Sugarcane Resources for Sustainable Development: A Case Study in Luena, Zambia

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Purpose

This study assesses the establishment of a new sugarcane estate in the Luena region of northern Zambia. Luena is a remote region for which new development alternatives are being considered by the Zambian government, while sugarcane offers a renewable resource that is quite suitable for the climate and the region. Although the establishment of a sugarcane estate has been considered in the region for many years, this study is the first to take a broad perspective based on the goals of sustainable development for the region. The study included two major components: (1) Techno-economic options; and (2) Social and Environmental Impacts. These components have been integrated using an interdisciplinary approach that recognizes the relevant linkages in a broad societal context and explores critical policy options that could promote sustainable development of the sugarcane resource. The market analysis addressed product strategies for raw sugar, ethanol, and surplus electricity, as well as flexible combinations of all three products. The results of the study include conclusions as to which strategies are viable and how they might be implemented in a way that promotes sustainable development.

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Currency Conventions

The reference year for all economic and financial data is 1998 unless otherwise noted.

ZMK = Zambian Kwacha
USD = United States Dollars

The 1998 average exchange rate was 1861 ZMK/USD.
1 Introduction

The potential for using sugarcane to support sustainable development in the Luena region of Zambia has been investigated in the project. Special emphasis has been placed on two of the major renewable energy resources that can be derived from the sugarcane plant: ethanol and electricity. The use of clean-burning ethanol fuel represents an important option for developing a sustainable transport sector in Zambia, reducing the oil import bill and saving foreign exchange. Electricity generated from cane residues and exported to the electricity grid offers a cost-effective means to strengthen and diversify Zambia’s electricity supply system.

To contribute to economic development, a project must improve the standard of living for poor people. A development project that is sustainable must also assure that these improvements do not come at the expense of the welfare of future generations. This project, if implemented, could contribute to sustainable development in Luena by stimulating the economy, harnessing a renewable domestic resource, and providing valuable social amenities to the local population. The project could improve the national economy by saving foreign exchange, and provide environmental benefits through the adoption of a renewable energy resource.

Discussions on the creation of a sugarcane estate and sugar factory in Luena have been going on for a quarter of a century. This project places the question in the context of the regional economy, bringing three new dimensions to this discussion. First, this study looks at the whole sugarcane resource, whereas previous studies focused on the commercial production and sale of sugar. The falling and/or volatile prices of sugar on the world market and fierce competition from other sweeteners have reduced prospects for financial success based on sugar alone. At the same time, the emergence of new technologies to exploit valuable agricultural biomass residues have created new opportunities to diversify and expand sugarcane use, while capturing its environmental benefits as a renewable energy resource.

Second, the environmental and social impacts of the project have been studied in addition to the technical and economic analysis. The creation of a new cane estate and new industrial facilities must be environmentally and socially compatible as well as being technically feasible and financially viable. Third, this study recognizes the fact that it is not sufficient to assess the problem from a national perspective. The contribution to development in the local community must be carefully considered. The project included several workshops in the Luena region as well as a series of interviews from which potential local impacts and mitigation measures were assessed.

The intersection of societal goals, technological options and economic reality has received careful scrutiny in this study. In this way, the project team has looked at the question of sugarcane in Luena through a completely different lens, so to speak. The project offers an in-depth evaluation of a potential sugar plantation in Luena within the context of sustainable development in the region. The boundary of the system evaluated in the project was extended beyond the economic viability of the commercial enterprise in order to examine the sugarcane resource in terms of its potential contribution to sustainable development at the local, regional and national levels. The conclusions and recommendations of the study reflect this broader perspective.
2 Background

The technical, economic, environmental and social viability of several options for using sugarcane as a tool for sustainable development in the region of Luena, located in northern Zambia, are evaluated in this report. The sugarcane resource can be used to produce a variety of commercial products that could be marketed domestically, regionally and internationally. In economic and environmental terms, three products — sugar, ethanol, and electricity — have special significance. The project team examined the market potential for these products and performed technical and economic analyses of development scenarios in the context of the markets identified. Because establishing a new sugarcane estate in Luena could have major socioeconomic and environmental implications, these were assessed and synthesized with the results of the technical and economic analyses of the scenarios.

Background on the project and the role of sugarcane resources in supporting sustainable development is provided in this introduction. The remainder of the report begins with descriptions of the approach, scope and methods used in the study, followed by an assessment of the contextual background for the estate and factory, including descriptions of the project site, the biophysical and socioeconomic environments, and market characteristics for the focal products. This is followed by an assessment of the physical, technical, capital and labor requirements for sugarcane, sugar, ethanol and electricity production under each of the scenarios, including estimates of the investment and operational costs. Next, the financial, environmental and social implications of the scenarios are examined. Finally, a summary of the main findings and conclusions regarding the viability of sugarcane-based development projects in Luena is presented.

2.1 Project History

Zambia currently has only one sugarcane estate and sugar factory, located at Nakambala and run by Zambia Sugar PLC. Studies of the potential to expand sugar production in Zambia by establishing an additional sugarcane estate have been carried out since the 1970s. In 1975 the Industrial Development Company (INDECO) commissioned a reconnaissance survey aimed at identifying the most suitable area for siting a second sugar estate. Seven sites were surveyed, and the Luena area in the Luapula Province was chosen as the most appropriate. In 1977, INDECO commissioned a feasibility study and investment/operational plan for a development project to include a sugarcane estate and other crops in the Luena area. The study was completed in 1978. Ten years later a review of the study was produced by Booker Tate Ltd., which considered development of a sugarcane estate and sugar factory. In 1991 a team of Cuban experts were hired to review the proposed project and confirm the Booker Tate conclusions regarding viability and potential of the second sugar estate.

In 1992, INDECO drafted a report on the feasibility of establishing a sugar estate in Luena. The 1992 report assessed the siting of the estate in Luena, including climate, soil and hydrology situation, land-use issues, infrastructural development requirements, social aspects and requirements for investment capital. The Luena area was deemed agriculturally suitable and economically viable for sugar production. The design proposal was for a small cane estate cultivating 6,650 hectares (ha) of irrigated land and producing 602,000 tonnes of cane per year. Expansion potential was identified to the north and south of the proposed estate.

The Swedish International Development Cooperation Agency (Sida) supported an interdisciplinary study on options for producing ethanol as an alternative transportation fuel in Thailand (Wilson, 1993). Another study generalized operational issues related to ethanol production and use in developing countries (Cornland, 1996a), and examined opportunities for utilizing sugarcane for this purpose in Southern Africa. The first phase of this investigation resulted in a report that proposed Zambia for a detailed feasibility study (Cornland, 1996b).

The Government of the Republic of Zambia (GRZ) and Sida agreed to support a second phase of analysis to begin in 1998: a case study focusing on the Luena region of Zambia. This second phase of the project was a feasibility study to advise the GRZ on options for using the potential sugarcane resource in Luena as a tool for sustainable development. The analysis was to consider sugar, ethanol and electricity production. The integrated approach developed in the Thailand study, examining techno-economic options along with socioeconomic and environmental impacts has been adopted in this project.
2.2 Sugarcane resources
The sugarcane plant is one of the most promising agricultural sources of biomass energy in the world. Sugarcane is a highly efficient converter of solar energy, and has the highest energy-to-volume ratio among energy crops. It is found predominantly in developing countries, due to environmental requirements that restrict its growth to tropical and sub-tropical climates. The sugarcane industry has traditionally focused on producing sugar for household consumption and (to a lesser extent) for use in industrial applications. But in recent years, sugarcane by-products and co-products (both energy and non-energy) have gained importance in the sugar industry. Non-energy co-products are made from the fiber contained in bagasse and the organic components of molasses and filter cake. Molasses and filter cake are used for animal feeds and fertilizers. Bagasse is the fibrous outer residue of the cane plant, and can be used to make particleboard and newsprint.

Energy by-products and co-products include alcohol fuels (ethanol), surplus electricity generated using bagasse and cane trash, and methane gas from the wastewater or stillage of ethanol production. Bagasse has long been used to provide steam and electricity in sugar factories, making them energy self-sufficient. This is a special characteristic of sugar factories. Advanced technologies can allow sugar factories to use bagasse much more efficiently, so that a sizable surplus of electricity can be generated and sold.

The broad variety of potential products that can be made from sugarcane has led the sugar industry historically to play many roles: producer of food, feed, fiber, and energy (Payne 1986). The two most economically significant co-products are ethanol and electricity.

Sugar companies around the world (and those in Africa are no exception) have faced a number of competitive pressures in recent decades, due to such factors as saturated demand in industrialized countries, competition from other sweeteners, and low and/or fluctuating sugar prices. These difficulties have increased economic incentives for sugar producers to diversify their product portfolio, and the production of fuels and electricity has naturally presented attractive options for an energyrich crop like sugarcane.

