cent - of the displaced population are to be recruited as labourers, they must have the opportunity to resettle elsewhere within the circle or close to its perimeter. The overall local recruitment rate will therefore be influenced by their number and by the proximity of their resettlement.)

The Table indicates the number of workers in unskilled and semi-skilled jobs who would presumably require housing upon taking up employment. From the standpoint of social policy, the basic issue is whether spontaneous settlements (in the private sector of the local economy) are an adequate solution, or whether the sugar project should accept responsibility for the housing needs of this segment of its labour force. There is an economic dimension to this issue as well, since a project heavily dependent on 'migrant labour' (defined rather strictly here as originating beyond the 10 km radius) may experience a shortage of labour if the supply and/or quality of private sector housing is unsatisfactory.

From the Table it is evident that the potential burden - if responsibility for this category of housing is assigned to the sugar project - varies considerably from one model to another. At a given combination of density and local recruitment rate, the short season projects must house more labourers than their long season counterparts. Similarly, the rainfed models must provide more housing than the corresponding irrigated models.

In all of the OPS models, however, sufficient labour would be available within a 10 km radius (except in the extreme case of 20/km^2 density and a 5 per cent recruitment rate) so that additional new housing for semi-skilled and unskilled workers would not be needed. Even if the radius were reduced to 5 km, a 5 per cent recruitment rate and density of 100/km^2 would still generate a sufficient number of locally housed labourers.

The specific criteria for project-supplied housing will vary from one country to another, but some basic guidelines with a quantitative dimension are offered in this Report.

To encourage stable family residence (as opposed to the prevalent pattern in agro-industrial settlements, where labourers are separated from their families), the following suggestions are made: each labourer from beyond 10 km would be supplied with a unit of approximately 40m^2, consisting of two main rooms and a kitchen, with tap water and electric wall sockets and light points. From 1976 project studies the probable unit cost of such housing is estimated at $4,000 (low price regime) and $7,000 (high price regime); an area (say 0.2 hectare per labourer) could be set aside near the housing area, on which food crops would be grown;28/ and physical plans for housing areas could use a system of clustering houses around common public spaces rather than the grid system that characterizes many 'factory towns'.

27/ It may be assumed that males constitute half of the total population and that the median age is 16: thus 40 per cent of males over 16 constitutes 10 per cent of the total population.

28/ Normally these areas would probably be found, if planned for from the beginning, within the gross plantation area (140 per cent of cane when rainfed, 150 per cent when irrigated).

TABLE 35

Numbers of Non-Local Labourers Required[a]

		Unskilled & semi-skilled labour requirement	Local recruitment rate[b] = 10%			Local recruitment rate[b] = 5%		
			Density			Density		
			20/km²	100/km²	250/km²	20/km²	100/km²	250/km²
Long season rainfed	100 tch	(3548)	2920	0	0	3234	1977	0
	200 tch	(6693)	6065	3551	0	6379	5122	2766
	100 tcd	(353)	0	0	0	39	0	0
	150 tcd	(512)	0	0	0	198	0	0
Long season irrigated	100 tch	(2677)	2049	0	0	2363	1106	0
	200 tch	(4978)	4350	1836	0	4664	3407	1051
	100 tcd	(317)	0	0	0	3	0	0
	150 tcd	(460)	0	0	0	146	0	0
Short season rainfed	100 tch	(3966)	3338	824	0	3652	2395	38
	200 tch	(7527)	6899	4385	0	7213	5956	3600
	100 tcd	(396)	0	0	0	82	0	0
	200 tcd	(580)	0	0	0	266	0	0
Short season irrigated	100 tch	(2886)	2258	0	0	2572	1315	0
	200 tch	(5387)	4759	2245	0	5073	3816	1460
	100 tcd	(348)	0	0	0	34	0	0
	150 tcd	(505)	0	0	0	191	0	0

[a] Non-local labourers are those recruited from beyond a 10 km radius for unskilled and semi-skilled employment

[b] Percentage of total population within 10 km accepting unskilled and semi-skilled employment

The most significant suggestion in terms of direct impact on project design and cost is that relating to the housing stock. Table 36 shows the additional capital costs to be incurred in rainfed situations in both high and low price regimes, if each non-local labourer is supplied with a house of the type described above. The Table shows the results at densities of 20/km^2 and100/km^2 for each recruitment rate: it will be seen that no costs are incurred by the OPS models except in the case of 20/km^2 density and a 5 per cent rate of recruitment. The additional costs for the vacuum-pan models, on the other hand,are shown to be quite substantial.

With regard to the criteria of developmental impact, clear distinctions can be drawn between the plantation-based models in the first set, and the outgrower-based models analysed in the next Chapter. Within the first set, contrasts between the OPS and VP units are apparent in terms of scale but are also influenced by industrial location policy and the availability of areas where sugar cane can be grown. Comparisons based on tsa imply that a network of OPS units could be established whose aggregate output would be equivalent to that of a vacuum-pan project. This theoretical possibility possesses certain features that potentially counterbalance the greater aggregate land requirement of the OPS units: (i) monocropping of cane would be confined to small pockets rather than concentrated on thousands of hectares; (ii) diversified agriculture, including subsistence crops, could be sustained; and (iii) the effects of displacement would be localized, enhancing prospects for orderly resettlement.

The essence of this network would be a decentralized approach with multiple foci, rather than one in which a single large-scale project serves as the stimulus to local and regional development. The critical constraint in the planning process is likely to be the availability of suitable cane land within an extensive area. The following example illustrates the problem: if 28 OPS units of 150 tcd capacity are built in a long season ecosystem, each within a circle of 10 km diameter, and the circles are contiguous on a 4 x 7 matrix, the required total area is thus 40 km by 70 km = 2,800 km^2.29/ By comparison, a single 100 tch vacuum-pan factory (with the same output in tsa as the 28 OPS plants) would require a gross area of only 127 km^2 (diameter = 12.7 km) if rainfed, or 67 km^2 (diameter = 9.2 km) if irrigation were used. It would also seem difficult to implement the OPS network if irrigation were required and was to be restricted to the 28 scattered plantations. Alternatively, the network could function as part of a larger integrated agricultural strategy, based on extensive irrigation. Further discussion of these developmental questions is contained in a paper prepared for the Nairobi Seminar.30/

The social implications of land utilization in the African sugar industry are explored further in Chapter IV, which examines outgrower-based sugar projects.

29/ It should be noted that the gross cane area within the block of 2,800 km^2 amounts to only 1 per cent.

30/ A.H. Barclay: "The Impact of Sugar Technologies on Social Change and Development".

TABLE 36

Capital Costs Incurred when Non-Local Employees are Housed a/

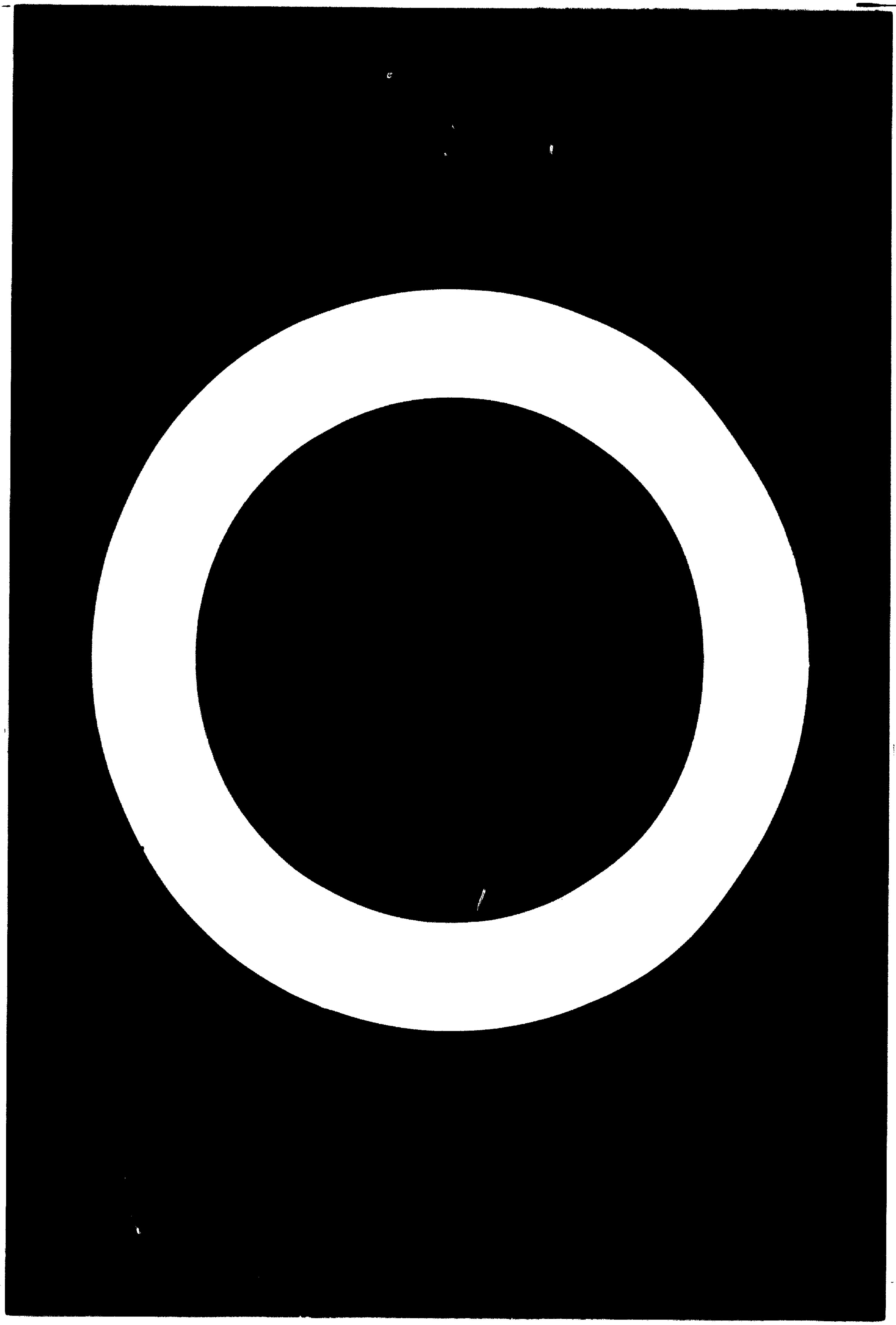
Rainfed Models	Low price b/		High price b/	
	Cost ($m)	Cost/K c/ (%)	Cost ($m)	Cost/K c/ (%)
Density = 20/km², LR = 10% d/				
long season 100 tch	11.7	37	20.5	42
200 tch	24.3	45	42.5	51
short season 100 tch	13.4	42	23.5	48
200 tch	27.6	51	48.3	59
Density = 20/km², LR = 5% d/				
long season 100 tch	12.9	41	22.6	46
200 tch	25.5	47	44.6	53
100 tcd	0.16	39	0.27	45
150 tcd	0.79	155	1.39	183
short season 100 tch	14.6	46	25.6	53
200 tch	28.9	54	50.6	62
100 tcd	0.33	79	0.57	93
150 tcd	1.06	204	1.86	242
Density = 100/km², LR = 10% d/				
long season 100 tch	0.00	0	0.00	0
200 tch	14.2	26	24.9	30
short season 100 tch	3.3	10	5.8	12
200 tch	17.5	32	30.6	37
Density = 100/km², LR = 5% d/				
long season 100 tch	7.9	25	13.8	28
200 tch	20.5	38	35.9	43
short season 100 tch	9.6	30	16.8	35
200 tch	23.8	44	41.7	51

a/ Housing to be provided for all unskilled and semi-skilled labourers recruited from beyond 10 km radius from factory

b/ Unit cost of housing = $4000 at low prices, $7000 at high prices

c/ Percentage increment in fixed capital if housing costs are included in project budget

d/ LR = Local recruitment rate: percentage of total population within 10 km radius accepting unskilled and semi-skilled employment with sugar project



CHAPTER IV

OUTGROWER-BASED PROJECTS

This Chapter examines a set of models in which cane supply is dependent on outgrowers (assumed to be peasant smallholders)[1], rather than the plantation systems assessed in Chapter III. The principal variant analysed here is one in which outgrowers are closely integrated with the factory, and in which specified inputs and services are provided to them on a credit basis. These include land preparation, seed cane, fertilizers, cane cutting and transport, and extension services. Charges for these items are deducted from the proceeds of cane sold to the factory. Two other variants will, however, also be considered: for the OPS technology, a system in which factory involvement with the cane supply is minimal; and for the vacuum-pan technology, an intermediate system in which half the cane originates from outgrower farms and half from a factory-managed plantation.

The shift to an outgrower-based system involves modification of the conventional method of cane supply in response to situational constraints, government policy preferences, or a combination of the two, so that - in a way - the second set of models incorporates responses to environmental phenomena. In this Chapter the analysis parallels that undertaken for the plantation-based models, though in somewhat briefer form. Comparisons are undertaken between models within the set in relation to the financial and broader environmental criteria used in the preceding Chapters.

(1) *Implications for Technical Parameters*

Close integration of outgrowers with the factory - as assumed at this stage in the analysis for all of the models and situations - offers the factory substantial protection against cane shortages. Downtime is therefore considered as identical to the levels used in Chapter III: 20 per cent of available crushing time for the vacuum-pan units, and 25 per cent for the OPS units. In other respects, too, technical parameters within the factory stage remain unchanged.

With regard to agricultural operations, however, reliance on outgrowers has important technical ramifications which, in turn, potentially influence each project's financial performance and environmental impact. Outgrower cane production is characteristically more extensive than plantation production in the following respects: cane yields on a per hectare basis tend to be lower, requiring more land to be placed under the crop to produce a given quantity; and since in most cases peasant landholdings are not consolidated into large blocks and since some areas are typically reserved for houses or other crops, while others are deemed unsuitable for cane (perhaps due to poor soils or inadequate drainage), the density of cane (proportion of land under cane within a given area) tends to be much lower than in plantation systems.

There is a wide range of potential values for these two parameters, both of which are influenced by situational factors and constraints. A decision-maker assessing possible projects in a given situation will hopefully have access to the relevant data on land tenure, population density, and agricultural practices and productivity. For the purpose of constructing models, and on the basis of field observations, the following assumptions have been made: that cane yields will be 80 per

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[1] Although private farms of more than 25 ha exist in certain areas, they are assumed to be outside the mainstream of agricultural development planning in Africa today, and are therefore excluded from this analysis.

cent of those achieved under a plantation system within the same ecosystem: e.g. 4t/ha/month for outgrowers in a long season rainfed situation, compared with 5t/ha/month for a plantation; and that cane density will be 20 per cent within a rainfed outgrower zone and 40 per cent within an irrigated outgrower zone. (The respective gross areas are thus 500 per cent and 250 per cent of cane, as compared with 140 per cent and 150 per cent in the plantation models.)

These values can be used to generate the overall land areas of the outgrower zone for each model, and thus a radius if the zone is conceived as a circle with the factory at the centre, as in the presentation of the plantation-based models. The increases in the cane catchment areas and radii are shown in Table 1.

It is assumed that cane will be cut green, rather than burned, in the outgrower zone. This implies lower productivity per man-day by cane cutters, since trash must be removed manually, and thus greater utilization of labour in harvesting operations than for the plantation-based models. Other differences observed during fieldwork and incorporated within this set of models relate to land clearance and preparation, loading of cane in the field (performed manually rather than by grab loader) and cane transport (using tractors and trailers of smaller size.)

The application of these technical parameter values to the various models influences their performance in relation to the evaluative criteria used in this Report. The following sections examine the principal outcome.

(2) *Financial Performance*

The technical parameters specific to this set of models produce a different configuration of unit costs in the agricultural stage of sugar production. The models have been constructed on the assumption that reliance on outgrowers has no adverse effect on the arrival of cane at the factory gate. Although the level of integration between cane growing and cane milling is lower than with plantations, in practice the activities of outgrowers tend to be regulated and co-ordinated to a significant extent.