2.3 Potential contributions to sustainable development
A new cane estate producing sugar, electricity, and/or ethanol would have local national, and global benefits. The primary local benefits would be the stimulation of rural economic development through a new local domestic industry and the provision of improved social amenities (such as schools and clinics) to the local population. The national benefits would include a reduction in oil imports, thereby saving foreign exchange, and the provision of a renewable energy resource that would reduce environmental impacts from the transportation sector and strengthen and diversify Zambia’s electricity supply system.

The role of sugarcane resources in fostering sustainable economic development has some special features in a global context. First, the sugar industry around the world faces competitive pressures that have increased economic incentives for sugar producers to diversify. The development of biomass co-product strategies offers competitive advantages to the cane sugar industry compared to the beet sugar industry. Beet sugar is grown mainly in developed countries with temperate climates, and does not have the favorable energy balance that makes cane so attractive as a renewable energy resource. The emergence of new technologies to exploit valuable agricultural biomass residues has created new opportunities to diversify and expand sugarcane use, while capturing its environmental benefits as a renewable energy resource. As a result, the sugar industries in developing countries can increase profits and reduce risk by diversifying their production portfolios to include cane-based bio-energy products.

Second, because sugarcane is grown predominantly in the developing world, the advanced expertise found in major producing countries such as Brazil and India offers good potential for South-South cooperation. Third, the sugarcane biomass resource is particularly valuable in developing countries due to population pressures, the need for rural development, and dwindling supplies of forest-based biomass. Finally, expanding the use of a renewable energy resource found mainly in developing countries has obvious appeal for international efforts to reduce carbon emissions.
3 Approach and Scope

3.1 Approach
The aim of this study was to assess the implications of establishing a new sugarcane estate in Luena, evaluating alternative uses of the sugarcane resource from a societal perspective. The approach was adapted from one used in a case study on Thailand (Cornland, 1993). The approach is highly interdisciplinary, integrating methods of analysis from the technical, economic, environmental and social sciences to construct and evaluate alternative development scenarios. Although complex, this approach offers opportunities to evaluate proposed projects and/or investments from the perspective of their potential to contribute to sustainable development, which was the objective of the study.

Evaluating potential scenarios has a number of advantages over other approaches (such as prescreening approaches or technology-specific analyses). It allows a direct comparison of the main alternatives and indicates the range of options that are available in managing and utilizing the sugarcane resource. The scenario approach also reduces the risk of ignoring options that are very close to the economically optimal alternatives but differ in one or more significant aspects, such as their social and environmental impacts.

3.2 Scope
A range of development scenarios was analyzed, including a baseline scenario in which the option of not establishing a sugarcane plantation in Luena is discussed. The development scenarios represent combinations of sucrose\(^1\) (focusing on sugar and ethanol) and bagasse (for electricity production) utilization strategies. The scenarios accommodate analysis of alternative technologies, alternative product management choices, and varying production levels for each of the three products. Although there are other co-products and by-products of interest (several of which are quite likely to be used and/or sold in any case), they are generally much smaller in economic terms, and consequently would not impact the choice of technologies or production options.

The basic structure of the development scenarios is based on the four sucrose strategies:

1) Sugar only (reference case)
2) Ethanol only
3) Sugar and ethanol in fixed quantities
4) Sugar and ethanol with flexible production

Each of the sucrose strategies was explored with and without energy-efficient bagasse cogeneration, encompassing three bagasse strategies:

a) No surplus electricity generated (reference case);

b) Surplus electricity cogenerated with Condensing Extraction Steam Turbine (CEST); and

c) Surplus electricity cogenerated with Biomass Integrated Gasifier/Combined Cycle (BIG-CC).

Three grades of molasses — A, B and C — are sequentially produced when processing cane juice, with each successive grade containing less sugar than the previous one. C molasses is also called final molasses, because further sugar extraction is not feasible. Cane juice as well as any of the three grades of molasses can be used as feedstocks, with the ethanol yield decreasing as the fermentable sugars decrease.

The primary difference between fixed and flexible co-production of sugar and ethanol (the third and fourth sucrose strategies) is the choice of feedstock. With fixed ethanol production levels, the same type of molasses would generally be used, either B or C molasses. With flexible co-production of sugar and ethanol, mixtures of the three different grades of molasses would be used, depending on the relative market value of sugar and ethanol. Assuming that the company is operating on a sound commercial basis, the use of A or B molasses generally implies that the market value of ethanol is greater than the market value of sugar at the margin. Otherwise the company would not forego sugar production to divert A and B molasses to ethanol production. The sugar only and ethanol only strategies each effectively dedicate cane juice to one or the other product. For the ethanol only case, there are significant savings in capital investment costs since only cane juice preparation facilities are needed rather than a complete (conventional) sugar factory.

The reference bagasse strategy provides for energy self-sufficiency (electricity and steam from bagasse) at the factory during the milling season, but results in no surplus electricity production. The CEST and BIG-CC strategies produce surplus electricity to be exported from the factory.

The sucrose and bagasse strategies combine to form the following matrix of twelve primary scenarios:

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\(^1\) Sucrose (\(C_{12}H_{22}O_{11}\)) is the chemical term for sugar produced from the sugarcane plant, or from other sources, such as the sugar beet.
The sucrose and bagasse utilization strategies are described in more detail in chapter 7. The technologies associated with each of the scenarios are described in detail in chapter 8. There are also secondary scenarios used to evaluate minor differences in the technical configurations. The full set of scenarios analyzed is also given in chapter 8.
4 Methods

4.1 Methods for performing the techno-economic assessment

The assessment of the comparative economic viability of a range of technical options was comprised of three components. First, potential markets for sugar, ethanol, and electricity were examined. Second, estimates of the costs associated with land, estate, and infrastructural development were made. Finally, financial analyses were performed for each development scenario, in the context of the markets identified.

The techno-economic assessment addressed:

- Market potential and dynamics;
- Land development;
- Estate and infrastructural development;
- State-of-the-art technologies for sugar, ethanol and electricity production;
- Systems design for flexible production;
- Investment, operating and maintenance costs for plant and machinery;
- Human resource requirements; and
- Financial/economic analysis.

Several steps were required to implement the techno-economic assessment. First, the project team conducted study visits to three cane estates/sugar factories in the region in order to appraise the options and strategies available for a new cane estate in Luena. Second, the potential market and the expected prices for sugar, ethanol, and electricity to be produced at the proposed site in Luena was assessed. Third, alternative production technologies were considered, with the main technical differences arising in the choice of cogeneration technologies. Fourth, based on the assessments of product markets and technology options, the sucrose and bagasse strategies that comprised the scenarios were refined. Fifth, the capital and labor input requirements, and associated costs, for agricultural operations and industrial production were estimated. Finally, the economic and financial characteristics of the different scenarios were quantified and compared, to determine which options were most promising. Sensitivity analyses on key variables within the financial model, including product prices, operating costs, and investment costs, were also conducted.

4.1.1 Study visits

Study visits were made to three sugarcane estates - Nakambala (Zambia), Triangle (Zimbabwe), and Dwangwa (Malawi) - to discuss specific issues related to the operations of sugarcane estates, sugar factories and ethanol distilleries. The knowledge gained and information collected during the visits was used to assess the feasibility and possible impacts of the scenarios.

4.1.2 Markets

The market analysis was designed to assess domestic, regional and international markets for sugar, ethanol, and electricity. Of the three, only sugar is a truly internationally-traded commodity. Sugar trade is governed by international agreements that create preferential markets and prices. EU sugar quotas were considered in the analysis, because this is the most likely preferential export market for Zambia. Primarily because of the transportation costs that must be internalized in international trading, only domestic and regional markets were deemed relevant for ethanol and electricity sales.

4.1.3 Technology assumptions

Technologies were selected for producing sugar, ethanol, and electricity, as well as agricultural technologies for cane production. The sugar industry is mature and modern sugar factories are fairly standardized, so only one design for the sugar plant was considered. The ethanol distilleries for the ethanol only (autonomous distillery) and the sugar and ethanol co-production (annexed distillery) scenarios share the same design, based on Brazilian standards, but differ in scale (the annexed distillery being considerably smaller). Another minor difference arises in the feedstock preparation at the sugar factory, which is based on cane juice (rather than molasses) in the case of the autonomous distillery. Two main technologies were analyzed for the cogeneration plant: Condensing Extraction Steam Turbine (CEST) and Biomass Gasification with Combined Cycle (BIG-CC). The technology assumptions are described in more detail in chapter 8.

4.1.4 Costs

Five main types of costs were estimated in this study: plant investments, infrastructure investments, other investments, operating costs, and labor costs. Plant investments include those capital investments needed for the plant itself: the agricultural facilities, sugar factory and/or ethanol distillery. Infrastructure investments include the surrounding infrastructure needed for both the operation of the
industrial facilities and the needs of the resident staff. Because of the remoteness of the region, this infrastructure investment includes roads, housing, telecommunications, and social and health facilities. Other investments include aspects such as land clearing, irrigation, and other activities that serve to prepare the site. Operating costs were constructed from estimates of the quantities of raw materials and inputs, while labor costs were based on skills needed and prevailing wage rates in the region. The costs of capital equipment were estimated on the basis of reasonably modern state-of-the-art facilities manufactured in Brazil and the United States.

4.1.5 Financial performance
The COMFAR model (software developed by the United Nations Industrial Development Organization (UNIDO)) was used to analyze the financial performance of the scenarios. The model calculates standard measures of financial performance, including Net Present Value (NPV) of investments and Internal Rate-of-Return. The assumptions input to the model are given in the Financial Analysis.

4.2 Methods for anticipating environmental and social implications
As this feasibility study was not carried out with the explicit objective to move forward with an investment proposal, a full EIA following Zambian regulations and procedures was not performed. However, initial assessments of the environmental and social implications of the scenarios were carried out. The scope of the current study was limited to: identifying public concerns within the local, regional and national communities; describing the baseline environment; evaluating and comparing potential impacts of sugarcane production and each of the sucrose and bagasse utilization strategies; identifying mitigation measures for potentially significant negative impacts; and making recommendations for further study.

There is very little hands-on experience in performing social impact assessments of feasibility studies for development projects, with the exception of analyses of large-scale hydroelectric dam proposals, where the primary focus is limited to resettlement. In addition, this case study is characterized by a local context for which data to support such an analysis is lacking. Where required quantitative data was lacking, qualified estimates were made. Qualitative rather than quantitative observations and input from local inhabitants were relied upon to a large extent. As a result, much of the information provided here regarding potential social impacts are anecdotal. Nevertheless, the analysis provides insights as to areas of potential concern from a social perspective and adds to the limited experience to date in attempting to implement social impact assessments of this type of development project. In addition, although the conclusions regarding gender impacts are limited, this is one of the few studies of its kind where a concerted effort to include a gender analysis in the evaluation of anticipated social implications has been attempted.

A baseline description of the environment was produced, to give an overview of the existing environment in the Luena area and provide insights as to the anticipated development of the area for a baseline scenario, assuming that no project is implemented. The baseline scenario provides a basis for comparing the anticipated impacts of the development scenarios.

Two methods were used to evaluate the environmental and social implications of sugarcane production and the sucrose and bagasse utilization strategies: analyses based on expert judgment regarding anticipated perturbations from activities at and around the Estate; and stakeholder meetings along with a survey to document community concerns.

4.2.1 Expert judgment analyses of activities
The expert judgment analyses of the environmental and social implications of the scenarios were carried out by briefly describing the activity and then assessing the anticipated implications and, where appropriate, actions required for minimizing or avoiding the negative effects of the activity. The Leopold matrix method (Leopold et al., 1971) was used for the scoping process of identifying potential impacts. All of the activities involved in implementing the strategies were listed on one axis and associated potential environmental and social impacts were listed on the other. Expert judgment regarding environmental and social significance was used to select potential impacts that required further study (see chapter 13).

The activities with identified environmental impact in the project area have been divided into two main categories: implications of establishing the Estate and implications of operating the Estate. Similarly, short- and long-term impacts on the socio-economic environment are distinguished where appropriate. The environmental and social impacts of sugarcane production and infrastructural development are the same for the different
scenarios. Therefore, no separate assessments were made for the different scenarios under these components of the study. However, the waste products from factory processes would be different for each scenario. Consequently, the impacts of factory processes on the biophysical environment were considered separately where appropriate.

In the absence of detailed field studies and adequate data on Luena area, the significance of the identified impacts was largely based on expert judgment supported by the project team’s limited knowledge of the area. Wherever possible, extrapolations from other studies and experiences were applied. This approach, however, has limitations, especially given the uniqueness of the Luena area. Except in special cases, the general approach used in classifying an impact as significant was based on the following considerations:

- The extent of the impact on the relevant environmental component;
- The rarity or uniqueness of the affected environmental component;
- Implications of the activity on human welfare, including social, economic and health;
- Ecological significance and/or sustainability of the activity; and
- Emissions of greenhouse gases.

For significant anticipated impacts, mitigation measures were identified (and in some cases recommendations were made) but not fully elaborated. Mitigation costs were not calculated due to the lack of reliable information and resources. Consequently, no mitigation plan or monitoring plan was developed. These are some of the issues that would require further study by a future project developer.

With the above constraints, the assessment of impacts on the biophysical environment was limited to:

- Describing and mapping current land use and vegetation/ecosystems, including wetlands, and evidence of land degradation;
- Assessing the existence of endangered, rare or vulnerable species with emphasis on mammals, birds, reptiles and amphibians, as well as arthropods and mollusks of economic importance to human or animal health;
- Assessing the extent of the impact of the development scenarios on biodiversity and the significance of such impacts to Luena area; and
- Recommending (a) measures required for mitigating anticipated impacts and (b) further investigation of issues that were not adequately addressed in the current assessment.

The social assessment was limited to anticipated impacts of the scenarios on the populations and institutions in the project area and its surroundings. This was done by:

- Describing existing settlement patterns;
- Describing demographic characteristics;
- Assessing the implications of anticipated land-use changes;
- Identifying resettlement requirements for the population in the area earmarked for the project;
- Assessing the implications of anticipated agricultural and industrial activities;
- Assessing potential development benefits and prerequisites for achieving them; and
- Recommending measures to avoid or minimize adverse project impacts.

4.2.2 Stakeholder meetings and local survey

Public concerns regarding the proposed Luena project were identified in stakeholder meetings held in Lusaka (the capital of Zambia), Kawambwa (the capital of the Luapula province) and Luena (the location of the project site). The primary objective of the stakeholder meetings was to provide opportunities for most of the stakeholders with interest in the Luena project to raise and discuss their concerns. The meetings were designed and implemented by the project team in collaboration with the Department of Energy. Participants at the Lusaka meeting were invited by the Department of Energy, while the District Council Secretary and the Ward Counselor for Luena invited those who attended the Kawambwa and Luena meetings, respectively.

A registrar recorded the attendance at each of the meetings but did not categorize attendees by age, sex or profession. Although the attendees participated on a voluntary basis without compensation, lunch was provided to participants at the Lusaka meeting. Each participant at the Kawambwa meeting was paid a lunch allowance of 10,000 ZMK. Similar amounts were paid, for the same purpose, to participants from Kawambwa that attended the Luena meeting. These payments were not indicated in the meeting invitations and were made at the end of the meetings. At the Luena meeting...
meeting, Chiefs were paid 10,000 ZMK, as a traditional way of recognizing their Royal presence.

The local survey was conducted in Luena in September and November 1998. The interviewers sampled 273 heads of household, using structured questionnaire-based interviews. The questionnaire contained both closed and open-ended questions that were designed to elicit individual views and concerns about the project and provide data describing the socioeconomic and demographic characteristics of the community. Male and female staff carried out the interviews. They were recruited locally and trained before implementing the survey. The questionnaire was written in English and filled out by the interviewers. The actual interviews were performed orally in Chishinga and/or Bemba, the local languages in the area. In most cases the respondent was the head of the household but, in the absence of the head, any adult member of the household present was interviewed. For the purposes of this study, a household was defined as a group of people who usually eat together and recognize one member of the group as head but do not necessarily live under one roof. Family members in rural areas in Zambia do not sleep under one roof (Central Statistics Office, 1990).

A deliberate attempt was made to achieve a gender balance in the respondents. Females headed 40% of the sample households. This was done in order to address potential and/or anticipated gender-specific impacts of the project. Therefore, the survey explicitly and intentionally did not cover a demographically representative sample of the community.

The geographical and gender distribution of the 273 respondents is given in Table 1. About 72% of the survey respondents were born in the project area and the majority (59%) had resided in the area for more than five years. The respondents ranged in age from 15 to over 55 years, with the dominant age classes between 15 to 29 (34%) and 30 to 44 (39%) years old respectively (Figure 1). About 87% were married while 3% and 2% were widowed and divorced, respectively. The majority of the respondents in the survey were Catholics (52%) and Protestants (37%).