Since cane is to be purchased by the factory from an outside source, some formula for pricing cane must be devised. In several African countries the price per tonne of cane is related to the ex-factory price for sugar, and both are specified by government. A ratio between the two prices of 0.05 would yield a cane price of $15 per tonne in a low price regime, and $30 at high prices.

In this section the analysis focuses on the relationship between the price paid for cane and the overall financial viability of each model. A cane price : sugar price ratio of 0.05 will serve as a useful yardstick in the comparisons. In Section (3) the broader economic consequences - affecting the outgrowers themselves - will be examined.

In Section (1) of Chapter III the internal rates of return were presented for each model in the plantation set. From these results the following question can be formulated: when cane must be purchased from outgrowers, what price can each factory project afford to pay while retaining the same IRR as was achieved with plantation cane supply? Results of this analysis are presented in Table 2. These indicate that most of the large-scale vacuum-pan models earn an equivalent rate of return only when the cane price : sugar price ratio is below 0.05. A pricing formula based on this ratio would lower the IRR in all such models. The highest cane prices and ratios are found in the short season rainfed ecosystem, where sugar production is least profitable.

TABLE 1

Agricultural Parameters for Outgrower-Based Projects

	Annual cane requirements 000 tonnes[a]	Average cane yields[b]	Cane area required[c]	Radius of cane zone (km)[d]
large-scale (VP)				
long season				
rainfed	518.4	4	11,323	13.4
irrigated	518.4	8	5,566	6.7
short season				
rainfed	288.0	3.2	8,159	11.4
irrigated	288.0	6.4	4,026	5.7
small-scale (OPS)				
long season				
rainfed	20.2	4	443	2.7
irrigated	20.2	8	216	1.3
short season				
rainfed	11.2	3.2	318	2.3
irrigated	11.2	6.4	159	1.1

[a] Annual cane requirements are for 100 tch and 100 tcd levels, respectively. Amounts required for 200 tch and 150 tcd are taken as 200 per cent and 150 per cent of those in the Table.

[b] In tonnes per hectare per month

[c] Areas for 100 tch and 100 tcd scales; to be increased by 100 per cent and 50 per cent for 200 tch and 150 tcd, respectively

[d] Based on assumed cane density of 20 per cent in rainfed outgrower systems and 40 per cent in irrigated outgrower systems. To compute radius for each 200 tch model multiply 100 tch radius by 1.41; for 150 tcd models, multiply radius of 100 tcd model by 1.22

TABLE 2

Notional Prices per tonne of cane when Projects Shift to an Outgrower System

	At low prices		At high prices	
	Cane price per tonne ($)	IRR %[a/]	Cane price per tonne ($)	IRR %[a/]
Long Season Rainfed				
200 tch	15.4	13.4	29.6	20.2
100 tch	14.7	8.7	26.9	15.0
150 tcd	11.6	0.4	23.9	9.9
100 tcd	12.4	0	20.5	0
Long Season Irrigated				
200 tch	10.0	16.1	24.5	22.2
100 tch	9.6	11.7	21.9	17.3
150 tcd	10.6	7.7	22.2	14.9
100 tcd	10.3	3.7	20.6	11.1
Short Season Rainfed				
200 tch	18.2	0.7	33.3	7.1
100 tch	18.7	0	31.8	1.9
150 tcd	20.5	0	34.0	0
100 tcd	21.1	0	35.1	0
Short Season Irrigated				
200 tch	13.4	6.4	26.0	12.0
100 tch	12.6	0.9	23.6	6.5
150 tcd	15.0	0	24.9	0
100 tcd	15.5	0	25.8	0

[a/] In all cases where a positive rate of return was earned with plantation-based cane supply, cane prices were computed which would allow the factory to earn an equivalent return when relying on cane supplied by outgrowers. For all of the loss-making models, the notional cane price was based on the cost of production for plantation-grown cane. In all of the latter cases an IRR of 0 per cent is shown

A second step in the analysis involves assigning a common rate of return to all the factory models and then comparing the cane prices required to earn this rate. An IRR of 10 per cent is taken to represent an intermediate case capable of attracting investment. The relationships are straightforward: cheaper raw materials (reflected in a lower cane price) will improve profitability, and reduced profitability (e.g. lowering an IRR previously over 10 per cent) allows a higher price to be paid for raw materials. To cite two examples: at low prices the 200 tch long season rainfed factory can pay $17.6/t rather than $15.4 when its IRR falls from 13.4 per cent to 10 per cent; at high prices the 100 tch short season rainfed factory can raise its IRR from 1.9 per cent to 10 per cent by reducing the cane price from $31.8/t to $16.5.

In general the results serve to demonstrate the financial rationale behind conventional integration of factory and plantation. The shift to an outgrower system tends to produce either a reduction in factory profitability because a formally gazetted price (e.g. $15 per tonne at low prices) must be paid for cane which is higher than the unit cost of plantation-grown cane; or, where no price is set by government, the offer of a cane price which sustains profitability but which may discourage rather than encourage outgrower production. This issue relates to the wider economic environment in which the sugar industry must operate, which is the subject of the following section.

(3) *Economic and Social Impact*

The recruitment of outgrowers and their incorporation into a system of cane supply depends on a number of factors, of which perhaps the most crucial is the grower's perception of returns to be earned from cane. The cane price levels discussed in Section (2) (as viewed by the factory in each model) can now be appraised relative to the costs incurred by outgrowers under low and high price regimes. Table 3 presents a simplified farm budget for one ecosystem and price regime, with cane yields at 80 per cent of those achieved for the comparable plantations and an assumed cane price : sugar price ratio of 0.05.

In the integrated outgrower schemes posited for these models, each outgrower retains responsibility for certain operations, including initial land clearance (e.g. removal of stumps), planting of seed cane, applications of fertilizer, gapping and application of herbicides (if necessary), weeding, and general maintenance of the crop. Weeding generally requires the greatest labour inputs, particularly in the plant crop phase. Often project studies conveniently assume that all of these tasks will be completed by unpaid 'family labour'. Field observations did not confirm the validity of this assumption, however, and it was deemed more realistic to cost in labour inputs organized by the outgrower at the standard wage (for each price regime) per man-day of unskilled agricultural labour.

One important difference in the farmer's income position relative to factory type and size occurs in the area of cane harvesting and transport charges. Table 4 shows the charges on a per tonne of cane basis levied by the various models in different ecosystems. The OPS units must pass on higher costs to the outgrower than the VP factories do, primarily because of higher running costs (caused by lower utilization rates in hours worked per day) and indivisibilities in equipment requirements (for which depreciation charges must be computed).

Following the procedure used in the farm budget in Table 3, notional returns to the outgrower can be calculated, on both a per hectare and per tonne of cane basis. The outgrower's costs are highest in the plant crop phase: it is usual for initial development costs to be deducted by the factory from the proceeds of plant cane. In the high price regimes the returns to the outgrower on a per tonne basis are very low from a cane price of $30/tonne. His position worsens in most cases if the cane price is set so as to allow the factory a return of 10 per cent: a 100 tch factory, for example, pays him only $16.5/tonne in a

TABLE 3

Sample Farm Budget Comparing Revenue Earned from Cane Sold to 200 tch and 150 tcd Factories

Long season irrigated situation (Low price regime)

	Plant Crop		1R and 2R		3R and 4R	
Gross Revenue[a]	2400		1920		1800	
Charges and Costs						
1. Land Preparation	125		-		-	
2. Seed Cane	135		-		-	
3. Fertilisers[b]	125		100		100	
4. Interest on above items[c]	64		13		13	
5. Irrigation Levy[d]	190		150		150	
	(A)[e]	(B)[e]	(A)	(B)	(A)	(B)
6. Harvesting and Cane Transport	475	811	380	649	356	608
7. Sub-Total	1124	1450	643	912	619	871
8. Overheads @ 10%	112	145	64	91	62	87
9. Labour	148	148	90	90	90	90
10. Total Costs	1384	1743	797	1093	771	1048
Net Revenue	1016	657	1123	827	1029	752

NPV of revenue when cane sold to A: $3557
(discounted at 10 per cent per annum) B: $2516

[a] Based on cane price of $15/tonne, and yields of 8t/ha/month over P + 4R cycle of 82 months

[b] Based on dosage of 2.1t/ha over P + 4R cycle, with 0.5t/ha on plant crop and 0.4t/ha on each ratoon

[c] Charged at 10 per cent per annum for items supplied on credit

[d] Irrigation levy based on initial development cost of $1000/ha for production of sugar cane over 25 years: the outgrower is thus charged a levy on each cane crop corresponding to repayment of principal and 10 per cent interest per annum over the 25 years

[e] (A) represents 200 tch vacuum-pan factory; (B) represents 150 tcd OPS factory

TABLE 4

Cane Harvesting and Transport Charges to Outgrowers
($ per tonne of cane)[a]

Low price regime	100 tch	200 tch	100 tcd	150 tcd
long season rainfed	3.77	4.88	5.22	5.84
irrigated	2.52	2.97	5.04	5.07
short season rainfed	5.15	6.34	7.79	7.52
irrigated	3.57	4.00	7.36	7.11
High price regime				
long season rainfed	6.32	8.10	9.18	9.77
irrigated	4.27	4.97	8.74	8.47
short season rainfed	8.72	10.62	13.19	12.75
irrigated	6.12	6.79	12.33	11.93

[a] Sum of following charges:
(1) Wages for cane cutters
(2) Wages for general labour
(3) Running costs for equipment
(4) Depreciation on equipment
(5) Allowance for 10 per cent return on capital invested in equipment

short season rainfed ecosystem, while his costs are on the order of $29/tonne. Under irrigation, where cane yields per hectare are assumed to be twice as high, the income position of the outgrower improves markedly, although his earnings per hectare will not be twice as great if the capital and operating costs of irrigation are passed on to him. Precise modelling of these costs poses difficult problems, but in this analysis it has been assumed that the initial capital (development) cost of installing irrigation is $1,000 per hectare at low prices and $1,625 per hectare at high prices, and that each outgrower is charged a levy sufficient to repay the amount over 25 years at an interest rate of 10 per cent per annum.

The income-generating potential of cane growing in the various ecosystems and price regimes is shown in Table 5. The results are presented in terms of NPV of income per hectare over the cane cycle, and a cane price : sugar price ratio of 0.05 has been assumed (although as already demonstrated the models differ in their ability to earn a profit while obtaining cane at this price). Significantly, outgrower incomes are shown to be highest in the ecosystems (long season irrigated) found most favourable for factory profitability.

Cane transport constitutes one of the principal items in the outgrower's farm budget. In theory, charges for this item should vary with the number of tonnes transported and the distance from farm to factory. For purposes of clarity, however, mean yields have been assigned to each ecosystem and a standard transport charge per tonne is assumed for all outgrowers in each model project. (This corresponds to actual practice as observed during fieldwork, in which book-keeping and accounts are facilitated from the standpoint of the agency supplying transport services.) Under such an arrangement, if the radius of the outgrower zone is extended - as required, for example, in the expansion of factory capacity from 100 tch to 200 tch - outgrowers located near the factory will to an increasing degree have to subsidise those near the perimeter. A potential problem arises, particularly for the 200 tch models, if the system is altered so as to charge each outgrower the actual cost of cane haulage on a tonne/kilometre basis. The consequent reduction in income for the more distant growers may be sufficient to discourage them from growing cane, thereby undermining the factory's cane supply.

More complex issues arise in the consideration of outgrower cane production, and while it is impossible to quantify and model adequately all potential secondary effects, certain major issues can be earmarked for close study in future appraisals of specific projects:

(i) important tradeoffs occur in the determination of cane density (assumed in the models to be 20 per cent for rainfed systems and 40 per cent for irrigated systems). Low density may facilitate selection of only the best soils, thereby promising potentially higher cane yields per hectare, and it allows land within the zone to be allocated to other crops, notably food crops. On the other hand, low density may have the effect of limiting participation in the outgrower programme (perhaps even to a minority of farmers), and it extends the radius of the cane catchment area (which has implications for transport costs and logistics.) Conversely, a high-density policy maximizing local participation may create 'plantations in minature' and *de facto* monoculture. The intensity of this conflict relates directly to the scale of the sugar project, for in the case of an OPS unit (or even a network of such units in adjacent localities) the goals of income distribution and agricultural diversification can be more easily reconciled;

TABLE 5

Net Present Values of Outgrowers' Income
($ per hectare)

		Low price [a]		High price [a]	
200 tch model	Discounted at:	5%	10%	5%	10%
Long season	rainfed[b]	1025	870	2682	2296
	irrigated[c]	4284	3557	9832	8180
Short season	rainfed[d]	234	182	1140	961
	irrigated[d]	1501	1302	4099	3565
150 tcd model					
Long season	rainfed[b]	815	687	2318	1979
	irrigated[c]	3038	2516	7757	6445
Short season	rainfed[d]	30	2	771	637
	irrigated[d]	426	353	2316	1992

[a] Cane price = $15/tonne at low prices, $30/tonne at high prices

[b] Cane cycle = P + 2R over 58 months, with mean yield of 4t/ha/month

[c] Cane cycle = P + 4R over 82 months, with mean yield of 8t/ha/month

[d] Cane cycle = P + 4R over 57 months; mean yield is 6.4t/ha/month for irrigated system and 3.2t/ha/month for rainfed system

(ii) the principal potential linkage arising from the choice of an outgrower- as opposed to a plantation-based project is that of agricultural diversification. It may be argued that because outgrowers who produce cane under close supervision benefit from extension, credit and marketing assistance, they will transfer knowledge and techniques to their other crops. Field observations indicate that this transfer is not spontaneous and that compartmentalized extension (focusing only on cane) narrows rather than broadens the scope for balanced rural development. This finding underlines the need for co-ordination between the cane supply system operated by the sugar factory and other development programmes (particularly those of government) affecting the agricultural sector of the national economy;

(iii) direct land acquisition is of course a minor factor in an outgrower programme, since the only land requirements are for the factory site, a housing estate and a seed cane farm. The first and third of these can be readily quantified, whereas the second depends on the policy towards human settlements, the local recruitment rate and population density. The introduction of cane growing implies dislocation or even cessation of other activities (agricultural or pastoral), and the magnitude of this impact should be carefully assessed on the basis of micro-level data collected in a proposed area;

(iv) the transfer of responsibility to the outgrower for specified operations in cane production has important implications for employment generation. The number of those directly employed by the sugar project is substantially reduced as compared with the plantation models.

Seasonal jobs in cane harvesting now account for most of the agricultural employment offered by the project itself. While a typical outgrower's cane plot (say one to two hectares) does not offer continuous employment, the aggregate opportunities for employment in an outgrower system are considerable. The land area under cane increases (by a factor of 25 per cent in the models) with lower yields per hectare; whether labour inputs per hectare remain constant depends on the outgrower's responsiveness to extension advice and the needs of the crop in the specific conditions obtaining on his landholding. Another significant feature of outgrower-based agricultural employment is its capacity to absorb large numbers of the local population on a short-term or *ad hoc* basis. This is particularly relevant to the situation of women, whose economic roles within their households generally require access to cash, but who are not normally recruited for regular wage employment on a plantation. Furthermore, on a smallholding work such as weeding is divisible to a degree that comparable tasks in plantation agriculture are not: for example, if 25 man-days are needed to weed one hectare of sugar cane, the work might be done by 10 individuals working half of each day (say 3-4 hours) over a 5-day period. This type of arrangement may in fact be most suitable in rural communities where adults (particularly women) must attend to other responsibilities besides casual wage labour;

(v) it has been argued that family members' contributions of labour cannot properly be assumed to be a 'free' resource available to the outgrower. The availability of adequate manpower within the household cannot be assumed *a priori*, in view of growing school enrolments which withdraw many children from the household labour force. And even where family members do participate, their involvement with a cash crop usually means that they anticipate receiving shares of the proceeds, in cash or in kind. In terms of the outgrower's own economic strategy it may actually make more sense to hire non-family labour (paid on a simple daily or task basis) than to try to limit the claims of relatives (whose cumulative participation in labour is difficult to measure) when the cane is sold and a lump sum of money is in hand.