<table>
<thead>
<tr>
<th>Location of current residence</th>
<th>Chiefdom residence</th>
<th>Proposed land use</th>
<th>Sex of respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Female</td>
</tr>
<tr>
<td>Mushota block</td>
<td>Mushota</td>
<td>Small-scale sugarcane growing</td>
<td>60</td>
</tr>
<tr>
<td>Luena block</td>
<td>Mushota</td>
<td>Estate</td>
<td>35</td>
</tr>
<tr>
<td>Lufubu block</td>
<td>Chama</td>
<td>Estate</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>109</td>
</tr>
</tbody>
</table>

Table 1: Geographical and gender distribution of the 1998 survey respondents

Figure 1: Age distribution of the 1998 survey respondents.
5 Contextual background

5.1 The site
The project site evaluated is located in Luena, in the Kawambwa and Mwense districts of the Luapula Province in northern Zambia, approximately 60 kilometers from the nearest town, Kawambwa (Figure 2). This site has been recommended and confirmed by several studies as the most suitable site in Zambia for a new cane estate (INDECO, 1992; Cornland, 1996b). In addition to climatic advantages, the Luena site is well placed geographically for exporting both sugar and electricity to neighboring countries. Hence, no effort has been made to explore other potential sites in this study.

The INDECO report included an evaluation of the climate, soils, hydrology, land-use issues, infrastructure development requirements, social aspects and requirements for investment capital for a Luena estate and sugar factory. The Luena area was deemed agriculturally suitable and economically viable for sugar production. The design proposal was for a small cane estate farming 6,650 hectares (ha) of irrigated land and producing 602,000 tonnes of cane per year. Expansion potential of nearly 10,000 hectares was identified to the north and south of the proposed Estate site. The parameters from the INDECO report have been adopted as an initial basis for analyzing the Luena project site in this study.

The proposed agricultural area in this study covers 6,650 hectares of land in the Luena and Lufubu blocks (Booker Tate Ltd., 1992) with possible future expansion (10,000 ha) in the Pambashye, Luwo and Luongo blocks to the south (Tate and Lyle, 1978) (see Figure 3). The Lufubu block is located in Chief Chama’s Chiefdom, the Luongo block in Chief Mwenda’s Chiefdom and Luena, Pambashye and Mushota in Senior Chief Mushota’s Chiefdom. The Mushota block in the north is densely populated and has been earmarked for cane production by local small-scale farmers under rain-fed conditions.

5.2 The local biophysical environment
The western boundary of the project site is approximately 30 kilometers east of Kawambwa and is drained by the Luena and Musambeshi Rivers in the west, Lufubu and Mupoposhi Rivers in the east and Pambashye River in the center. These rivers drain a total land area of about 2,830 square kilometers (Table 2). About 27% of the area is in the Mwense district. The dry land elevation ranges from 1,200 to 1,500 meters above sea level (a.s.l.) with slopes of 1.0 to 1.5%, while wetlands are flat at altitudes of 1,160 to 1,240 meters a.s.l.

<table>
<thead>
<tr>
<th>Catchments</th>
<th>Area in square kilometers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry land</td>
</tr>
<tr>
<td>Musambeshi</td>
<td>130</td>
</tr>
<tr>
<td>Luena</td>
<td>830</td>
</tr>
<tr>
<td>Pambashye</td>
<td>430</td>
</tr>
<tr>
<td>Lufubu</td>
<td>800</td>
</tr>
<tr>
<td>Mupoposhi</td>
<td>275</td>
</tr>
<tr>
<td>Total</td>
<td>2,465</td>
</tr>
</tbody>
</table>

Table 2: Catchments in the Luena area

5.2.1 Climate
The Luena area has alternating dry and wet seasons. The wet season is from October through April. Climate variables for Kawambwa are summarized in Table 3. Mean annual rainfall at Kawambwa was 1,294 mm during the 59-year period from 1911 to 1970. The mean daily temperature is 20.2°C and is highest in September and October and lowest from May through August. There are 7.1 hours (mean) of sunshine per day, with the highest insolation from May through August. Winds are predominantly from the east, with an average speed of 2.7 knots per hr. The Luena area is generally frost-free, and dry spells of more than four days during the wet season are rare.

5.2.2 Geology and soils
The geology in the Luena area consists of Precambrian quartzite, sandstone, slates and schist that form the upper elements of the Basement Complex. Folded rocks occupy the escarpment zone in the southeast of the area. Rivers have formed wide alluvial swamps and dambos (seasonally waterlogged areas) with very low gradients, because they cannot cut into the rocks of the Basement Complex.

The soils in Luena are deep and permeable with a uniform physical and chemical composition. The topsoil is loamy sand to sandy clay loam, while the subsoil is sandy loam to clay. The subsoil is friable, reddish-brown to reddish-yellow and is overlain by thin humus topsoil. The soils have a high proportion of silt and very fine sand with a laterite zone at a variable depth of 30 to 70 cm. The Luena soils, like most soils in northern Zambia, are strongly to very strongly acidic (pH 4.2 to 4.8).
Figure 2: NW Zambia, indicating the Project Site.
Figure 3: The proposed Estate, Factory and Extension areas.
throughout the profile, with a low cation exchange capacity (CEC, measured in milli-equivalents per 100 grams soil (meq/100g)) and fertility status. The chemical characteristics of the soils reflect the fact that they are derived from parent material that is poor in basic minerals (Table 4). Nitrogen, phosphorus and organic matter levels are also low.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Topsilt</th>
<th>Dry</th>
<th>Wetland</th>
<th>Dry</th>
<th>Wetland</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEC (meq/100g)</td>
<td>7.3</td>
<td>21.0</td>
<td>6.2</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>Base saturation (%)</td>
<td>47.7</td>
<td>42.8</td>
<td>20.7</td>
<td>43.7</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Cation exchange capacity and base saturation of Luena soils

5.2.3 Vegetation and ecosystems

There are four main vegetation types or ecosystems in the Luena area (Table 5). Dry land areas are covered with Miombo woodland, dominated by Brachystegia, Julbernardia and Isoberlinia trees. The transition zone between dry land and wetland is covered with Chipya woodland that consists of tall grass with scattered trees of the Pterocarpus angolensis, Erythrophleum africanum, Burkea africana and Combretum and Terminalia species. The dominant trees close to some wetlands, especially dambos, belong to the Piliostigma thonningi, Albizia and Uapaca species. The wetlands vegetation is primarily grass, with occasional patches of evergreen swamp/riverine forest, which is locally called mushitu. Syzygium cordatum, S. owariense, Ficus brachypoda and Xylopia aethiopica are common mushitu forest trees.

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (mm)</th>
<th>Open pan evaporation (mm)</th>
<th>Mean daily temperature (°C)</th>
<th>Mean daily isolation (hrs/day)</th>
<th>Mean wind speed (knots/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Mean</td>
</tr>
<tr>
<td>July</td>
<td>0.5</td>
<td>159</td>
<td>11.1</td>
<td>25.5</td>
<td>17.8</td>
</tr>
<tr>
<td>August</td>
<td>0.8</td>
<td>199</td>
<td>13.0</td>
<td>28.2</td>
<td>19.9</td>
</tr>
<tr>
<td>September</td>
<td>11.7</td>
<td>197</td>
<td>15.8</td>
<td>30.0</td>
<td>22.5</td>
</tr>
<tr>
<td>October</td>
<td>67.1</td>
<td>201</td>
<td>17.1</td>
<td>29.7</td>
<td>22.6</td>
</tr>
<tr>
<td>November</td>
<td>174.0</td>
<td>144</td>
<td>16.7</td>
<td>27.1</td>
<td>20.6</td>
</tr>
<tr>
<td>December</td>
<td>250.4</td>
<td>135</td>
<td>16.5</td>
<td>25.8</td>
<td>20.0</td>
</tr>
<tr>
<td>January</td>
<td>214.6</td>
<td>138</td>
<td>16.7</td>
<td>25.8</td>
<td>20.0</td>
</tr>
<tr>
<td>February</td>
<td>191.3</td>
<td>128</td>
<td>16.7</td>
<td>26.1</td>
<td>20.1</td>
</tr>
<tr>
<td>March</td>
<td>237.7</td>
<td>143</td>
<td>16.7</td>
<td>26.2</td>
<td>19.9</td>
</tr>
<tr>
<td>April</td>
<td>128.0</td>
<td>140</td>
<td>16.2</td>
<td>26.6</td>
<td>20.4</td>
</tr>
<tr>
<td>May</td>
<td>16.5</td>
<td>169</td>
<td>14.0</td>
<td>26.4</td>
<td>19.6</td>
</tr>
<tr>
<td>June</td>
<td>1.0</td>
<td>146</td>
<td>11.7</td>
<td>25.6</td>
<td>18.2</td>
</tr>
<tr>
<td>Annual</td>
<td>1293.6</td>
<td>1899</td>
<td>15.4</td>
<td>26.8</td>
<td>20.2</td>
</tr>
</tbody>
</table>

Table 3: Average climate conditions at Kawambwa, 30 km west of the Luena area

5.2.4 Landcover

The assessments of land cover and use below were performed based on: a two-day reconnaissance survey conducted in November 1998 in the project area and its neighboring areas; analysis of satellite imagery for the mid-1990s (obtained from the Forest Department Headquarters in Lusaka); a literature review; and secondary data analysis. The only available aerial photographs for the project were from 1977. These were considered outdated. Discussions were held with the local people as well as government and private sector employees in the area to obtain additional information. The biodiversity assessment was based on a review of species distribution data found in existing literature.

There are three forest reserves in the area — Pambashye, Luena and Mushota — covering a total area of 38,441 ha. Pambashye (38,300 ha) is the largest, and has three separate compartments: one at the bottom of Lufubu river, another at the top of Pambashye swamp and a third at the southern end of the Mushota peninsula (Figure 1). The forest reserves are relatively small for effective ecosystem
maintenance. In addition, the forest cover in the reserves has been degraded over the years (see Land ownership and use in section 5.3.2).

Current land cover status in the Luena area and the surrounding environment is summarized in Table 6. Forest cover has declined by about 45% from 2,460 km² in 1977 (Miombo woodland, swamp/riv erine forest, and Chipya woodland, Table 5) to 139,000 (forest and degraded forest together) ha (Table 6) while grassland has increased by nearly 75%. Land devoid of natural cover is most conspicuous around main villages, where vegetation has been intensively removed and land converted to gardens.

<table>
<thead>
<tr>
<th>Type of cover</th>
<th>Extent, in hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kawambwa</td>
</tr>
<tr>
<td>Bare land</td>
<td>46,000</td>
</tr>
<tr>
<td>Grassland</td>
<td>56,000</td>
</tr>
<tr>
<td>Degraded forest</td>
<td>30,000</td>
</tr>
<tr>
<td>Forest</td>
<td>75,000</td>
</tr>
<tr>
<td>Total</td>
<td>207,000</td>
</tr>
</tbody>
</table>

Table 6: Land-cover types in the Luena area, mid-1990s (from satellite image interpretations by the Provincial Forestry Action Program in Ndola, Zambia)

5.3 The local socio-economic environment

The following description of the socio-economic environment is based on: information from literature on the Luena area and/or the Luapula Province; a questionnaire survey carried out on the project site as part of this study; and an analysis of socio-economic statistical data for the Luena area from the 1990 national census of population and housing. The inhabitants of the Kawambwa and Mwense districts in Luapula Province belong to the Chishinga tribe. A map (produced by the Lands Department in Lusaka) showing the boundaries of the chiefdoms in and surrounding the project site was used to determine which chiefdoms would be directly affected by the project. Maps and field surveys were used to describe settlement patterns and distribution of institutions, such as schools, health facilities, business centers etc.

The Luena and Lufubu blocks (see Figure 4) are earmarked for the establishment of the Estate and therefore house the population that would be displaced by the project. Three census supervisory areas (CSAs) in the 1990 national census of population and housing covered these two blocks. The population of the Mushota block would not be displaced but would be encouraged to grow sugarcane to be sold to the Estate. The Luena and Mushota blocks are located in Senior Chief Mushota’s chiefdom. The Lufubu block is in Chief Chama’s chiefdom (see Governance, below).

5.3.1 Governance

The people are governed by a dual political and legal system — traditional and modern — as is common in rural Zambia. The former is based on customs and norms, while the latter is based on constitutional laws and regulations. This dual system of governance has important implications for the people’s perspectives and expectations regarding their personal and the community’s rights and obligations with respect to significant changes in land use and settlement patterns.

The modern system of government has an executive wing and a legislative wing. The executive wing is based at district centers, commonly known as bomas. The district executive secretary is in charge of the district. All departments of the government ministries are represented at the bomas. All constitutional laws and regulations, including criminal law within the bomas and criminal laws in the chiefdoms, are implemented and enforced under this structure. The various wings of central government appoint officers at the district level. An elected Member of Parliament represents the legislative wing of the government. His/her influence covers a spatial area known as a constituency, which can cover areas of one or several chiefs but only one district.

The district council is the policymaking body on local matters within its spatial area and draws its membership from government officers, traditional rulers and ordinary citizens. Heads of government departments and the area Member of Parliament are automatically district council members, as are the chiefs. Chiefs are elected to local government and are also representatives of the political parties.

The Senior Chief is at the apex of the traditional political hierarchy and rules a spatially defined area called a Chiefdom. The senior chiefdom of the Luena area spans over both the Kawambwa and Mwense districts. Although the positions of Senior Chief, Chief, Group Village Headman/woman and Village Headman/woman are hereditary, a traditional council composed of some members in the existing traditional leadership class officially appoints them. The traditional rulers have jurisdiction over civil cases in their areas. The Chiefs and traditional councils have influence over the same area and people. In the Luena area, Senior Chief Mushota rules a larger area than the district council, as his rule covers both the Mwense and Kawambwa districts.
Figure 4: Proposed Estate site and affected Chiefdoms.
The traditional organization of the Chishinga people is summarized in Figure 5. Senior Chief Mushota is at the apex of the structure. He rules the area through a number of Chiefs that have spatially defined Chiefdoms in both the Kawambwa and Mwense districts. The project site falls in the Chiefdoms of Senior Chief Mushota and Chief Chama, and borders the chiefdoms of Chiefs Munkanta and Mwenda (both of which fall under Senior Chief Mushota) (Figure 4).

Chiefdoms are composed of a number of villages that are governed by Headmen/women. The main functions of a Headmen/women are representing the Chief at the village level, maintaining harmony in the village (resolving disputes among the village inhabitants, etc.), allocating land to village newcomers, and performing traditional ceremonies. The Headman/woman has the power to summon and punish, through fines, any erring member of his/her village. The Headman/woman also has the power to expel anyone who is deemed a threat to the peace and harmony of the village. However, an aggrieved person has the right to appeal the ruling of the Village Headman/woman to the Chief.

Village settlements follow linear patterns and are located along access roads. In densely populated areas, such as Mushota, adjacent villages coalesce, with no visible boundaries between them. A village is comprised of a number of households. Members of each household recognize one person as household head. Generally, kinship determines membership to a household. The household is therefore the basic unit of social organization in the project area. The Chishinga people also have a clan system that is used, among other things, to determine marriages. Almost all of the adults in the project area are married. Within-clan marriages are usually discouraged. The Chishinga are matrilineal matrilocal. They generally do not object to inter-tribal marriages, but the man is required to live in the wife’s village. The people in the project area belong to a number of religious organizations, and churches are scattered throughout the area.

5.3.2 Land ownership and use
Much of the land in Luena is under customary tenure that is administered by Chiefs. In the questionnaire survey for the project area, the majority of respondents (57%) perceive the Chief as the owner of the land, while the rest consider the land that they inhabit as either theirs or belonging to their families. Among those who perceive that they own their land, about 74% stated that they acquired it through inheritance or as a gift. However, two-thirds of them believe that they are free to dispose of the land as they wish.

Forest reserves in the area were established by the Government to be used on a sustainable basis by local communities under the management of the Forest Department. In the past, the major land use in the Luena area was shifting cultivation — locally known as chitemene — that is practiced on upland dry land (away from wetlands). This cultivation system is based on lopping tree branches and piling and burning them at the center of the cleared plot to make an ash garden in which crops (such as, millet and cassava) are grown (Trapnell, 1953; Chidumayo, 1987; Stromgaard, 1984; Araki, 1992; Oyama, 1996). The ash garden is cultivated for three to four years and subsequently abandoned.

Due to the depletion of upland forest cover, few households currently practice traditional chitemene cultivation. Only a few chitemene gardens were observed in the area during the reconnaissance survey in November 1998. The majority of households grow cassava in intensively cultivated plots near villages. The major land cover changes in the Luena area have largely been caused by land clearing for subsistence cultivation.

5.3.3 Demographics
This description of the population in the project area and its surroundings is based on the 1990 national census of population and housing. The census data were based on census enumeration areas that are aggregated into census supervisory areas (CSAs). In 1990, people from sixteen CSAs populated the site. However, eight of these CSAs extended beyond the site. Population density data were used to estimate the fraction of the population in these eight CSAs that was living on the project site. In total, 8,789 people are estimated to have lived in the Estate and Mushota areas in 1990 (see Table 7).
Between 1963 and 1975 Luapula was the only province in Zambia that showed a negative rate of population growth. This was because of labor migration out of the province to the Democratic Republic of Congo (DRC) and the Zambian copper mines. In the 1980 census the Luapula province had the smallest group of citizens in the 15 to 49 year old age category in the country, indicating that for many young men and women migration had become institutionalized. In 1990 the Luapula province recorded a positive population growth rate (2.2%) for the first time since comprehensive population censuses were introduced. However, the growth rate was lower than the national average (3.6%). Assuming the same growth rate as that of the province, the population of the study area would have been 19,459 in 1998.