For these reasons in projecting outgrowers' incomes it has seemed appropriate to cost all labour inputs organized by them at the prevailing market rate for unskilled agricultural labour. Similarly, it is

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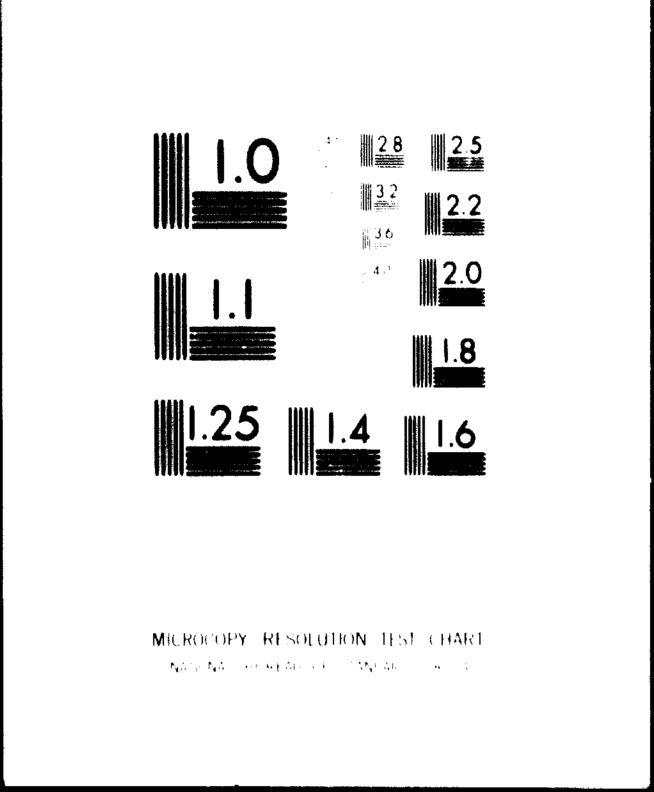

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suggested that assignment of a shadow price for labour should treat 'family labour' and hired labour as equivalent. Because the implementation of cash crop agriculture has complex secondary effects, the true social opportunity cost of labour may prove more difficult to quantify than many conventional project feasibility studies would suggest.

(4) *Physical Environmental Implications*

In terms of the physical environment, the comparisons within the set of outgrower models and between outgrower and plantation systems are confined to the agricultural sector of the sugar industry, since the parameter values for factory performance have been held constant.

A major contrast within the set of outgrower models occurs between rainfed versus irrigated ecosystems. As indicated earlier, a rainfed agricultural zone tends to be fairly densely populated with an established land use pattern while a zone suited for irrigated crop production is typically sparsely populated, often with the main traditional activity being seasonal grazing. The establishment of an outgrower system, therefore, presents differing requirements and impacts in these situations.

In the rainfed environment, little physical disruption need be involved in the establishment of an outgrower system. A possible exception is the consolidation of land units; a probable exception is improvement of the road network for cane transport. The main problems in this operation tend to be social and organizational. In the typical irrigated situation, however, crop production was not previously an important part of the local system. The environmental effects of setting up outgrower cane growing would be very similar to those of establishing a plantation. The irrigation and drainage layout obviously must be on a smaller scale than on a plantation, the actual plot areas depending on the settlement policy and the extent to which mechanization is to be part of the agricultural system.

Water can be provided in a number of ways, but the scope for use in an outgrower system is more limited. A plantation might depend on irrigation by surface, sub-surface or overhead methods according to the nature of the land and soil; the availability of water; the availability of power for pumping; and the availability of the required level of expertise for successful operation of more sophisticated techniques. Currently the most common system is furrow irrigation, and indeed this is the most likely to be used in an outgrower system. Furrow irrigation has low capital requirements (after its establishment) and a high capacity to utilize labour. In physical terms, it demands a regular field layout and minimally sloping land. The application of water, at say 14-21 day intervals (determined by soil type and prevailing climatic conditions), means that cane is growing in alternately water-logged and drought conditions. Furthermore, some 60-70 per cent of the water is lost by evaporation and deep percolation, meaning that only 30-40 per cent is of direct benefit to the crop. In most situations an irrigation system will be planned with this level of irrigation efficiency determining the area that can be irrigated with the available water supply. However, looking to the future with an increasing global concern for efficient water utilization, plantation agriculture can more readily apply methods whereby irrigation efficiency is increased to over 90 per cent, for example by trickle or drip irrigation. Crop yields may also be substantially increased by this method. Although the more efficient and sophisticated systems require greater capital investment and less labour, it is important to recognize the trends both in the industry and in environmental awareness.

Cane yields in the outgrowers system have been taken to be 80 per cent of the corresponding plantation system, and as a result the land area involved in meeting the factory's crushing capacity is 25 per cent greater. The agricultural operations are, by necessity, virtually the same in both cases and consequently physical inputs and factors of environmental concern such as energy and water remain constant in terms of quantity per hectare but increase per tonne of cane. However, a reduction in the quantities of additional inputs such as fertilizer and more generally, labour, is likely to play a large part in the 20 per cent yield reduction.

Harvesting in all of the outgrower-based models is carried out manually with green cane. The question of air pollution, therefore does not arise. In fact, the outgrowers are able to take considerable advantage from the leafy trash and tops, some of which are short-term and quantifiable (use of cane tops as cattle fodder), whereas others have longer term, more intangible benefits (e.g. addition of organic matter to a heavy clay soil may help improve its workability and drainage, while organic matter on a light sandy soil may help improve its water holding capacity). A benefit of direct application to the outgrower system is the mulch/weed suppression effect of the trash blanket on ratoon crops.

The simplified manual loading operation in the outgrower system effectively reduces the problem of soil damage by heavy equipment; the presence of the trash also helps in this respect. Environmental damage caused by the cane transport would appear to be less concentrated in an outgrower system with 62 hp tractors hauling 3-6 tonne trailers over a wide area, as opposed to more powerful machines hauling 18 tonnes each in a more concentrated zone. As a counter to this, however, the former involves a greater proportion of travel on public roads and through settlements, while in the latter case the majority of roads would tend to be private plantation roads constructed principally for cane transport and removed from population centres.

(5) *Mixed Systems (Plantation plus Outgrowers)*

This variant is most likely to apply to the large-scale vacuum-pan models, where an intermediate arrangement is sought in which a 'nucleus estate' supplies a proportion of the factory's cane needs and the remainder is supplied by outgrowers. For the purpose of modelling a 50/50 division of the cane supply can be considered, although in practice the proportions within a given project may shift over time. Thus, for example, a 100 tch factory when installed might draw perhaps 60 per cent of its cane from a nucleus estate, and following expansion to 200 tch the estate's share would fall to only 30 per cent. Where outgrower production is to be closely regulated by the factory a gradual transition of this nature holds certain advantages from an organisational point of view. In specific situations where the output of a 200 tch factory is a middle-range target (to be achieved after perhaps 7 to 10 years) and where government policies favour outgrower production but sugar cane is an entirely new crop, the possibility exists of beginning with an estate-cum-outgrower system at the 100 tch level, so that expansion of the outgrower scheme to its full extent (including thousands of peasant farmers) can proceed gradually.

From a technical viewpoint the nucleus estate in such a mixed system can serve to even out fluctuations in the cane supply, whose impact in actual situations may be greater than implied in the models, where downtime was held constant. Intermediate values will occur for parameters such as total cane area and radius of the cane catchment zone: these can be interpolated from Table 1. With a 50/50 division of the cane supply, the 200 tch model in a long season rainfed ecosystem requires 20 380 ha under cane and a radius of 14.9 km. The corresponding values for this model with a 100 per cent plantation system are 18115 ha and 9.0 km; with a 100 per cent outgrower system they are 22644 ha and 19.0 km.

The co-existence of two modes of cane production within the same supply system may create linkages of potential interest. One linkage is generally assumed to exist with regard to methods of cultivation and productivity: the nucleus estate can have a demonstration effect on outgrowers in the surrounding area, eventually narrowing the differential in yields per hectare (and possibly spilling over to other crops, though as noted above this is not necessarily spontaneous). Cane density and other factors (including the competitiveness of other crops) will influence this process, and cane pricing policies will also affect the farmer's willingness to emulate the intensive cultivation methods practised on the estate.

Another possible linkage, not always anticipated in conventional project appraisals, concerns the effect that co-existing agricultural systems have on the supply and cost of labour. Outgrower farms have somewhat greater flexibility in the absorption of labour, but when they operate alongside a plantation they may be faced with the need to offer comparable daily wages in order to attract sufficient labour. Insofar as this effect applies to sugar cane growing it does not reduce the outgrower's income as shown in Table 5 above, since all labour inputs organized by him were costed at market (sugar project) prices. But the same effect is likely to be felt in the cultivation of other crops, substantially raising their costs of production. This has serious implications for the local food supply, unless the increase in labour costs is matched by comparable opportunities to raise productivity. Thus even formal reservation of land for food crops on each outgrower's holding does not ensure continuation of his ability to produce them; those who for one reason or another do not become outgrowers feel the effects more acutely, and may alter their subsistence strategies by placing greater reliance on earnings from wage labour and less on food crops produced by the household.

(6) *Alternative Systems of Cane Supply by Outgrowers*

In the sensitivity analysis conducted in Chapter III, it was shown that the financial performance of the OPS models improved substantially when cane growing (on the factory farm) was made more extensive and production costs were reduced. It was noted that the shift to a 'low-input low-output' system of cane growing implied that land itself was not a scarce resource; this in turn indicated that this option would be more applicable to rainfed than to irrigated situations.

A similar alternative could be employed in a project based on outgrower production. Yields on a per hectare basis would fall (perhaps from 0.8 of the plantation level - as assumed in the integrated outgrower systems - to 0.6). While the total cane area would be enlarged one possible benefit of this shift would be distributional, in that larger numbers of growers might participate. (In a densely settled area this would have important implications for equity.) Lower costs per hectare would be assumed by the grower: land preparation might be undertaken by ox-plough; seed cane might be obtained from cane on his own or his neighbour's plot; and smaller amounts of artificial fertilizers might be used, possibly with some substitution of organic fertilizers. Some reduction in labour inputs per unit of land (perhaps fewer weedings) might also be anticipated, although this would not be encouraged by the factory, which would have a continuing interest in cane quality.

Resulting from these adjustments would be the opportunity for the factory to purchase cane at a somewhat lower price than in an integrated outgrower system, where input costs are comparatively high. As shown in Table 2 the OPS models earn no financial return in most cases even with cane prices below the $15/t (low price) and $30/t (high price) yardsticks. It is to their relative benefit, then, to obtain cane at prices corresponding to ratios below 0.05. From the grower's point of view, this lower price for cane may be acceptable either if alternative markets for cane do not exist, or if net income per hectare remains constant. The latter result could be achieved if the grower's share of the price per tonne (after deduction of costs) were increased so as to compensate for lower yields per hectare.2/ In countries where a formally gazetted cane price already exists, however, it may prove difficult to institute a differential pricing system for cane produced in different regions, and even more so for cane grown in the same region but by different methods and destined for different markets.

Cane harvesting and transport charges constitute a large proportion of the costs incurred by the outgrower in an integrated, factory-directed system. If cutting and transport were taken care of by outgrowers themselves - depending on the local availability of tractors and trailers or animal-drawn carts - the scope for reduction in the cane price without adversely affecting growers' incomes would be much greater. The extent of possible savings in this area is shown in Table 4 above which indicates that the OPS units must pass on higher charges (due to indivisibility of certain equipment requirements and lower utilization rates) to the outgrower than the large-scale units. Thus shifting this responsibility from factory to grower has decided economic advantages for each, if the latter can organize labour for harvesting and has access to means of transport. In the latter regard his proximity to the factory (assumed to be characteristic of the OPS models) increases the ranges of theoretical possibilities to include animal-drawn carts or trailers.

2/ For example, if yields fall by 25 per cent from 4t/ha/month to 3t/ha/month, the grower's net revenue per tonne of cane would have to rise by 33.3 per cent to maintain a constant net income/ha.

CHAPTER V

THE IDENTIFICATION OF ENVIRONMENTALLY-SOUND TECHNOLOGIES

At this point it is desirable somehow to bring together the results of the earlier Chapter which described and examined the operation of alternative technologies for producing sugar under a variety of agricultural/climatic regimes. Ideally, it would be appropriate to set out all of the characteristics of each of the technologies considered and, on the basis of well-defined criteria, to arrange a rank ordering of the technologies which could directly guide decision-making related to the expansion of the sugar industry in Africa, with due allowance being made for individual country conditions. Unfortunately, the complexity of the factors which should be taken into account when decisions are extended to cover the economic, social and physical aspects of the environment rules out such straightforward procedures. Given this, the present Chapter comprises a discussion of currently available methodology; an attempt to make the best possible use of the earlier results in a comprehensive setting; and some comment on further methodological work which might be fruitful. The last point is discussed again in Chapter VI.

(1) *Methodology*

Hitherto the investment decision in developing countries (as indeed in developed countries) has been taken largely, often entirely, on narrow economic grounds.[1] It has been recognized that since the decision is taken at the project level it represents, at best, an attempt to approximate to what economists call a partial rather than a general equilibrium situation. In general equilibrium analysis everything is seen as relating to everything else and the formal requirement for general equilibrium solutions is that there should be as many independent equations as there are unknowns. The equations are specified in such a way as to identify the behavioural relationships among the various elements in the system.[2] In partial equilibrium analysis it is assumed that the behaviour of many variables in the larger economic system are of little consequence for decision-making at the micro level, so that the price of tea, for example, may be regarded as being independent of that of cement.

It is clear, from what has been said earlier, that this Report is based on the belief that narrowly economic considerations are not adequate to the task of identifying environmentally-sound technologies. In seeking, however, to go beyond the economic it would be possible to follow either the general or partial equilibrium approaches. In principle, of course, the general approach would be preferable. It has, however, already been pointed out that most decisions in industrial development are taken at the project level. This is not accidental. On the contrary it reflects the very considerable difficulties which would arise if attempts were made - even on narrowly economic criteria - to reach general equilibrium solutions in the absence, *inter alia*, of much of the required data. These difficulties which confront general equilibrium analysts in the realm of economics would be considerably compounded if an attempt were made to extend the general approach to

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1_/ This is true in principle. The motivation of decision-makers in practice has been the subject of a large and lively literature. Such factors as engineering influence and a penchant for a quiet life do not, however, invalidate the basic distinctions between the particular and the general made in the text.

2/ In addition to the behavioural equations other equations which are required to fulfil equilibrium conditions are also necessary.

include the physical and social environment of developing countries. For this reason it is realistic in present circumstances to proceed along the lines of partial equilibrium analysis.

Before developing this conclusion, it is worth briefly considering further the character and weaknesses of more general approaches. As has been seen, general equilibrium analysis as it has hitherto been practised by economists is simultaneously too narrow and too complex for present purposes, so that its main utility is in serving as a reminder of the fact that all the elements in a system do interact. Policies are consequently more likely to be successful the more they unravel these interactions. In this regard, one of the difficulties with the traditional general equilibrium analysis is that it is too limited and does not pay sufficient attention to externalities.[3] Again it has been argued that this kind of economic analysis either implicitly assumes that all valuable assets can be individually owned or that it confuses capital and income.[4] Apart from the difficulties of making the general equilibrium model operational, possibly its most serious disadvantage is that it is static in the sense that it takes as given resource endowments, tastes, technologies and population, etc., and simply concerns itself with the optimum allocation of resources, given these things.

The question consequently arises whether there is a more suitable aggregate framework within which to consider the relationships between economic growth (development) and the environment. Among potentially promising approaches mention should be made of the adaptation of input-output analysis and national income accounting to provide measures of materials as well as economic flows.[5] Unfortunately, the usefulness of these adaptations for present purposes is severely limited. One difficulty with input-output analysis is that it assumes that technical relations are fixed (and is hence particularly inappropriate in a choice of technology study). A further difficulty common to both input-output analysis and national income accounting is that they are both more highly developed in industrial than in developing countries.[6] Finally approaches based on these techniques could, in principle, greatly illuminate overall policy objectives and problems, but still leave a need for a corresponding redesign of project appraisal.

All of this said, it should be recognized that even if partial analysis is perforce used, the world nevertheless remains one in which all the elements in a system are inter-related. For this reason the partial

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[3] A simple, frequently used, example of an external diseconomy is smoke from a factory chimney which adds to laundry bills, but does not represent a charge on the producer. Generalization of this example illustrates possible conflicts between growth and the environment. For a more sophisticated, but still elementary, discussion, see Richard Lecomber, *Economic Growth versus the Environment*, Macmillan, 1975, Chapter 2.

[4] Although the two criticisms have been made at different levels of sophistication, they ultimately reduce to one. For relevant discussion see Kneese, *op.cit.*, Chapters 1 and 3. The distinction between capital and income is less easily made than might appear at first sight. Kneese argues that since the capital represented by (non-renewable) natural resources are not individually owned, the market has encouraged profligate use of them. The same point is made somewhat differently in E.F. Schumacher, *Small is Beautiful*, Abacus edition, Sphere Books, 1974, pp. 10-18.

[5] For a summary account of these see Kneese, *op.cit.*, Chapter 3.

[6] For a fuller discussion of this point see UN, *Survey of Economic Conditions in Africa*, Part II, New York, 1971.

approach should neither be seen as final nor should it ignore general considerations where these can plausibly be introduced. Thus, for example, a strict application of partial analysis would exclude consideration of linkages. It is evident, however, that well short of rigorous general equilibrium analysis it is often possible in considering individual projects to identify a range of backward and forward linkages and to quantify these to the point where consideration of them can be made an integral part of the investment decision.

At the level of the firm or individual project the main criterion used hitherto in decision-making has been profitability. The measure of this which most satisfies the economist's sense of rigour is the net present value. This can be calculated either at market prices or at 'shadow' prices which are thought to reflect the social valuation of the resources used in a project and the value to society of the outcome of the project. Again it can be noted that even this apparently straightforward extension of private profitability to social profitability is not without its conceptual and informational difficulties. This suggests that an attempt to deal with environmental considerations simply by incorporating these into an extended social cost-benefit framework would not be entirely successful. It is true that certain environmental variables - such as energy inputs - could be so treated, provided only that it were possible to determine the 'real' opportunity costs to society of using these over a project life. Moreover, the smoke costs mentioned in footnote 3 could conceivably be estimated and included in a relevant calculation. More complex examples of externalities would, however, provide greater difficulty, and there is some possibility that social cost-benefit analysis can be dangerously misleading, because it is dangerously unbalanced in its effective quantification.

The principal advantage of traditional methods of project appraisal is that they yield a single figure on the basis of which alternatives can be rank ordered. This advantage, however, is highly dependent on the comprehensive availability of all the necessary information. Even when the considerations entertained are confined to the narrowly economic it would be possible to argue that in actual economies valuation of some important parameters must necessarily be subjective. Certainly when the range of consideration is widened to include extra-economic elements then the possibility of entirely objective evaluation becomes the more remote. In addition, it has to be recognized that economic, social and political circumstances vary across countries and that even the decision concerning the desirability or otherwise of, say, a particular sugar factory could be influenced by these differences and, indeed, by differences in industrial locations within a particular country. Thus, for example, if a sugar factory were to be located in a rural area in which industry was otherwise absent then the view taken of the environmental consequences of particulate matter would be very different than if the factory were to be located in the middle of an already existing industrial complex which was, *inter alia*, discharging sulphur dioxide into the atmosphere.

When complete objectivity is not possible and information is less than adequate there is much to be said for avoiding summary methods of decision-making. This is because these do not normally reveal to the policy-maker the weights (which to repeat are, of necessity, often subjective) which have been used in combining the various elements in the evaluation, so that he or she has little information on which to base an alternative decision or to challenge the decision suggested by the traditional methods.

Considerations of this kind have already led to some modification to traditional project appraisal. Thus, for example, the World Bank now have an office of Environmental and Health Affairs which plays some part (at least sometimes) in project appraisal. The Bank recognizes that traditional project appraisal has been based on a least-cost approach. It makes efforts to accommodate environmental questions within this approach, but recognizes that this is not easy. It consequently has developed measures for handling projects thought to have significant environmental implication. Thus, for example, it argues that the differences between benefits and costs - assuming them to be positive - can be taken as a measure of the additional environmental advantages which could accrue from a project. In other circumstances it argues for an explicit presentation of the environmental consequences - increase or decrease, for example, of sulphur dioxide emission in industrial locations - and a measure of the costs and/or benefits of these. Beyond this the Bank where appropriate refers projects to the environmentalists for explicit consideration of environmental consequence.7/

In the United States where problems of the physical environment are in some ways acute but where the capacity for dealing with these is perhaps correspondingly great, there is a National Environmental Protection Agency which is responsible for assessing the environmental impact of existing and proposed economic activities. Since it is concerned that its measures be operational and since several levels of decision-makers are involved, the EPA seeks "to avoid overly complex methods" and in fact has developed over 50 relatively simple methods using a variety of qualitative and quantitative techniques. These have been classified into five types: ad hoc; overlays - involving the use of a set of maps capturing different environmental characteristics; checklists; matrices; and networks - these developing from a list of project activities a series of cause-condition-effect networks.8/

UNEP itself, of course, has been wrestling with the problem of introducing environmental considerations into project appraisals and relating this to the selection of environmentally-sound and appropriate technologies.9/ In this regard recognition has been accorded to the usefulness of matrices in impact assessment, and in particular to that designed by Leopold *et.al.*10/ Possibly, however, the most important contribution made by UNEP to date has been emphasis on the potential utility of decision filters. Thus, it has been suggested that - beginning from a recognition that technologies may be imported from the developed countries, may come from developing countries with a capital goods capacity to produce generically the same equipment as is produced in the developed countries, may come from such technologies adapted or may build on traditional technology or improved variants of it - the choice of technology should be made by using a series of decision filters seriatim. If this were done, then the technologies might first be appraised on the basis of their ability to produce goods which would satisfy the basic needs of the mass of the population in developing countries. Those technologies which survived this screening could then be appraised in terms of their contribution to the economic surplus; of their provision of employment opportunities; and, thereafter, on the basis of the extent to which they promote widespread social participation. The technologies could subsequently be appraised first in the light of their environmental impact and then in terms of cost efficiency.

The filter approach, like that which uses matrices, has the powerful advantage that it provides a reasoned checklist of questions which have to be considered. Its main disadvantage is that it oversimplifies, and it leaves open the question about the rank ordering of the decision filters. This ordering must either explicitly embody value judgements or explicitly incorporate something like national priorities. Both of these things might be expected to vary across countries and individuals, so that the filtering approach does not escape some at least of the difficulties which have been earlier associated with attempts to extend the social cost-benefit analysis to

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7/ For a brief account of the Bank's treatment of the environment see *Environment and Development*, World Bank, Washington 1975.

8/ Rebecca W. Manmer, *The EIS Process*, US Environmental Protection Agency, Washington D.C., 1976, (mimeographed).

9/ See, for example, UNEP, *Methodology for Selection of Environmentally-Sound and Appropriate Technologies*, Discussion Note for Expert Group Meeting, 30 August-3 September, 1976, Nairobi.

10/ Leopold L.B., Clark F.B., Henshaw, B.B. and Balsley, J.R., "A Procedure for Evaluating Environmental Impact", Geological Survey Circular 645, US Department of the Interior, Washington D.C., 1971.

the search for environmentally-sound technologies. One other difficulty with the filter approach as it has been presented hitherto is that it does not distinguish - even by implication - between direct and indirect approaches to the attainment of particular development goals. Thus, for example to make the production of goods directly designed to satisfy basic needs the touchstone in the first filter is to beg the question as to whether or not these might be better satisfied in this way rather than, for example, on the basis of a development strategy which paid significant attention to the export of 'luxury' goods.

(2) *Measuring the Environmental and Economic Impact of Alternative Sugar Technologies*

Given the present state of the art of evaluating projects in the light of national objectives and the consequent need for compromise, the simplest way of proceeding is to set a sugar quantity target and then to consider the options capable of achieving it. Thus the process may begin with, for example, a target output of 75,000 tonnes of sugar per annum (tsa) which could reflect a country's import-substitution requirements. Comparisons among the alternative technologies which could meet this target, with cost effectiveness in producing the specified target as the standard of measurement, cannot adequately deal with all of the relevant issues.

Sugar processing produces physical outputs other than sugar (e.g. effluent, smoke, filter mud). Environmental concern should imply specific quantitative targets for these too so that technologies may be compared according to their profitability in meeting a number of objectives. Some of these however can be only loosely specified (e.g. rural development in broad socio-economic terms).

What is proposed here is a two-stage process, with comparison of the economic, social and physical impact of the alternative ways of producing the required quantities of sugar as a first stage. If one alternative proves superior with respect to all quantitative criteria (economic, social and physical - assuming the existence of adequate data for these), then the optimal choice is straightforward; but if the ranking of options varies across criteria, the evaluation must proceed to a second stage in which weights are assigned to the different criteria and a close examination is made of qualitative issues.

When the results for the models are collated, and performance in relation to specific criteria is presented - for example in matrix form, as illustrated below - the weaknesses of a single measure are graphically revealed. As has been recognized, a value of 'environmental NPV' could perhaps be obtained ideally, based on rigorous shadow pricing of all possible inputs and outputs of each technology. But such rigour and coverage is not yet possible. Social NPV is a measure whose limitations are frankly acknowledged. While somewhat more inclusive in an environmental sense than other criteria relating to specific areas, it does not necessarily supersede them, and thus does not free the decision-maker from the need to assign weights to the different criteria.

To illustrate the task facing decision-makers and further to illustrate the procedure suggested above a matrix may be constructed - representing one of the four ecosystems and one price regime - in which six technology options are related to a selected number of criteria (not meant to be exhaustive). This has been done in Table 1. The options comprise two scales of production for both the vacuum-pan and OPS technologies with cane supply based on a plantation; two levels of labour-intensity in agricultural practice are assessed for the OPS units.

The matrix serves at least two useful purposes. It makes it clear that - even when only a limited number of technologies and extra-economic factors are considered - the chance of a single technology ranking first on all measures is not high. This may be most graphically

TABLE 1

Matrix Illustrating Economic and Environmental Impact of Alternative Sugar Technologies

Long season, rainfed, plantation, low prices

Factory crushing capacity	Social NPV[a]	Financial NPV[a]	Fixed capital	Total employment	Energy intensity[b]	Land requirement[c]	Factory effluent[d]	
				per tonne of sugar per annum			Concentration	Load
A. 200 tch VP	2	1	5	6	1	1	1	5
B. 100 tch VP	4	3	6	5	2	1	1	5
C. 150 tcd OPS	5	5	3	4	5	3	3	1
D. 100 tcd OPS	6	6	4	3	6	3	3	1
E. 150 tcd[e] OPS	1	2	1	2	3	5	3	1
F. 100 tcd[e] OPS	3	4	2	1	4	5	3	1

a/ Discounted at a real rate of interest of 10 per cent per annum

b/ The lower the index, the lower the energy used

c/ Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative target, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP methods would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be a perfect correlation between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

d/ Concentration is measured by milligrammes of BOD per litre; load is concentration times volume

e/ E and F differ from C and D in that cultivation practice is more labour-intensive with a consequent fall in yield

TABLE 2

Matrix Illustrating Economic and Environmental Impacts of Alternative Sugar Technologies

Long season, irrigated plantation, low prices

Factory crushing capacity		Social NPV[a/]	Financial NPV[a/]	Fixed capital	Total employment	Energy intensity[b/]	Land requirement	Factory effluent[d/] Concentration	Load
				per tonne of sugar per annum					
A.	200 tch VP	1	1	3	4	1	1	1	3
B.	100 tch VP	2	2	4	3	2	1	1	3
C.	150 tcd OPS	3	3	1	2	3	3	3	1
D.	100 tcd OPS	4	4	2	1	4	3	3	1

a/ Discounted at a real rate of interest of 10 per cent per annum

b/ The lower the index, the lower the energy used

c/ Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative targets, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP methods would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be a perfect correlation between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

d/ Concentration is measured by milligrammes of BOD per litre; load is concentration times volume

TABLE 3

Matrix Illustrating Economic and Environmental Impact of Alternative Sugar Technologies

Short season, rainfed, plantation, low prices

Factory crushing capacity	Social NPV[a]	Financial NPV[a]	Fixed capital	Total employment	Energy intensity[b]	Land requirement[c]	Factory effluent[d]	
			per tonne of sugar per annum				Concentration	Load
A. 200 tch VP	2	1	5	6	1	1	1	5
B. 100 tch VP	4	4	6	5	5	1	1	5
C. 150 tcd OPS	5	5	3	4	4	3	3	1
D. 100 tcd OPS	6	6	4	3	5	3	3	1
E. 150 tcd[e] OPS	1	2	1	2	2	5	3	1
F. 100 tcd[e] OPS	3	3	2	1	3	5	3	1

[a] Discounted at a real rate of interest of 10 per cent per annum

[b] The lower the index, the lower the energy used

[c] Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative targets, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP methods would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be a perfect correlation between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

[d] Concentration is measured by milligrammes of BOD per litre; load is concentration times volume

[e] E and F differ from C and D in that cultivation practice is more labour-intensive with a consequent fall in yield

TABLE 4

Matrix Illustrating Economic and Environmental Impact of Alternative Sugar Technologies

Short season, irrigated, plantation, low prices

Factory crushing capacity	Social NPV[a/]	Financial NPV[a/]	Fixed capital	Total employment	Energy intensity[b/]	Land requirement[c/]	Factory effluent[d/] Concentration	Load
			per tonne of sugar per annum					
A. 200 tch VP	1	1	3	4	1	1	1	3
B. 100 tch VP	2	2	4	3	3	1	1	3
C. 150 tcd OPS	3	3	1	2	2	3	3	1
D. 100 tcd OPS	4	4	2	1	4	3	3	1

[a/] Discounted at a real rate of interest of 10 per cent per annum

[b/] The lower the index, the lower the energy used

[c/] Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative target, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP models would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be a perfect correlation between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

[d/] Concentration is measured by milligrammes of BOD per litre; load is concentration times volume

TABLE 5

Matrix Illustrating Economic and Environmental Impact of Alternative Sugar Technologies

Long season, rainfed, plantation, high prices

	Factory crushing capacity	Social NPV[a/]	Financial NPV[a/]	Fixed capital	Total employment	Energy intensity[b/]	Land requirement[c/]	Factory effluent Concentration	Load
				per tonne of sugar per annum					
A.	200 tch VP	2	1	5	6	1	1	1	5
B.	100 tch VP	4	3	6	5	2	1	1	5
C.	150 tcd OPS	5	5	3	4	5	3	3	1
D.	100 tcd OPS	6	6	4	3	6	3	3	1
E.	150 tcd[e/] OPS	1	2	1	2	3	5	3	1
D.	100 tcd[e/]	3	4	2	1	4	5	3	1

[a/] Discounted at a real rate of interest of 10 per cent per annum

[b/] The lower the index, the lower the energy used

[c/] Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative target, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP methods would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be a perfect correlation between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

[d/] Concentration is measured by milligrammes of BOD per litre; load is concentration times volume

[e/] E and F differ from C and D in that cultivation practice is more labour-intensive with a consequent fall in yield

TABLE 6

Matrix Illustrating Economic and Environmental Impact of Alternative Sugar Technologies

Long season, irrigated, plantation, high prices

Factory Crushing capacity	Social NPV a/	Financial NPV a/	Fixed capital	Total employment	Energy intensity b/	Land requirement c/	Factory effluent d/ Concentration	Factory effluent d/ Load
			per tonne of sugar per annum	per tonne of sugar per annum	per tonne of sugar per annum			
A. 200 tch VP	1	1	3	4	1	1	1	3
B. 100 tch VP	2	2	4	3	2	1	1	3
C. 150 tcd OPS	3	3	1	2	3	3	3	1
D. 100 tcd OPS	4	4	2	1	4	3	3	1

a/ Discounted at a real rate of interest of 10 per cent per annum

b/ The lower the index, the lower the energy used

c/ Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative target, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP methods would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be a perfect correlation between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

d/ Concentration is measured by milligrammes of BOD per litre; load is concentration times volume.