Due to data limitations, it was not possible to do a share shift analysis of the various population groups in order to determine the age structure of the Luena population in 1998. In 1990, the age class of 15 to 29 years was dominant (Figure 6) while those above 49 years old made up about 9% of the population. In 1990, women headed about 22% of the households in the project area. That figure is low compared to the female-headed households (FHHDs) in the province (38%) as a whole.

The average household in the project area (the proposed estate and Mushota North) was comprised of 4.97 people in 1990, with little variation between those in the Estate and Mushota areas (Table 7). This figure is low compared to the national average, which was 6.5 in the same year.

<table>
<thead>
<tr>
<th>Area</th>
<th>Male-headed</th>
<th>Female-headed</th>
<th>Total</th>
<th>Population</th>
<th>Average household size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estate</td>
<td>545</td>
<td>148</td>
<td>693</td>
<td>3,491</td>
<td>5.04</td>
</tr>
<tr>
<td>Mushota</td>
<td>833</td>
<td>244</td>
<td>1,077</td>
<td>5,298</td>
<td>4.92</td>
</tr>
<tr>
<td>Total</td>
<td>1,378</td>
<td>392</td>
<td>1,770</td>
<td>8,789</td>
<td>4.97</td>
</tr>
</tbody>
</table>

Table 7: Average household size in the project area based on the 1990 census

5.3.4 Public services
Data on services provided by public institutions were obtained through interviews with employees working in these institutions and discussions with service recipients, local leaders (such as village Headmen/women) and government officers at Kawambwa boma (the administrative headquarters of Kawambwa district, in which most of the project area is located).

5.3.4.1 Community, kinship and sharing
Due to the lack of sociological literature on the Chishinga tribe, not much is known about Chishinga intra-household social, cultural and economic relations. The 1998 survey did not cover aspects of community, kinship, and sharing. Inferences can be made based on literature describing the Bemba tribe, as Chishinga and Bemba tribes have cultural links (Musonda and Kashoki, 1973).

Literature on the Bemba indicates that community, kinship and sharing are important aspects of traditional life. Community, kinship and sharing among tribal clans constitute the only existing forms of social support, due to the absence of a formal state social security system in Zambia. Members of the community exchange food, labor, childcare services, care of the sick and elderly, and share responsibility for mourning and initiation ceremonies and the exchange of gifts. In times of shortage, this often means that members of the clan provide support services, such as farming labor, food during famine or illness and education and health services for the poor (Moore and Vaughan, 1994).

5.3.4.2 Education
The project site and its surroundings contain five primary schools (3 in Mushota and 2 on the Estate site) and one basic school located at Mushota that offers education up to grade nine. All of these are publicly-run institutions, except Kabombo primary school on the Estate site, which was built on a self-help basis by the local community. All of the primary schools are generally under-enrolled. 45% of the households surveyed in 1998 had at least one
school-aged child (> 6 years) who was not attending school. Lack of money was the main reason reported by parents/guardians for not sending children to school. The nearest secondary school is at Kawambwa boma, which is the headquarters of the district.

The literacy level in 1990 for people over four years old was 51%. Of these, 81% and 19% respectively had primary and secondary school educations. Attaining an education has been a vehicle for upward social mobility, allowing people from poor socio-economic backgrounds to move up in income class. Comparisons of the highest education levels attained by respondents in the 1998 survey revealed significantly more educated males than females.

5.3.4.3 Health services

The two health centers in the project area are located at Mushota and Kanengo. Each of them services a population of about 6,500. The Mushota health center has three beds and an ambulance that also serves Kanengo health center. Serious cases at the health centers are referred to Kawambwa hospital, where there is a doctor. The health centers are staffed by clinicians/nurses.

In addition to the two health centers, there are a number of community health posts that have been established to dispense medicine for simple ailments. Community health workers supplied with pre-packed medical kits staff these health posts. However, medical supplies to the health centers and posts are erratic. For example, the Kanengo health center had no drugs at the time of the survey in November 1998. This has tended to reduce the number of people seeking treatment and has reduced the value of the facilities to the community.

Malaria is the most common disease treated at the health centers. Other diseases include respiratory infections, diarrhea, pneumonia and injuries. The most serious diseases among children are malnutrition, diarrhea and measles. High levels of malnutrition, coupled with disease, have caused the province to have the highest levels of undersized children in the country. Other services offered by the health centers include child immunization, public health inspection and natal care.

5.3.5 Infrastructure

Luapula Province is well known for its good standard of rural housing units, which it owes to early missionaries who taught brick making and laying skills in the area (Kay, 1971). Very few houses are made out of the pole-and-dagga that is common in most rural areas of Zambia. In fact, in 1963 about 92% of all the dwellings in Kawambwa were made of brick (Kay, 1971). The 1998 survey revealed that 97% of the houses in the project area are made of brick with thatch roofs and many have wooden doors and windows. Tate and Lyle (1978) reported that the project area has skilled thatchers and bricklayers who are employed by some villagers to build houses or roofs, although most villagers build their own houses. The roofs are re-thatched and houses re-painted every three years. The houses have from one to seven rooms, with four rooms as the median. Most households also have other structures, such as kitchens, bathing shelters and pit latrines. Food storage bins or granaries are rare because cassava, which is the staple crop, is harvested from the field as needed so that the gardens also serve as food reserves.

Settlements are generally close to watercourses. This eases access to water. Potable water in the project area is usually obtained from springs, rivers and bore holes while water for general purposes, such as, washing, bathing and cooking, is collected from open shallow wells. Firewood is the common energy source for cooking, but charcoal is also used (Kalumiana, 1996). Most households use kerosene for lighting. Expenditures on kerosene purchases in 1998 were estimated at 36,000 ZMK (about 19.35 USD) per household per year.

There is limited access to the Estate areas, as there are few roads and those that do exist are in poor condition. For a more detailed discussion of the road system see section 10.2.1.

5.3.6 Economic and subsistence activities

The socio-economic structure of the population in the project area in 1990 is summarized in Table 8. Among the respondents to the 1998 survey, 76% were unemployed and those in waged employment
and self-employment were 13 and 11% respectively. Thus there appears to be a high level of unemployment in the project area. However, 75% of the male and 25% of the female respondents reported that they had been in wage employment previously.

The people in the study area practice a traditional system of subsistence agriculture based primarily on fishing and growing cassava (Schultz, 1976). Other crops include groundnuts, millet and beans. Every household has chickens. Goats are also common in the area.

Cassava is planted on ridges or mounds using the grass manure technique. Cultivation is confined to a strip of land adjoining dambos. In the first year, maize, beans, pumpkins and groundnuts may be planted between the cassava plants. The average size of the total cultivated area on the Estate site was estimated at 0.77 ha per farming household, with cassava accounting for 0.39 ha (51%), groundnuts 0.20 ha and beans 0.18 ha. Other crops are usually inter-planted with these three main crops.

The number of cultivated plots per household ranged from one to seven, with five as the average. The average number of plots was not significantly different between female-headed and male-headed households. However, the sizes of cultivated plots often were. In addition, the size of the plots did not correlate to production (yield per area). Female-headed households were observed to realize lower yields than male-headed households.

The large number of cultivated plots is due in part to the diversity of crops grown and in part to the nature of the cassava crop. Cassava is a tropical crop that is well suited to the poor acid soils in the project area. Trapnell (1996) reports that, although the first lager tubers of cassava are available 18 months after planting, harvesting is usually done three to four years later. The cassava harvest is continuous and begins in the second year at the earliest and finishes in the fourth year. Consequently, a household has several cassava plots at different stages of maturation. The crop is harvested from the field as required by the household. After the cassava is harvested, it is peeled, soaked in water for about a week in holes dug in dambos, and then split into small pieces and dried in the sun before milling/pounding into flour. The men make the cassava mounds. Both men and women tend the crops. However, the women plant, harvest, and process the crops and prepare meals for the household.

Some chitemene gardens are cultivated on the upland areas where finger millet is grown for brewing beer (Tate and Lyle, 1978). Fishing (in the swamps, lakes and rivers) provides an important source of protein during the off farming season. Hunting (mostly of small mammals) serves the same purpose. Gathering of wild foods (mushrooms, livingstone potatoe or icikanda), fruits etc. and beer brewing are the other subsistence activities in the area, especially for women. The poorest women also work for food — a practice called.ukupula — during the peak agriculture season.