TABLE 7

Matrix Ilustrating Economic and Environmental Impact of Alternative Sugar Technologies

Short season, rainfed, plantation, high prices

Factory crushing capacity		Social NPV a/	Financial NPV a/	Fixed capital	Total employment	Energy intensity b/	Land requirement c/	Factory effluent d/	
				per tonne of sugar per annum				Concentration	Load
A.	200 tch VP	2	1	5	6	1	1	1	5
B.	100 tch VP	4	3	6	5	5	1	1	5
C.	150 tcd OPS	5	5	3	4	4	3	3	1
D.	100 tcd OPS	6	6	4	3	5	3	3	1
E.	150 tcd e/ OPS	1	2	1	2	2	5	3	1
F.	100 tcd e/	3	4	2	1	3	5	3	1

a/ Discounted at a real rate of interest of 10 per cent per annum

b/ The lower the index, the lower the energy used

c/ Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative target, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP methods would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be a perfect correlation between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

d/ Concentration is measured by milligrammes of BOD per litre; load is concentration times volume

e/ E and F differ from C and D in that cultivation practice is more labour-intensive with a consequent fall in yield

TABLE 8

Matrix Illustrating Economic and Environmental Impact of Alternative Sugar Technologies

Short season, irrigated, plantation, high prices

Factory crushing capacity		Social NPVa/	Financial NPVa/	Fixed capital	Total employment	Energy intensity b/	Land requirement c/	Factory effluent d/	
				per tonne of sugar per annum				Concentration	Load
A.	200 tch VP	1	1	3	4	1	1	1	3
B.	100 tch VP	2	2	4	3	3	1	1	3
C.	150 tcd OPS	3	3	1	2	2	3	3	1
D.	100 tcd OPS	4	4	2	1	4	3	3	1

a/ Discounted at a real rate of interest of 10 per cent per annum

b/ The lower the index, the lower the energy used

c/ Since, as indicated in the text, the matrix is to be seen in the context of meeting some quantitative target, the use of tsa here (as elsewhere) is justified, and the implication of the matrix rankings is that to meet the target by OPS rather than VP methods would require more land. On convenient assumptions about population density, the same is true *ipso facto* of population displacement, so that there will be between land use and the number of people displaced. The index of land requirement consequently serves a double purpose. It should, however, be noted that in outgrower situations the rank ordering of displacement could be different from that shown in the matrix

d/ Concentration is measured by milligrammes of BOD per litre; load is concentration times volume.

seen with respect to water pollution, where two different measures - discussed more fully below - are used, with the result that the ranking varies according to the measure used. Similarly, the rank ordering based on financial NPV is quite different from that based on social NPV, with the latter identifying an OPS and the former a vacuum-pan technology as the 'optimal' choice.

It should be recognized that both NPV measures subsume, in whole or in part, fixed capital, employment, land use and energy. This duplication, however, provides the basis for the second purpose of the matrix - to provide the decision-maker with more information than that contained in a single indicator (such as NPV) which might be used as a choice criterion. The point here is that the decision-maker can see at least impressionistically if the weights used in calculating the NPV coincide with or differ from those he or she would like to attach to the separate elements identified in the columns of the matrix. In this way the matrix provides a bridge between the first part of the procedure described above (that of ruling out the possibility that one alternative is 'superior' on all criteria) and the second.

The degree of variation in the rankings is certain to increase when the matrix is expanded to encompass a larger number of technology options and more environmental measures. With regard to the first, Chapters III and IV of this Report have assessed eight basic possibilities (four plantation-based models and four integrated outgrower-based models) with several variants, including plantation-cum-outgrower systems, and (potentially applicable to the OPS technology) systems in which cane is produced by extensive as opposed to intensive cultivation. Similarly, a range of environmental issues has been discussed from which a checklist - constituting the horizontal axis of an expanded matrix - can be assembled.

Logically eight matrices could be generated from the methodology employed here representing the four ecosystems in each of two price regimes. This is done in Tables 1 to 8 for plantation-based models. It is evident from these that the presumption against settling matters at the first stage is strengthened, since in no case does a single technology appear 'superior' on all criteria. At the practical level, since the ecosystem and price regime will be predetermined,11/ a decision-maker will usually require only one matrix for each cane supply system under consideration. Unambiguous judgements can only be based on a cardinal system of parameter values (as opposed to simple ordinal ranking) which reflects the magnitude of differences between options. Even when such values can be assigned to quantities of output or impact, any attempt at pricing implicitly involves a weighting procedure embodying certain value preferences.

Although it would have been possible to have assigned more or less arbitrary weights to the elements includes in the above matrices, this has deliberately been avoided. For this there are a number of reasons. The first is, to repeat, that the weights would evidently be unacceptably arbitrary, since they would reflect the judgements of outside investigators rather than those of national decision-makers. Moreover, this evident fact notwithstanding, there is a real danger that illustrative quantification would be seized upon and used as if it represented firm results. In this circumstance, the prsent discussion is intended to describe a usable methodology rather than exhaustively to apply it. Given this it may be helpful to offer some further thoughts on methodology.

In this regard it may first be noted that a sequential filtering system poses similar difficulties to those described earlier, since the ordering of the filter directly affects the outcome of the evaluative process. For example, if financial NPV ÷ tsa 12/ were placed first in

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11/ One possible exception concerns marginal situations wherein irrigation is a possibility but not a necessity, and where two matrices (holding season length and price regime constant) would be desirable so as to compare the range of options under rainfed and irrigated agricultural systems.

10/ Discounted at 10 per cent per annum.

the sequence, and all options with a result below 0 were to be rejected, then in the situation represented by Table 1 only the 200 tch model would 'survive' to be scrutinized in subsequent filters. Effectively only one 'choice' would remain, and in an actual situation the rigour of assessment in the subsequent filters might be expected to diminish so as to preserve at least one possibility for the eventual investment decision.

Expansion of the number of indicators leads naturally to a situation in which five levels of precision may be distinguished:

(i) measures to which both market and social prices can be assigned, and for which the models in this Report provide guidelines;

(ii) measures to which market prices apply in a given situation (e.g. a price for land in voluntary transactions), but for which social prices (e.g. the cost of involuntary displacement from land) can be computed only with varying degrees of subjectivity;

(iii) indicators based on cardinal parameter values which show relative magnitudes (e.g. volume of water effluent), but for which neither market nor social prices normally exist;

(iv) rank ordering with respect to a specific criterion, where differentials between technological options cannot be quantified; and

(v) identification of extremes within the set of options being considered (the end-points being 'most' and 'least') while accepting that the intermediate options may not be clearly distinguished on the basis of available data.

Since what is sought is a method for integrating the economic, social and physical aspects of the environment into the selection process, it may be noted that their respective distribution across these levels of precision tends to differ. Generally speaking most economic criteria can be assessed at levels (i) and (ii); the physical criteria tend to be concentrated at level (iii), and to a lesser extent at (ii) and (iv); while the social issues reviewed in this Report range between (ii) and (v), with movement towards greater precision dependent either on detailed, micro-level demographic and sociological data; or a set of simplifying assumptions such as were used in the models within this Report.

Brief reference may be made to ways of handling issues related to the physical environment which take cognizance of levels of precision. In Tables 1-8, the ordinal ranking of total energy consumption per tsa conceals the magnitude of differences and, more significantly, the composition of the total in terms of cane production, sugar production and sugar distribution. In cane production the large-scale plantations use 20-25 per cent more energy per tonne of cane but up to 25 per cent less per tsa than the small-scale extensive system. This difference serves to illustrate the comparative advantage of the vacuum-pan system where higher sugar recovery is sufficient to reverse the rank ordering. In sugar production the OPS factory buys in six times more energy units, in the form of firewood and electricity, than the most efficient vacuum-pan factory (long season, 200 tch). However, in a comparison of all inputs including capital equipment, annual replacements, chemicals and labour the OPS unit is very close to the vacuum-pan and in fact in the short season situation the 150 tcd unit uses 35 per cent less energy *on a per tsa basis* than the 100 tch factory. Sugar distribution, when based on the same population density, is very much less energy using in the small-scale; it accounts for less than 0.7 per cent of total energy consumption compared to 2-8 per cent in the large-scale.

An indicator presented in two forms in the matrix is that of water pollution. As discussed in Chapter III, the type of standard used (i.e. BOD concentration or load) influences the rank ordering of the technologies. To illustrate the problem numerically a brief comparison of actual vacuum-pan effluents and estimated open-pan effluents is presented. Thus if a discharge of 20,000 litres per tonne of cane is assumed from a vacuum-pan factory, with an average BOD concentration of 600 mg/l, then in terms of load this is equivalent to 12 kg BOD per tc.

On the other hand, given a discharge of 150 litres per tonne of cane from an OPS unit, doubling the BOD concentration to 1200 mg/l means that the load factor is only 0.18 kg per tc. In fact, to be as potentially polluting as that of the vacuum-pan factory, the effluent could be 10,000 mg/l (for example by discharging filter mud as part of the effluent) and the volume up to 1200 litres per tc. A rank ordering on either basis can be misleading, however, as the significance of a given pollution factor is entirely dependent on local circumstances. That is to say in certain conditions a BOD load of 0.18 kg per tc could be very damaging to the local environment; but in other situations, notably with a high dilution factor, a load of 12 kg per tc could be assimilated with negligible deoxygenation of the river.

Expansion of the list of environmental indicators means that phenomena must be compared at different levels of precision. While complicating the decision-maker's task, this has the advantage of ensuring that no important issues will be overlooked, and thus holds promise of improving the outcome of the selection process.

It should be pointed out that a further use to which the present approach to including technologies could be put is to identify 'inconsistencies' across criteria and thus to raise the question of whether these can be eradicated or, at least, reduced. A particular example would be a conflict between social and financial profitability in the rank ordering of the two technologies. If, as seems reasonable, the social criteria were to be given priority, it might still be desirable to improve the financial performance of the technology thus preferred.

In this regard, in considering the future expansion of the sugar industry in Africa, the work reported here has identified tradeoffs in the performance of the models with respect to various economic and environmental criteria. In the short run, modification of existing economic policies offers one possible means of reducing the gaps in performance and even altering the rank order of options. The most obvious area for such intervention concerns pricing policies for cane and/or ex-factory sugar. The gap in sugar recovery (6.25 per cent on cane for OPS against 10.6 per cent for the vacuum-pan technology) places the small-scale units at a serious disadvantage when they must operate the same price system as the large-scale units. If they are not financially profitable in such circumstances, the question arises as to how they might become so on the basis of changes which could be justified economically or on environmental grounds.

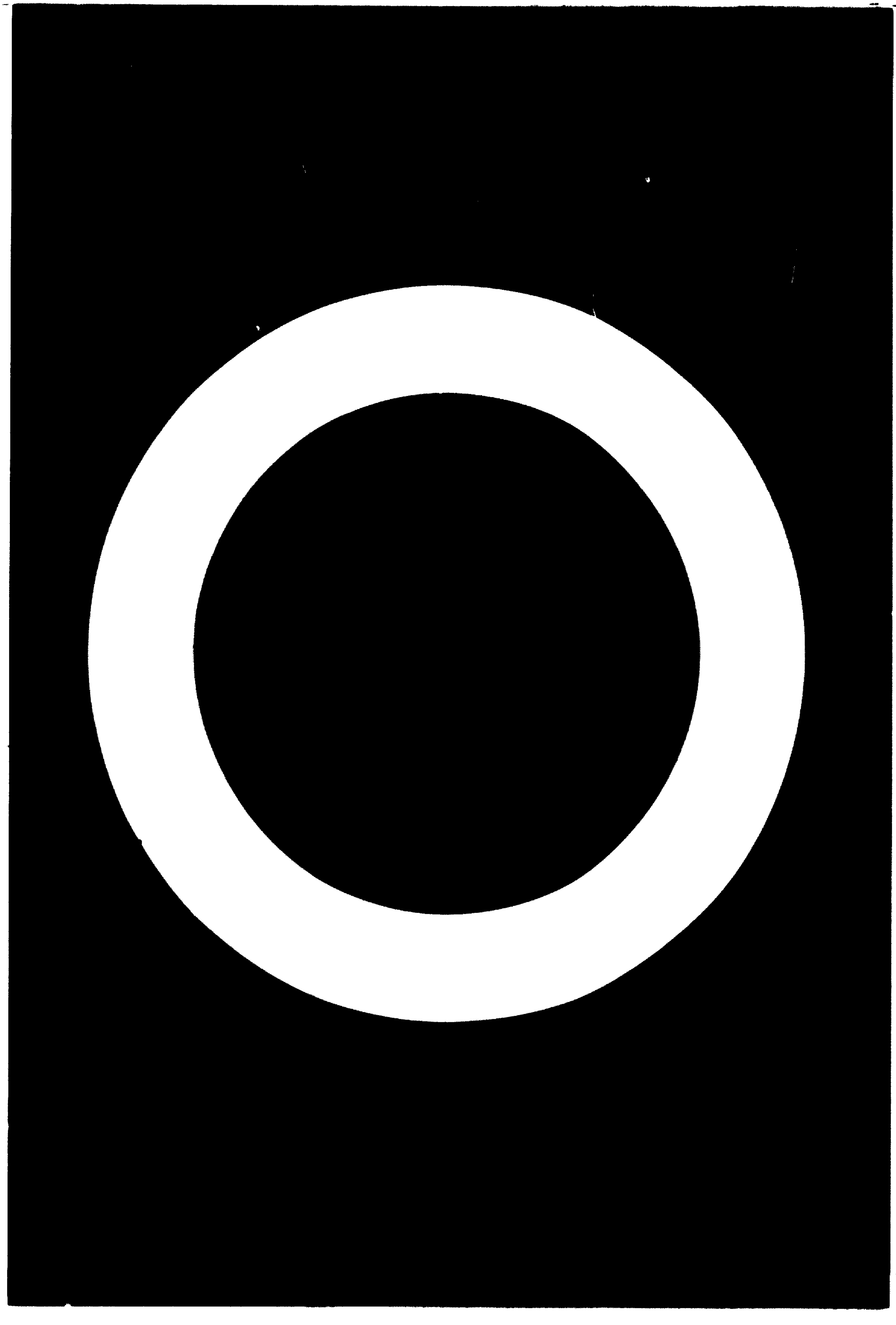
Over the longer term significant research and development efforts may be brought to bear on the technologies themselves. To the extent that these influence critical parameters such as sugar recovery and energy utilization, they could substantially alter the comparative results presented earlier in this Report.

Most of what has gone before can be readily related to the Terms of Reference of the present project. The one exception to this concerns policy aspects. In particular the project document called for consideration of present policies and proposals for appropriate modification of these, including proposals for the modification of a project currently under consideration. In a sense much of the above can be seen in the context of this particular Term of Reference. Beyond this discussions were held with government ministers and officials and policy proposals were reviewed and suggestions for modification made on a confidential basis. In addition the Seminar held in Nairobi in April 1977 provided an opportunity for an exchange of views between some African policy-makers and members of the project team. In the course of this exchange discussions were held on a number of actual and proposed projects.

(3) *Further Methodological Work*

In the light of general earlier discussion of methodology and of the consideration of the present results for the African sugar industry, it is clear that much remains to be done in the elaboration of an operational methodology. Such elaboration, it is thought, can best proceed from the kind of detailed characterization of technologies and their economic, environmental and social consequences as are contained in this Report. In the meantime it may be suggested that the two stage procedure described above should be applied. From the illustration it seems probable that decision-makers must normally expect to pass to the second (and operationally more difficult) stage. They might wish, therefore, to have some further guidance on how to proceed at this point. Such guidance can be offered in a way that helps identify an important element for future work.

Thus, particularly given the importance of the economic environment in developing countries, alternative technologies can be compared first by means of extended and explicit cost-benefit analysis and subsequently examined for particular environmental effects that inevitably escape the net of such analysis. In this approach the question of evaluation is, of course, left open and the more straightforward environmental impacts could be accommodated in the analysis. Thus accommodated they should, of course, remain explicitly before the decision-maker at the point of decision. The coverage of the cost-benefit analysis would clearly vary from case to case. In principle, however, this method - with, to repeat, due emphasis on making as much explicit as possible - amounts to choosing the economically viable technology subject to a somewhat informal constraint that it is also an environmentally sound one. Much subsequent work could be directed to increasing the formality of the constraint, and it is recommended in Chapter VI that such work should be incorporated in any extension to the present project.



CHAPTER VI

PROPOSALS FOR FURTHER WORK

The investigation which comprises the subject of the earlier pages of this Report may be regarded as a pilot one - both in that it explores the suitability of the sugar industry as a focus for attempts to improve the environmental soundness and appropriateness of technology and in that it tests a methodology which may be applied to other industries. Consequently in considering the design of further work it is apt to include proposals which - based on the present enquiry and its findings - relate to sugar and to identify another industry which could fruitfully be investigated along the lines described above. Although the present somewhat pragmatic approach would be difficult to replace in the current state of knowledge, it is also apt explicitly to consider methodology. Thus, the remainder of the Chapter is in three parts. The first details further work which could usefully be done toward increasing the environmental acceptability and the economic efficiency of sugar technologies used in developing countries; the second suggests that cement is a suitable candidate for the next 'industry' study; and the third touches briefly on methodology.

(1) *The Sugar Industry*

As has already been pointed out, the present enquiry has focused, *inter alia*, on two factory technologies (the modern vacuum-pan and the traditional open-pan sulphitation techniques) in their 'purest' and basically most highly developed forms.[1] This fact can be used to answer one question and raise another - *viz.* (a) does the OPS technique compare sufficiently well with the modern process in various respects to justify further work on it? and (b) is there scope for critical choice within the modern process itself which, if exploited, could lead to more effective pursuit of developmental (including environmental) goals?

From what has been said (and, indeed, in any event), it is evident that the OPS system is appropriate to the achievement of a number of developmental and environmental aims. At the least, it uses much less capital and provides much more employment than does modern technology. It is, moreover, less abruptly disruptive of existing life styles and - since it would lead to greater dispersal of the industry, and since there is some presumption that the greater the industrial concentration, the greater the degradation of the physical environment - it is kinder to the environment than the more sophisticated alternative.[2] The main doubt which has surrounded the OPS technique has been that it is not economically viable.

The choice of technology can be made - within the confines of economics - in one of two ways. The social opportunity cost of resources can be estimated and the least-cost technology at 'shadow' prices subsequently identified. Alternatively, factor prices can be taken at their market value - even when the markets are known to be imperfect - and a narrower financial calculation made. From the information contained in Chapter III of this Report the standing of the two technologies on each of these measures is as follows:

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[1] This strong statement could stand some modification - since, for example, the use of diffusers in the modern technology was, on consideration, not included. What is said in the text is, however, sufficiently accurate for present purposes.

[2] A qualification is again in order. The exposure to sulphur fumes of workers in the open-pan factory is probably greater than in the modern factory. Moreover, worker safety standards are probably generally lower in the small-scale factory.

Inter-technology comparisons of profitability

	Financial				Social			
	NPV[a] per tsa		NPV ÷ K		NPV per tsa		NPV ÷ K	
	$	Index	$	Index	$	Index	$	Index
Long season, rainfed (at low prices)								
1. 200 tch	875	100	1.62	100	1579	100	2.92	100
2. 150 tcd[b]	289	33	1.04	64	1420	90	5.13	176

a/ NPV discounted at 5 per cent per annum in real terms in all measures shown, capital (K) similarly discounted

b/ The 150 tcd model is the labour-intensive agricultural variant discussed in Chapter III, Section 1

Thus it can be seen that factories operating in a long season rainfed situation would have different profitability according to whether the evaluation was conducted on private or social terms. When market prices are used the large-scale factory is clearly absolutely superior; and the small-scale (OPS) factory would yield but 33 or 64 per cent of the net present value of the large factory, depending on the present value measure used.[3] When shadow pricing is used the situation changes dramatically. The small factory would now earn 90 per cent of the profits achievable by the large factory per tonne of sugar per annum, and would in fact yield 176 per cent of the large factory profits if the measure used is net present value per unit of capital.

Given what has been said above, it is clear that, even as things now stand, the choice between the two technologies when factors other than economic viability are considered would not be clear-cut, but would require consideration of a number of possible tradeoffs. More strongly, it could be argued - particularly if the social evaluation is accepted [4] - that the open-pan technology already performs sufficiently well economically compared to the modern to justify further work on it. This, at any event, is the view taken here and it is consequently felt that further work on the OPS system is justified.

On the second question concerned with the scope for choice within the modern process, it may first be noted that previous work done by the Livingstone Institute has established that a range of technical choice certainly exists.[5] At the time this work was undertaken the alternative machines then available and the prices and manning levels associated with them suggested that, particularly at levels of scale of 50,000 tonnes sugar per annum and above, an 'exacting' economic measure would identify the 'best-practice' technology as being optimal even in developing country conditions. The same data which sustain this

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[3] The net present value per unit of capital measure is introduced at this point since this is arguably the more relevant measure in a situation of capital rationing.

[4] Generally speaking social evaluation is clearly preferable in this context to that based on market prices. It should, however, be recognized that - at least in a mixed economy - it is necessary to identify and use policy instruments which would achieve the results indicated as desirable by social pricing. Thus, for example, it may be appropriate to use labour subsidies.

[5] See J. Pickett, *A Report on a Pilot Investigation of the Choice of Technology in Developing Countries*, University of Strathclyde, December 1975, Chapter 4.

conclusion, however, also reveal that the range of profitability across technologies is much narrower than that of employment. Thus, for example, in the production of 50,000 tonnes of sugar per annum it was shown that - depending on the price of sugar - a technology which was recognizably less sophisticated than the 'optimal' technology could increase employment by 74 per cent compared to that provided by the 'optimal' technology, reduce total capital investment by 3 per cent and provide 93 or 98 per cent of the net present value that would accrue from the use of the 'best-practice' technique.

It is five years since this earlier study was undertaken and recent fieldwork suggests that it might not now be easy to obtain from developed country sources the full range of equipment that would be necessary if the corresponding full range of technology choice were to be possible. Specifically some of the machines might have to be manufactured on a 'one-off' basis and consequently be discouragingly expensive. This possibility of limited developed country supply is consistent with the concern of developing countries to lessen their technological dependence on the richer countries of the world, and suggests that it could be fruitful to focus some part of further work on sugar on a related set of questions concerned with trade among developing countries and the promotion of the capital goods industry in such countries.

In the light of the foregoing, it is now appropriate to specify in some detail proposals for further work on the sugar industry. These comprise suggestions for improving and upgrading the OPS technology; suggestions for simultaneously increasing the engineering linkages between the sugar industry and the capital goods industry in one or more developing countries and increasing the effective scope for choice in the modern technology; and some proposals for the further utilization of bagasse which could enhance the contribution that the modern technology makes to economic and social development.

(a) Improving/upgrading the OPS

The aim here would be to improve the economic and technical efficiency of the OPS technology and hence to increase its environmental acceptability. This part of the work would comprise five stages, the first two of which at least could be undertaken simultaneously. The stages are:

(i) further investigation of the Indian experience of the OPS technology, and of the associated capital goods industry in India. This investigation would be followed by developed country research and development designed to improve the technical (and it is hoped economic) efficiency of the OPS equipment;

(ii) improvement in fuel economy. It has already been seen that the main present disadvantage of the OPS system is that, in certain circumstances, it is economically less attractive than the large-scale technology. An important reason for this is that the OPS technology is technically inefficient in processing when compared with larger plants. A combination of fuel diseconomy and sucrose loss through inversion means that an OPS unit uses two to six times as much outside (bought-in) fuel per tonne of sugar produced compared with the 100 or 200 tonnes of cane per hour factories; and it produces only 60 to 70 per cent as much sugar per tonne of cane crushed.

It follows from this that improvements in fuel technology could radically alter the financial attractiveness of the OPS unit. Recent work on fuel technologies - in particular the development of the tubular bio-gas generator - suggests that such radical alteration is possible and consequently this stage of the work would seek to develop the most suitable type of digestor to produce methane from bagasse; and to develop a heating vessel system which would use the methane as its fuel. This part of the research could yield a number of advantages. The methane is produced from a slurry with high moisture content so that it would be feasible to introduce imbibition at the cane crushing stage and thus directly raise juice extraction rates. Moreover the methane can be expected to be a more controllable form of heating than the existing wet bagasse furnace system and consequently sucrose inversion should also be reduced. Again, the successful achievement of the first two objectives would make it possible to modify the design of the heating vessel in order to reduce the incidence of sources of material degradation - by, for example, investigating the economies of coating or metal spraying of pans and of hand-polishing after installation. Moreover the production of methane need not solely depend on the quantity of bagasse: in the existing OPS technology supplementation usually takes the form of firewood, the supply of which in many parts of developing countries can itself prove environmentally damaging; in contrast supplementation in the case of methane production can take the form of agricultural waste - a readily renewable resource - and further a more useful by-product (organic fertilizer) is obtained;

(iii) improved design. The research and development implied in the first two stages should lead to a 'superior' design of OPS equipment. At this stage it would then be important to relate this to the engineering capacity of selected developing countries, in order to install the relevant production technology in such countries;

(iv) checking the improved technology for environmental impact. It is, for example, just possible that the introduction of imbibition could increase the water effluent discharged by OPS units. If this were so then simple measures could be designed to deal with this problem. It would normally suffice to construct ponds or lagoons; and

(v) an examination of the role of OPS sugar production in integrated rural development. This could bring together the various phases of the work and, *inter alia*, would make possible more detailed examination of OPS irrigated regimes than could have been undertaken in the pilot investigation.

(b) Larger-scale production and engineering linkages

Many developing countries might follow a mixed strategy in expanding their capacity to produce sugar. They might consequently combine some expansion of production utilizing modern technology with some development of the OPS system. In this regard it is useful to consider the advantages of not relying in the modern sector on 'best-practice' technologies available from developed countries. Such technologies require a considerable degree of instrumentation and a reduction in this and other modifications to the most advanced technologies would offer at least two advantages: there would be less need for skilled engineering manpower, both to operate and to maintain the instrumentation (on the several occasions during the fieldwork of the present project where sophisticated instrumentation was seen to be available it was observed not to be in use); and it would be potentially easier for developing countries to commence manufacture of sugar machinery for themselves. Consequently this part of the work would:

(i) determine the engineering and other skills required to manufacture equipment for the various stages of sugar production;

(ii) rank this according to the stages of sophistication required in terms of the capital goods manufacturing process;

(iii) compare this in turn with detailed information on the engineering capacity of selected developing countries; and

(iv) evaluate the economic and environmental implications of the range of feasible technologies.

It should be realized that this part of the work directly challenges conventional wisdom in the sugar industry which maintains that considerable economies of scale exist. If, however, it were possible (and the Egyptian experience, *inter alia*, suggests that it is) for developing countries to manufacture less sophisticated 'modern' equipment at lower cost than could now be done in the developed countries (given the factor price configurations there and where, for example, manual centrifugal machines would not now readily be available and would have consequently to be specially made) this would cause a structural break in the unit cost of production, and it would no longer follow that the capital cost of a 100 tonnes of cane per hour factory would be about 70 per cent of a 200 tonnes of cane per hour factory. It is worth adding that in present circumstances at least one major international sugar organization would be interested in the application of results obtained from this part of the work.

(c) Further utilization of bagasse

In the design of large-scale vacuum-pan factories it is common to find that the steam balance is built up on the basis of an objective that the available bagasse should entirely be consumed within the factory. Conventionally, excess bagasse is considered to be a nuisance unless the surplus is sufficiently great to support a secondary industry such as particle board production. There are, however, other possibilities for utilizing surplus bagasse in ways that would be in keeping with development goals as expressed by many developing countries, and whilst some of these require further research the benefits they might have to offer are potentially great. As mentioned earlier bagasse can be used in the production of methane which would seem to be an attractive alternative fuel to those presently used for village domestic needs.

Another potential use for surplus bagasse involves upgrading it through micro-biological treatment in order to produce protein. This alternative is particularly attractive in the light of the fact that one way in which the growing gap between developed and developing countries is most palpable is in the dietary intake of the mass of the population in the respective sets of countries. Moreover there has been widespread concern about the adequacies of world food supplies in the light of recent and present very high rates of population growth. Thus work on transforming bagasse into usable protein either for direct human consumption or for animal use is, to repeat, attractive. In this regard, the relevant work would comprise three stages. The first would, on the basis of laboratory study, identify the range of suitable organisms for this purpose. Having established the correct conditions for bagasse colonization the second task would be bio-technological and would be concerned to identify the correct type of technology which could transform the bagasse into protein in the location in which bagasse is produced. The final stage would comprise an economic and environmental appraisal of the relevant technology.

It should be recorded that these various proposals for further work on sugar would all lend themselves admirably to co-operation between developing and developed country institutions. Moreover it should be evident that they are designed to lead to practical application in developing countries.

(2) *Cement*

In the comparison made above between the economic attractiveness of the modern and open-pan sulphitation sugar technologies, the modern technology could have been further handicapped by considering the additional costs that have to be incurred if pollution is to be avoided. In this regard it may be noted that capital costs of a 50,000 tonnes of sugar per annum factory in Hawaii would probably be about 3 per cent higher if air and water pollution were to be dealt with than if they were to be ignored.6/ Depending on the absolute size of net present values this could significantly effect the comparison between the modern and traditional sugar technology. More generally this statistic can serve another purpose. Impressionistically it can be taken as suggesting that, as these things go, the sugar industry is not a particularly 'dirty' one.

The suggestion has on several occasions been made that one way in which the share of developing countries in world manufacturing output could be increased would be by the transfer of 'dirty' industries from developed to developing countries. Presumably the rationale behind this suggestion is the thought that the physical environment in the developed countries is already more polluted than that in the developing countries because of the higher level of industrialization in the former. This, however, has not been systematically tested. Consequently, there is a case for following a study of sugar - a relatively 'clean' industry - with a corresponding study of an evidently 'dirty' industry. Cement, which is a common import-substituting industry in countries with the necessary raw materials, particularly limestone, is a clear candidate in this regard - if only because of the significant amounts of sulphur dioxide and particulate matter which are emitted when cement is produced by using modern technology.

The dirtiness of the cement industry is not the only reason for suggesting it as the second industry to be studied. It has in fact a number of interesting parallels with the sugar industry. Thus there is a clear generic distinction between the modern technology and the traditional technologies which might be used in developing countries to produce cement. Moreover the economies of scale in the modern production of cement are if anything more fierce than those encountered in the production of sugar. Again within the modern spectrum of techniques there are sufficient options to raise some interesting questions. The basic choice in the modern technology is between the wet and dry processes, but this choice raises other interesting questions concerning the utilization of raw materials, the generation of employment, the consumption of energy, and the degree of pollution. Thus there is considerable scope for systematic research and development on the small-scale cement technologies; and for serious investigation of the economic and environmental impact of alternative modern technologies in developing country conditions. It follows from this that the methodology evolved in the course of the present project should - modified in the light of experience - be readily applicable to a study of cement.