There are a number of agricultural camps in the project area that are staffed by extension officers who provide technical advice to farmers and collect data about farm plots and crop production.

### 5.3.7 Incomes and wealth

Although farming is predominantly for subsistence needs, about 72% of the respondents in the 1998 survey reported that they sell crops, either within or outside the project area. Reported incomes from crop sales ranged from less than 10,000 to over 100,000 Zambian Kwachas (5 to 54 USD) per year. The average annual income from crop sales was 74,500 ZMK per household.

Annual disposable incomes among respondents in the 1998 survey among female-headed (FHHDs) and male-headed (MHHDs) households were estimated based on reported expenditures (Figure 8). Disposable incomes among the survey respondents ranged from less than 120,000 ZMK to over 1,180,000 ZMK (65 to 634 USD) per year (Figure 8). The estimated average income of 150,000 ZMK (81 USD) among female-headed households was significantly lower than that of 414,000 ZMK (223 USD) among male-headed households.

<table>
<thead>
<tr>
<th>Socioeconomic group</th>
<th>Estate Area</th>
<th>Mushota Area</th>
<th>Estate plus Mushota Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male  Female</td>
<td>Total</td>
<td>Male  Female</td>
</tr>
<tr>
<td>Labor force</td>
<td>604  461  1,065</td>
<td></td>
<td>889  422  1,311</td>
</tr>
<tr>
<td>Working category</td>
<td>569 425 994</td>
<td></td>
<td>751 338 1,089</td>
</tr>
<tr>
<td>Economically active</td>
<td>964 189 1,153</td>
<td></td>
<td>1,022 235 1,257</td>
</tr>
<tr>
<td>Self-employed</td>
<td>415 179 594</td>
<td></td>
<td>471 157 628</td>
</tr>
<tr>
<td>Unemployed</td>
<td>35 36 71</td>
<td></td>
<td>138 84 222</td>
</tr>
</tbody>
</table>

Two factors account for this gender difference in reported incomes. First, as already alluded, the women are poorer and produce smaller crops and, consequently, have fewer surpluses to sell. Second, the system for distributing consumer goods in the area is poor. As a result basic household consumer goods cannot be purchased for cash in the villages. Women cannot travel long distances to go shopping at the bomas. Therefore, the women prefer to barter their surpluses for second hand clothes, textiles, salt, cooking oil and other necessities (Gould, Mickels and Chimamba, 1990). The questionnaire did not address bartered goods so this trade was not captured as income in the survey.

The most important measure of wealth in the project area is the houses, unlike in other provinces where wealth is held in the form of livestock holding, grinding mills, motor vehicle, tractors etc. (Kay, 1971). Although rural, the Luapula province has expensive houses. The thatched brick houses that are the norm for the area are of high quality. They require large cash investments. The social status of individuals is judged with respect to this one asset. Not having such a house is considered a sign of poverty or ukupina.

5.4 The policy environment

5.4.1 Institutional responsibilities

The question of which government agency would be responsible for a Sugarcane Resources Project such as the one investigated in this study is a key policy issue that was raised by stakeholders. The question posed was, is it an energy project, an agricultural project, an industrial project, or is there some other appropriate categorization? The answer was that it is a development project, and that it involves aspects that fall under the jurisdictions of many government ministries and agencies. Hence, for its success, a Sugarcane Resources Project would require cooperation and coordination amongst those agencies. This is perhaps the largest policy challenge of implementing such a project. The ministries and agencies whose involvement would be required were such a project to be implemented, and their areas of responsibility relative to the project, are listed below.

a) Ministry of Energy and Water Development (MEWD)
- Fuel blending policy and strategy
- Fuel pricing policy
- Independent power production (IPP) policy
- Renewable energy policy
- Infrastructure development (electricity transmission and distribution facilities)

b) Cabinet Office (Including Office of the Vice-President)
- Resettlement issues
- Compensation for displacement
- Loyalties and ownership for chiefs and local community.
- Policy coordination
- Gender policy

c) Ministry of Local Government & Housing
- Loyalties and ownership for chiefs and local community

d) Ministry of Environment and Natural Resources and The Environmental Council Of Zambia (ECZ)
- EIA criteria and compliance
- Emissions and impact
- Policy on CDM, Carbon trading and joint implementation

e) Ministry of Finance and Economic Development
- Economic policy
- Duties and tariffs (rebate on plant, machinery and equipment, tax exemptions, etc)
- Financing and guarantee (ascertain possible Government participation in equity)
- Loyalties and ownership
- Compensation for displacement
- Infrastructure development from national budget perspectives.
- Job creation
f) Ministry of Communications and Transport
   - Infrastructure development (communications)
   - Transport issues

g) Ministry of Works and Supply
   - Infrastructure development (roads)

h) Ministry of Trade, Commerce and Industry
   - Investment incentives
   - Rebate on plant, machinery and equipment
   - Incorporation fees

i) Ministry of Lands
   - Land acquisition and time frame

j) Ministry of Agriculture
   - Agriculture issues (outgrowers, food versus exports and fuel substitutes)
   - Research on sugarcane varieties
   - Extension services for outgrowers
   - General agricultural policy

k) Zambian Electricity Supply Company (ZESCO) and Energy Regulatory Board (ERB)
   - Implementation of IPP policy
   - Electricity tariffs and bulk purchasing arrangements
   - Implementation of policy on transmission and distribution infrastructure in rural areas
   - Use of rural energy development fund for Luena project.
   - Implementation of policy on leaded fuel

l) Zambia National Oil Company (ZNOC)
   - Liquid fuel pricing
   - Blending policies and strategies
   - Investment requirements for ethanol storage and transportation

m) Indeni Oil Refinery
   - Technical considerations and implications of use of ethanol for fuel substitution and/or octane enhancement
   - Blending implications

n) Zambia Investment Centre
   - Investment incentives
   - Rebate on plant, machinery and equipment
   - Tax holiday
   - Marketing strategy
   - Project promotion
   - Investment licensing

Given the large number of potential public-sector actors in the project, stakeholders recommended that a core team of representatives from the following key ministries and agencies should take a leading role in promoting the project:

- Ministry of Energy & Water Development
- Cabinet Office
- Ministry of Agriculture, Food & Fisheries
- Ministry of Works & Supply
- Zambia Investment Centre
- Ministry of Local Government & Housing

These agencies agreed to form a Steering Committee, chaired by the Ministry of Energy & Water Development, which will lead and coordinate efforts to move the project forward. The involvement of non-governmental actors (in the form of a secretariat or implementing arm) would help to expedite the project by reducing bureaucratic obstacles and balancing competing public and private sector objectives.

5.4.2 Economic reforms

Although the Zambian economy was very turbulent over the past ten years, economic prospects for the future look promising (Sikabange, 1996). In 1991 the Government initiated policy reforms including economic liberalization through privatization of parastatal companies and removal of currency exchange control regulations and subsidies. The economic reform program is expected to result in improvements in the country’s economic performance, increasing the country’s annual economic growth rate until it stabilizes at 4% between 2000 and 2010 (CEEEZ, 1998). During this period, most of the privatized companies are expected to invest more in technology and expansion programs to become more competitive. In addition, in view of the liberalization policies and Zambia’s considerable natural resource endowment, new investments are expected in mining, manufacturing and agriculture.

5.4.3 Environmental standards and compliance

A number of laws regulate the management of natural resources in Zambia. The GRZ, through its environmental agency, the Environmental Council of Zambia (ECZ), has established strict environmental standards and guidelines to be followed by project promoters/developers. The ECZ, which was created by the Zambian Parliament in 1990, provides advice on environmental protection, deals with pollution control, and licenses commercial development projects. Regulations that guide the process and content required when conducting environmental impact assessments and presenting impact statements were established following the enactment of the Environmental Protection and Pollution Control Act (EPPC) in 1990. Under the current EPPC law (Environmental Protection and Pollution Control Statutory Instrument No. 28 of 1997(3)), full Environmental Impact Assessments (EIAs) are mandatory for all
commercial development projects and must be approved before the ECZ can issue licenses. There is no general standard for emission and effluent control, but general standard guidelines and statutory instruments exist. These include:

- 71/93 waste management;
- 141/96 air pollution from stationary sources; and
- 20/94 pesticide and toxic substance regulations.

GRZ strictly enforces these regulations for new projects.

A full EIA for an investment proposal for a Sugarcane Resources Project in Luena would be required to address impacts on indigenous forests, wetlands, and human settlements. The EIA would be expected to include:

- A resettlement scheme including schools and health care institutions;
- Impacts of land clearing;
- Impacts of irrigation infrastructure;
- Plans for sewage disposal;
- Impacts of road construction;
- Impacts of electricity production and distribution; and
- Impacts of the industrial plant.