(3) *Methodology*

The main methodological thrust of the present Report has been that if practical application is an important immediate objective, then a detailed consideration of the economic, technical and physical characteristics of particular industries in specified social settings is necessary. This somewhat pragmatic approach is, to repeat, dictated largely by the present state of knowledge. In the longer run what is required is an operational model or models capable of handling the interactions of the many variables that comprise the economic and environmental systems. It consequently would be desirable to add to the foregoing some explicit work on methodology.

The first requirement here is the elaboration of appropriate models and ensuring that these are logically consistent. This done the second task is to consider the problems of making the models operational and identifying the data and other requirements necessary to this end. In this regard the importance of identifying and collecting relevant data cannot be too strongly emphasized. This requires a clear definition of the categories of data needed and the specification of appropriate data

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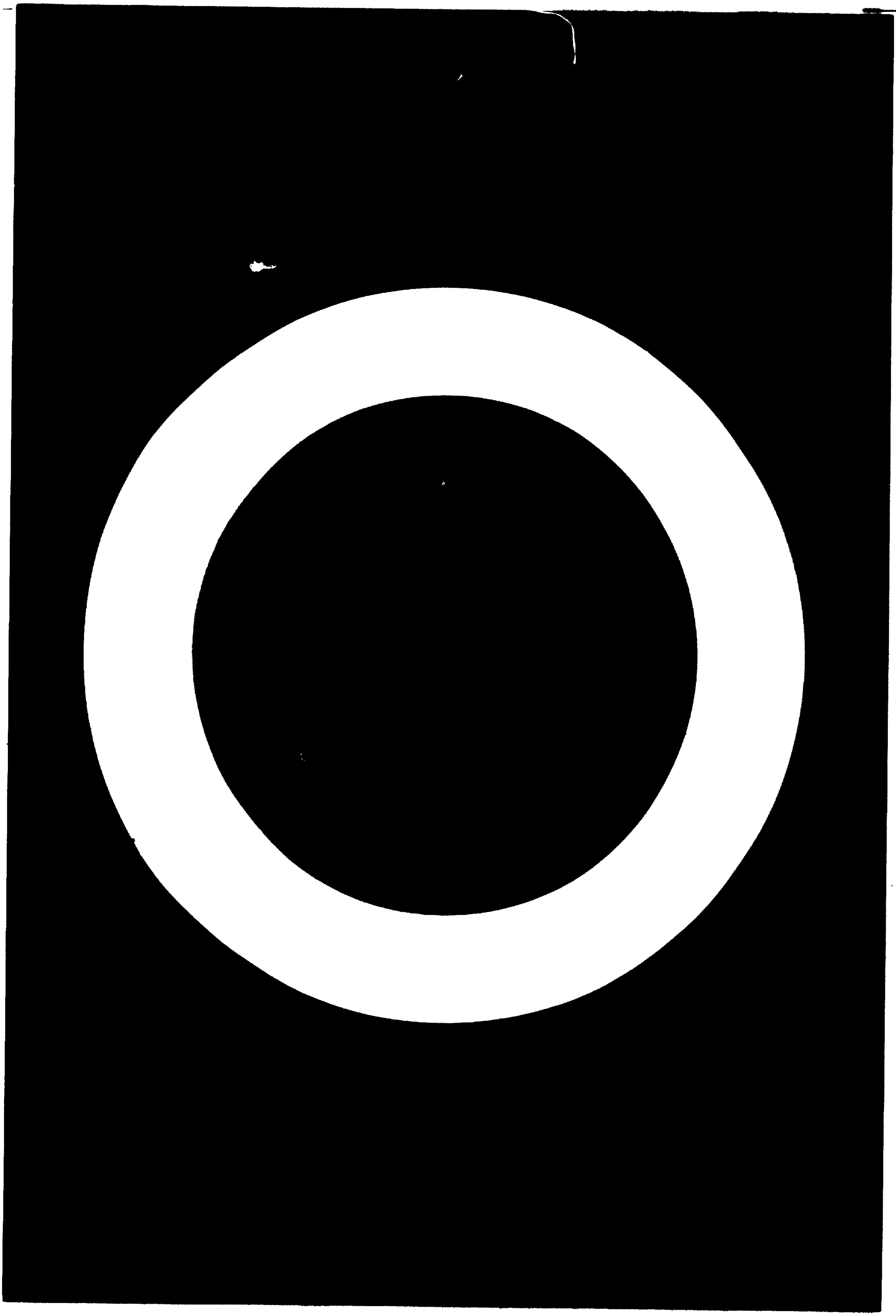
6/ Joint report by Dept. of Agriculture and Office of Environmental Quality Control on the Sugar Industry of Hawaii, March 1973. Figure refers to one factory. 1977 estimates based on the most modern sugar factory in USA suggest a figure of 10 per cent to comply with strict US EPA legislation (See page 56).

collecting methods. To illustrate the importance of this, it may be remarked that one difficulty experienced in the present investigation was the lack in most fieldwork countries of measures of pollution. It would be appropriate in the prosecution of the cement enquiry to take some direct steps to fill this gap.



ANNEX I

LIST OF PAPERS PREPARED FOR UNEP/UNIDO SEMINAR, NAIROBI, APRIL 1977[1]

Paper 1: Recent Developments in the World Sugar Industry
- R. Robson* 2/.

Paper 2: Large-Scale Production of Sugar by the Vacuum-Pan Process
- A.W. MacGillivray and G. Wood.

Paper 3: Economic Viability in African Conditions of the Large-Scale Vacuum-Pan Technology
- R. Alpine* and Fiona Duguid*.

Paper 4: Economy of Scale in the Sugar Industry with Special Reference to Sugar Manufacture and Transport
- J.M. Paturau.

Paper 5: Environmental Implications of Different Sugar Technologies with Special Referencs to India
- B. Behari.

Paper 6: Economic Viability in African Conditions of the Small-Scale Open-Pan Technology
- R. Alpine* and Fiona Duguid*.

Paper 7: Subject of Engineering Issues in Manufacture of Open-Pan Sugar Processing Equipment in Developing Countries
- S.W. Ohingo.

Paper 8: Australian Cane Growing and Sugar Milling - Some Implications of the Technology Employed
- G.A. Ferguson.

Paper 9: The Long-Term Agricultural Implications of Cane Growing
- Z.A. Menshawi.

Paper 10: Thailand's Experience in Sugar Industry Pollution and Measures Taken to Deal with the Problem
- P. Kiravanich and Y. Unkulvasapaul.

Paper 11: Possibilities for the Further Processing of Sugar Industry By-Products
- Fiona Duguid* and R. Alpine*.

1/ Joint UNEP/UNIDO Seminar on the Implication of Technology Choice in the African Sugar Industry, Nairobi, 18-22 April 1977.

2/ * indicates a member of staff of the David Livingstone Institute, University of Strathclyde, Glasgow.

Paper 12: Potentials and Impact of By-Products of the Sugar Cane Industry in Developing Countries
- O. Alamazon del Olmo.

Paper 13: Energy Consumption in the Sugar Industry
- Fiona Duguid* and R. Alpine*.

Paper 14: Environmental and Economic Impact of Alternative Agricultural Sugar Technologies
- J. Pickett* and Fiona Duguid*.

Paper 15: Sociological Issues in the Design of Cane Growing Systems
- A.H. Barclay*.

Paper 16: The Impact of Sugar Technologies on Social Change and Development
- A.H. Barclay*.

Paper 17: Present and Potential Sugar Production and Consumption in Africa
- T. Gedamu.

Paper 18: Impact of Different Technologies on the Economic Environment
- R. Alpine*.

Paper 19: The Sensitivity of Sugar Technology Performance to Changes in Technical and Economic Parameters
- R. Alpine*.

Paper 20: Measuring the Environmental and Economic Impact of Alternative Technologies
- J. Pickett.

ANNEX II

ADDITIONAL INFORMATION ON THE ESTIMATION OF FINANCIAL PROFITABILITY

This Annex provides additional detail relating to the assumptions and calculations in order to enable the reader to follow the derivation of the cash flows underlying the profitability results. Most detail is given for the long season rainfed models: where different parameter values were used in other situations these are shown in summary tables.

(1) *Long Season Rainfed Situation*

(a) 100 tch model

Basic assumptions are as follows:

(i) crushing season 270 days gross less 10 per cent planned stops and 10 per cent unplanned stops to give 216 days net. Cane requirement is thus 518,400 tonnes per annum;

(ii) cane cycle of plant crop (22 months) followed by two ratoon crops (each 18 months) and 2 months fallow: total 60 months, with land use efficiency of 58/60 = 96.67 per cent;

(iii) cane yield 5 tonnes per hectare per month on average throughout 58 months.

The land area required is thus 8640 hectares under cane, excluding seed cane which requires 1 hectare per 15 hectares planted. The total area under cane is 9058 hectares, comprising plant crop 3277 hectares, ratoon crops 5363 hectares, seed cane 115 hectares and 303 hectares fallow: the annual rotation (ARA) area is 1812 hectares.

Cane transport requirements It is assumed that cane is delivered to the factory throughout 24 hours per day, and that the average trip length from field to factory is 8.5 km.

(i) Grab loaders: 40 tch at 75 per cent utilization requires 3.5 and allowance for spare capacity 1.5 = 5;

(ii) Crawler tractors: 2 per operating grab loader plus 2 spare = 9;

(iii) Wheel tractors: 4.5 tonnes cane per trailer in sets of four implies 18 tonnes per tractor trip;

Total number of trips per day = 134. Trip time per tractor comprises 20 minutes pickup/discharge, 34 minutes in, 26 minutes out totalling 80 minutes. At 75 per cent utilization this yields 13.5 trips per day giving a requirement of 10 tractors plus 2 spare = 12.

(iv) Cane trailers: 12 trailers per wheel tractor = 144;

(v) Allowance is also made for eight light units for night-time loading plus three tractors for water, knife disinfectant and fuel transportation.

Employment requirements for drivers/operators and for field workers (excluding cane cutters paid task rate) is based on the 3 crew 3 shift system.

Expenditure distribution It is assumed that the factory commences production in year 4 at a rate of 33 per cent of normal, building up to 100 per cent by year 7. The required agricultural operating cost expenditure in the early years (expressed as a percentage of normal or equilibrium expenditure) is shown in Table 1.

TABLE 1

Expenditure on Various Activities as Percentage of Normal

	Year						
	2	3	4	5	6	7	8
Preparation/planting	67	167	133	100	100	100	100
Plant cultivation	25	100	140	125	100	100	100
Ratoon cultivation			35	75	115	130	110
Civil engineering		25	50	75	100	100	100
Harvesting		.	33	75	95	100	100

Furthermore it is assumed that expenditure on agricultural overheads builds up from 20 per cent in year 1 to 100 per cent by year 4.

The distribution of fixed capital expenditure is shown in Table 2. Replacement capital expenditure - at a rate of 15 per cent per annum from year 6 for agricultural equuipment and 25 per cent per annum for cane transport equipment from year 7 is added to annual operating cost.

TABLE 2

Breakdown of Expenditure on Fixed Capital (percentage)

	Year			
	1	2	3	4
Agricultural equipment	80	15	5	
Land clearance/preparation	30	40	30	
Cane transport equipment			25	75
Factory		10	50	40
Administration	10	21	23	46

TABLE 3

Breakdown of Factory and Administration Expenditure

(percentage of normal)

	Year							
	1	2	3	4	5	6	7	8
1. Managerial staff including supervisors:								
long season rainfed			40	80	100			
long season irrigated			50	90	100			
short season		40	80	100	100			
2. Other staff:								
long season rainfed				60	90	100		
long season irrigated			20	60	90	100		
short season			60	90	100	100		
3. Repairs & replacement materials:								
long season				5	20	40	60	80
short season			5	20	40	60	80	100
4. All other materials:								
long season rainfed				33	75	95	100	
long season irrigated			10	35	70	90	100	
short season			30	65	90	100	100	
5. Fuel/miscellaneous expenditure:								
long season rainfed				50	100	100		
long season irrigated			15	50	95	100		
short season			50	90	100	100		
6. Administration operating costs:								
long season rainfed	5	50	75	100				
long season irrigated	5	50	80	100				
short season	10	60	90	100				

Similarly replacement expenditure on administration capital (vehicles) - taken as 20 per cent per annum from year 8 - is added to administration operating costs, and factory replacements included under repairs and replacement materials in factory operating costs.

The factory and administration operating costs (as percentage normal) in the early years are shown in Table 3.

Some allowance is made in the final years of the project's life for a reduced need to replace capital, though this makes little difference to the discounted cash flow calculations.

(b) 200 tch model

Technical parameters for the most part have been given the same values as in the 100 tch model. A minor difference appears in the cane transport requirement, reflecting a higher average trip length (12 km) due to the greater area involved. This is however largely offset by certain economies - as in the number of grab loaders required - resulting from the presence of indivisibilities in the 100 tch case.

(c) OPS models

The time distribution of expenditure on agricultural operations in the small-scale models is taken as the same as those used in the large-scale models (Table 1). The time distribution of expenditure on fixed capital and factory operations are shown in Tables 4 and 5 respectively.

TABLE 4

Breakdown of Expenditure on Fixed Capital
(percentage of normal)

	Year			
	1	2	3	4
Agricultural equipment	100			
Land clearance/preparation	40	40	20	
Cane transport equipment			25	75
Factory equipment and buildings			50	50

TABLE 5

Breakdown of Expenditure on Factory Operations
(percentage of normal)

	Year			
	4	5	6	7
Permanent labour	75	100	100	100
All other items	33	75	95	100

(2) *Other Climatic Situations*

This Section highlights the most important parameter changes underlying the calculation for each of the other situations. The results are shown in Table 6 for large-scale models and Tables 7 and 8 for small-scale models.

(a) Large-scale models

(i) Long season irrigated situation:

Crushing season:	216 days net
Cana cycle:	Plant crop (20 months) plus 2 ratoons (each 16 months) plus 2 ratoons (each 15 months), plus 2 months fallow - 84 months
Cane yield:	10 tonnes per hectare per month
Cane area:	4453 hectares (100 tch); 8905 hectares (200 tch)

Agricultural operations in early years (as percentage of normal) are shown in Table 6

(ii) Short season rainfed situation

Crushing season:	150 days gross less 10 per cent planned stops less 10 per cent unplanned stops = 120 days net
Cane cycle:	Plant crop (13 months) plus 4 ratoons (each 11 months) plus 2 months fallow = 60 months
Cane yield:	4 tonnes per hectare per month
Cane area:	6527 hectares (100 tch); 13053 hectares (200 tch)

(iii) Short season irrigated situation

Crushing season:	120 days net
Cane cycle:	as short season rainfed
Cane yield:	8 tonnes per hectare per month
Cane area:	3221 hectares (100 tch); 6442 hectares (200 tch)

See also Table 6

TABLE 6

Expenditure on Various Agricultural Activities

(percentage of normal)

	Year								
	2	3	4	5	6	7	8	9	10
A. Long season irrigated:									
preparation/ planting	150	167	150	100	100	100	100	100	100
plant cultivation	75	160	160	125	100	100	100	100	100
ratoon cultivation			30	70	100	120	140	130	110
civil engineering	20	60	80	100	100	100	100	100	100
harvesting		10	35	70	90	100	100	100	100
B. Short season:									
preparation/ planting	150	175	125	100	100	100	100		
plant cultivation	150	175	125	100	100	100	100		
ratoon cultivation		40	90	125	140	120	105		
civil engineering: rainfed		25	50	100	100	100	100		
irrigated	20	60	80	100	100	100	100	100	100
harvesting		30	65	90	100	100	100		

(b) Small-scale models

The relevant data concerning the assumed time distribution of expenditures (where different from those used in the long season rainfed models) are shown in Tables 7 and 8.

TABLE 7

Breakdown of Expenditure on Fixed Capital in Short Season OPS Models

(percentage of normal)

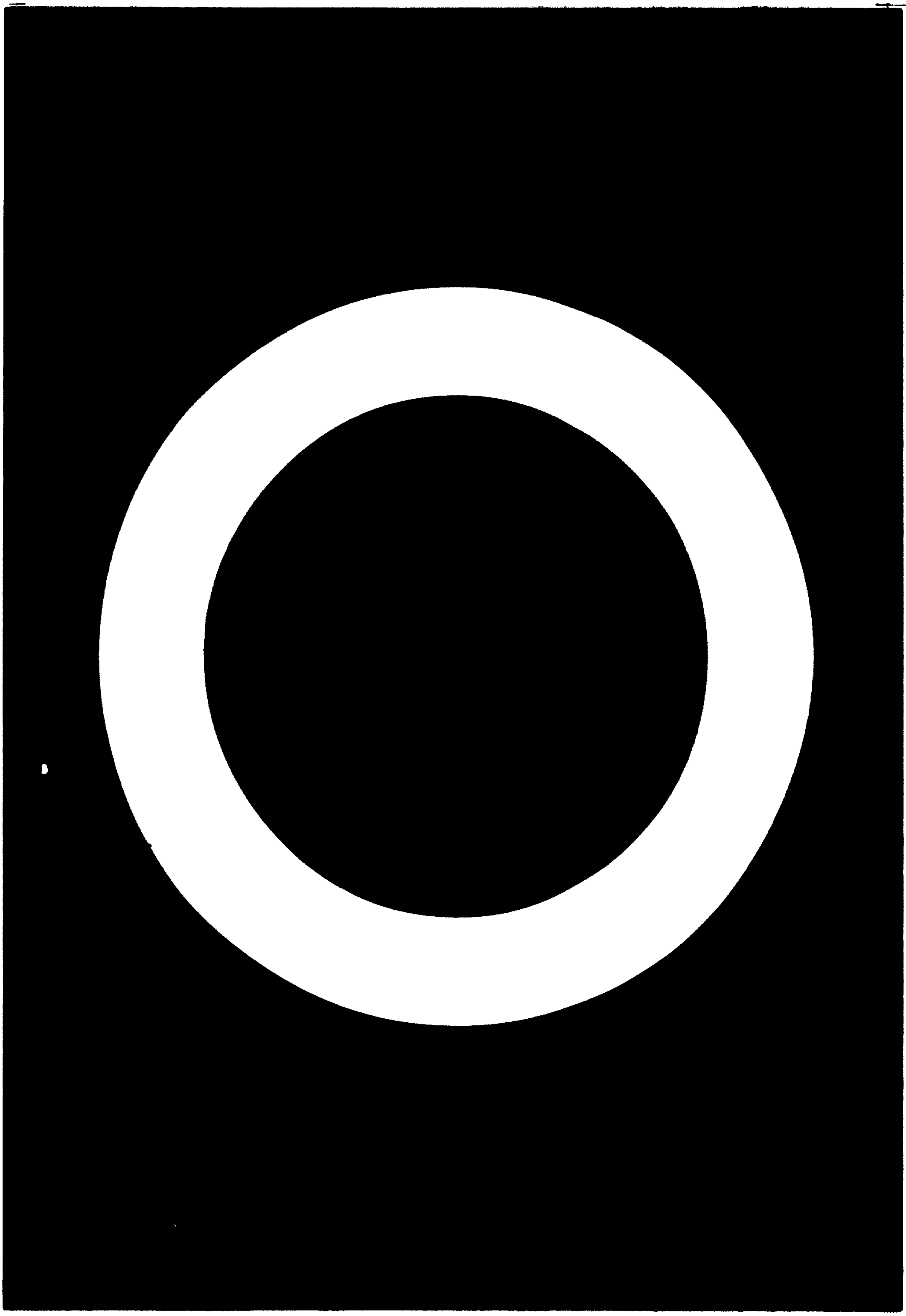
	Year		
	1	2	3
Agricultural equipment	100		
Land clearance/preparation	50	50	
Cane transport equipment		25	75
Factory equipment and buildings		50	50

TABLE 8

Breakdown of Expenditure on Factory Operations

(percentage of normal)

	Year			
	3	4	5	6
Long season irrigated:				
permanent labour	50	75	100	100
all other items	10	35	70	90
Short season:				
permanent labour	90	100	100	100
all other items	30	65	90	100



ANNEX III

SOME ASPECTS OF MECHANIZATION IN THE SUGAR INDUSTRY

It is often said that 'sugar is made in the field' and for this reason sugar cane agriculture throughout the world has received tremendous amounts of research inputs. One of the major areas of interest is the mechanization of field operations, and particularly of cane harvesting. The general trend in the industry is the replacement of field labour, usually employed on a daily basis, by increasingly sophisticated and efficient machines.

In the land preparation and cultivation operations mechanization is already of major importance but the labour input can be decreased further, for example, by a greater use of inter-row cultivation and chemicals for weed and pest control; the use of a cane planter where two hours work replaces about 20 man-days; and the application of fertilizer during other cultivation operations. With these changes at present prices observed in fieldwork countries the annual cost of land preparation and planting is reduced by about 10 per cent; the cost of plant crop cultivation is increased by 10 per cent; and that of ratoon crop cultivation is virtually unchanged. The effect on the unskilled labour force is a reduction of 55 per cent in the rainfed situations and 45 per cent in the irrigated situations (as no change has been made in the labour used for giving water).

The standard practice for cane harvesting in most developing countries is cutting by hand. Traditionally cane was cut green, but where cane is grown in blocks of adequate size with sufficient clear width around to act as a fire break, it is usual to burn the cane a few hours before it is due to be harvested. The burning of cane allows manual cane-cutting productivity to be at least doubled, as well as providing improved working conditions for the cutters: the cool, moist micro-climate within a cane crop is an ideal habitat for snakes, and cane leaves are very sharp-edged and hence easily cut into the skin.

In sugar-producing areas such as Australia and U.S.A., cane cutting has almost entirely been mechanized and many developing countries are currently being forced in this direction because of increasing wage rates, unionization and absolute or artificial labour shortage. Before discussing the financial and environmental implications of mechanical harvesting it is worth noting some of the circumstances which led to mechanization in Australia and U.S.A.

In the U.S.A., mechanized harvesting had to be introduced hurriedly in the post-war years. Since then the high cost of labour has supported the trend, for example the cost of unskilled labour in Hawaii amounts to $15,000 per man-year. The main exception to this, however, is in Florida where more than half of the cane is still cut by hand using immigrant West Indian labour.

In Australia, the process of mechanization was much more gradual with full benefit being taken, first of manual productivity, and then of time to alter field layout and operation and to develop machinery suited to local conditions. Cane cutting by hand began to be replaced in the late 1950s, but by this time the productivity of labour was of the order of 20t/burnt cane per man-day.1/ This can be compared to 5t per man-day in the most efficient agricultural regime cited in this Report. There are a variety of reasons for this high productivity, some of which could perhaps be applied to the sugar industry in Africa. For example, the shape and sharpness of the knife and the stance of the cutter allows him to cut two stalks of cane with each stroke. More importantly, the cane

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1/ J.F. Morrison, *What Made the Australian Cane Cutter So Durable?* Producers' Review, August 1972.

cutters had an enormous intake of food and liquid throughout the day; in fact a gang of six men had one cook who shared their payment.

Mechanization, however, did take over beginning with relatively small, lightweight machines which cut and topped the cane. The progression to the present day chopper harvester, cutting up to 100 tch in certain conditions has taken some 20 years. During this time factors such as field layout, planting technique and the vitally important cane transport system have been altered and improved in parallel with the harvesting. This highly efficient Australian system supplies cane to the factory with say 3 per cent extraneous matter. In contrast to this, some Hawaiian sugar mills have to deal with up to 30 per cent extraneous matter as recumbent cane, field layout and terrain necessitate the use of push-rakes and grab loaders; the twisted mat of cane also prevents good burning of trash.

Table 1 gives a comparison of the present value of all agricultural costs in the standard system used throughout this Report and in a highly mechanized system (at low prices). The latter involves the cultivation operations as previously mentioned and harvesting by chopper harvester (costing $200,000 each); loading directly to infield haulers ($100,000 each); and transporting to the factory gate by tractor and groups of four, four tonne bins. It has been assumed that the chopped cane is equally acceptable to the mill and that the cost of the chopped cane handling system in the yard would be similar to the cost of the overhead gantry system taken in the models.

The capacity of the chopper harvester has been varied in the same way as the manual cutting productivities across climatic regimes, reflecting cane yield and hence area to be covered per given quantity of cane. Capacities used in the calculations are as follows:

long season irrigated - 1152 tcd

long season rainfed - 922 tcd

short season irrigated - 576 tcd

short season rainfed - 461 tcd

The results show that the discounted costs are relatively close, particularly in the long season, where the mechanized system is within 15 per cent of the standard. Table 2 compares employment in the alternative systems and illustrates a reduction in unskilled employment of 60-70 per cent, mainly cane cutters, and a reduction of up to 5 per cent in semi-skilled and skilled employment, mainly headmen and field assistants. It is interesting to note that, in the long season models, the proportion of seasonal unskilled labour decreases from 30 per cent to 10 per cent with mechanization and in the short season models, from about 50 per cent to 15 per cent.

Reference to Table 30 of Chapter III (e) shows increased energy consumption of the order of 12-40 per cent over the standard practice, reflecting the greater dependence on heavy equipment with very high fuel consumption rates.

Mechanical harvesting is often associated with the need for cane washing - a very costly and polluting process. This is the case, for example, in USA where poor burning, push-raking and grab loading leave a large proportion of trash, soil and stones in the cane bins, possibly accounting for about 1/3 of the weight, and considerably more when harvesting is done in wet weather. Washing can cost up to 10 per cent of the sucrose content. Cane wash water is recycled but if discharged, untreated it has very high BOD and SS contents as well as any chemicals which may have been used on the crop. Cane trash can be screened out and the remainder left to settle in lagoons.

The harvesting system discussed here, however, presupposes that cane is cut, chopped and loaded by one machine i.e. the cane never

TABLE 1

Financial Comparison of Standard and Highly Mechanized Agricultural Technologies

	Standard Practice $m[a]	Highly Mechanized $m[a]	Index[b]
Long season rainfed			
200 tch	96.45	105.35	110
100 tch	49.18	56.59	115
Long season irrigated			
200 tch	78.08	87.26	112
100 tch	40.44	45.58	113
Short season rainfed			
200 tch	85.46	106.75	125
100 tch	44.19	55.88	127
Short season irrigated			
200 tch	64.60	83.05	129
100 tch	33.66	42.71	126

a/ Present value of agricultural costs; low prices; discounted at 10 per cent per annum

b/ Standard practice is taken to be 100

TABLE 2

Comparison of Agricultural Employment in Standard and Highly Mechanised Agricultural Technologies

	Unskilled			Semi-skilled and skilled[a]		
	Standard	Mech.	Index[b]	Standard	Mech.	Index
Long season rainfed						
200 tch	5564	1948	35	588	558	95
100 tch	2816	992	35	310	289	93
Long season irrigated						
200 tch	3975	1626	41	434	398	92
100 tch	2012	819	41	227	201	89
Short season rainfed						
200 tch	6394	1887	30	577	569	99
100 tch	3230	960	30	308	303	98
Short season irrigated						
200 tch	4394	1355	31	412	400	97
100 tch	2226	691	31	215	210	98

a/ Excluding management

b/ Standard practice is taken to be 100

touches the ground. Burning of trash before cutting and a blower unit on the harvester to remove more trash allows cane to be delivered to the factory with a minimum of trash and the need for cane washing is removed. Although sucrose loss is greater from chopped cane than from wholestick cane, the saving by not washing more than compensates.

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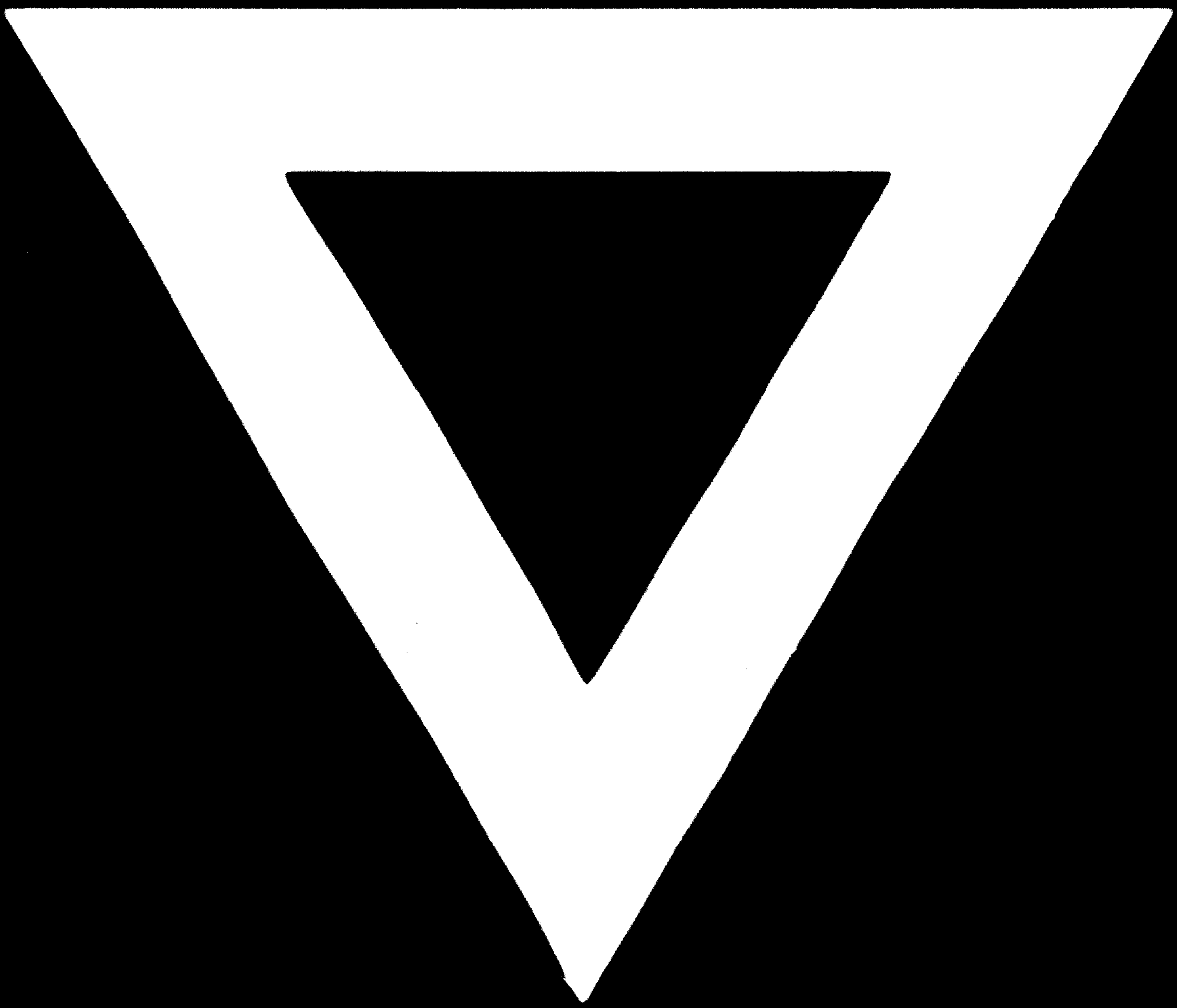

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