5.4.4 Land acquisition

Land would be one of the most important resources for a Sugarcane Resources Project in Luena. By law, all land in Zambia belongs to the state. The Land Act of 1995 limits land ownership to Zambians but also allows non-Zambians to be granted land rights if the President has approved the application. The President, who is represented by Commissioner of Land, may allocate land to non-Zambians under special circumstances, such as when land is required for commercial projects financed by foreign investors. Land held under customary tenure — as is the case for much of the land in Luena — can only be allocated after the local chief(s) has (have) been consulted. In Luena, the chiefs have agreed in principle to give land rights to an investor.

Usually, after the chief has granted the right to an investor, the District Council is required to prepare a sketch map of the area for approval by the Surveyor General. The cost of surveying the proposed Luena sugarcane plantation should be included in any investment proposal. Once the sketch map of the area is done, a 14-year lease may be granted to an investor, who can also be assisted by the government to get the chief(s)’s approval and title to land.

Unlike in the past, customary land in Zambia is now valued. The original intention was to charge market value for land, but this has not been done because the land market in Zambia is still low. Therefore, in the case of Luena, the investor might not be asked to purchase the land at full market value, but would still be expected to make some payment to the local authority. The timeframe from application to getting land title, depending on a number of factors, ranges from approximately three weeks to one month. However, this period can be shortened when there is significant government interest in a proposed investment.

5.4.5 Water access

Because a sugarcane estate in Luena would require irrigation, access to water is another critical factor determining project viability. Under the water policy of 1994, agricultural water usage falls under three categories: irrigation, livestock watering and freshwater aquaculture. Water is considered fit for irrigation if it: does not cause soil degradation; enhances high crop yield and profitability and ensures sustainability of production. Investors must apply to the Water Development Board (WDB) to gain water access rights. The process of granting water rights, which involves a public hearing, can take up to five years. Once granted water rights, an investor is required to limit use to a specific volume of water, and allow sufficient water to flow downstream.

5.4.6 Financing development of public infrastructure

Financing for the development of public infrastructure in Luena must be found before any investment proposal can be made. The issue of which infrastructural investments the GRZ should finance and which should be financed by the investor is contentious, and was a primary factor in the government’s rejection of the most recent formal proposal for a new sugar estate in Luena.

An alternative to the governments’ involvement in infrastructure development would be to establish a policy that would allow an investor to Build, Own, Operate and Transfer (BOOT) such infrastructure. This policy option is already being promoted in the energy sector for the construction of transmission lines, and may be extended to other infrastructural development.
5.4.7 Energy sector deregulation and Independent Power Production (IPP)

The National Energy Policy (NEP) of 1994 and the Electricity Act of 1995, both developed by the Ministry of Energy & Water Development (MEWD), include measures aimed at increasing households’ access to electricity. Policy also aims at developing the most cost effective electricity generating sites for the domestic and export markets. To achieve this goal, the GRZ through the NEP allows Independent Power Producers (IPPs) to generate electricity and transmit it using the national grid for sale in domestic and export markets.

5.4.8 Government investment incentives

In 1993 the GRZ enacted an Investment Act that offered general incentives to investors. These included tax exemptions, low income tax, entitlement to capital allowance deductions on gains or profits, etc. The act also offered special incentives to investors who: exported non-traditional products that resulted in net foreign exchange earnings; produced products for use in local agriculture, and the production of agricultural commodities for export with a significant proportion of local raw material usage, that resulted in net foreign exchange savings; and were located in a rural area. Under this act, the Luena Sugarcane Project would have qualified for all of the above-mentioned incentives. However, in 1996 the Act was amended, and sections 30A and 31, which offered the special incentives listed above were deleted.

In 1998, the Ministry of Energy and Water Development (MEWD) developed a framework and package of incentives for private sector participation in hydropower generation and transmission. Under this framework, Independent Power Producers (IPPs) are allowed to generate hydropower and export it to the national grid. The framework includes fiscal incentives for hydropower project investments and a complementary transmission line package. In addition, GRZ decided that in the future, licenses for hydropower projects will be offered to the private sector on the basis of build, own, operate and transfer (BOOT) in case of generation, and build, own and maintain (BOM) for transmission.

Some of the scenarios explored in this study involve producing significant quantities of surplus electricity from bagasse. The question that remains unanswered is whether the sales of this surplus would be allowed under the regulations regarding IPPs, and whether the project would qualify for incentives outlined in the framework originally designed for hydropower investments. MEWD has indicated that — because the electricity will be produced from a renewable resource — it would.

While the above-mentioned incentives and others still exist on paper, the GRZ, through the Zambia Investment Centre (ZIC), has moved away from offering standard incentive packages. Instead, the granting of incentives occurs on a case-by-case basis. The location and level of the investment are key criteria for eligibility for incentive measures. Investments in rural areas are given better incentives than those in urban areas, and the bigger the investment, the better the incentive package.

5.4.9 Policies related to ethanol

There is general support from both government and the private sector for the production and use of ethanol as a gasoline substitute or octane enhancer. Stakeholders such as the Zambian National Oil Company Limited (ZNOC) and Indeni Oil Company perceive the production and use of ethanol from a Sugarcane Resources Project in Luena as being economically viable. However, in order to introduce gasohol (a gasoline-ethanol blend) on the Zambian market, the GRZ would require tests to determine the desired level of ethanol blending and the effect of gasohol on vehicle engines. These tests could be carried out by the GRZ or an investor.

Another aspect would be broadening the policy on renewable energy to address the issue of ethanol use in Zambia. Structures for pricing and taxation are two critical policy issues with regard to introducing ethanol as a transportation fuel. These issues fall under the jurisdiction of the Energy Regulation Board. The sales price of ethanol at the distillery would have to be 0.50 USD per liter for it to be economically viable (see the Economic/Financial analysis in chapter 12). This price seems feasible in the current market since the price of gasoline at the pump (1998 average) was 0.70 USD per liter.

5.4.10 Policy support to improve regional markets

It is expected that all tariffs among COMESA member states will be abolished, as the region becomes a free trade area. The creation of a free trade region is expected to increase the product and service markets (including markets for sugar, ethanol and electricity) in the region, provide new opportunities for inter-regional investment cooperation, and allow free movement of goods and people. In addition, transport and communication systems, the financial and monetary system, and
production and investment promotion will be harmonized. Such harmonization is expected to create a favorable economic and trade environment in the entire Southern Africa region.

5.5 Product markets: local, national and regional

The potential markets for the three main products — sugar, ethanol, and electricity — have been analyzed in this study, on the basis of local, national, regional, and/or international demand. Sugar is an international commodity, whereas ethanol and electricity tend to be limited to national or regional markets. Historical data quantifying these markets are provided in this section, to the extent that data were available. The likely development of these product markets in the near future has been evaluated based on existing trends and the prospects suggested by industry experts.

5.5.1 Sugar

Approximately 90,000 tonnes of sugar are sold in Zambia per year, of which 10% is used for industrial applications. Most of the sugar is consumed in the household sector. Domestic consumption of white/brown sugar and exports is given in Table 9 (Zambia Sugar, 1998). Population, per capita consumption and GDP are also given in Table 9.

5.5.1.1 Domestic consumption

Domestic consumption has declined over the last ten years. General economic decline in Zambia during the same period, leading to reductions in per capita disposable income, is one of the factors contributing to this. The economic growth anticipated between 2000 and 2010 (see section 5.4.2 above) can be expected to result in increased per capita sugar consumption in Zambia, returning at least to the 1990 level of 14.56 kg/person per year. Assuming this per capita consumption and a projected population of 13.2 million (CSO, 1990), domestic sugar consumption would reach 190,000 tonnes per year in 2010. With annual per capita consumption held constant at 14.56 kg but continued population growth, domestic sugar consumption would increase to 240,000 and 265,000 tonnes in the years 2015 and 2020 respectively. This is equivalent to a tripling of domestic consumption over a twenty-year period.

5.5.1.2 Regional and international export potential

Zambia currently exports approximately 80,000 tonnes of sugar per year. Exports have increased more than ten-fold since 1989, as shown in Table 9. The average growth rate in exports has been 10.5% per year in the last five years. These exports include regional exports to Congo DR, Tanzania, Burundi, Rwanda as well as international export markets such as the EU. Exports are given in Table 10 (GRZ, 1997).

<table>
<thead>
<tr>
<th>Country exported to</th>
<th>tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congo</td>
<td>32,000</td>
</tr>
<tr>
<td>Tanzania</td>
<td>16,800</td>
</tr>
<tr>
<td>Burundi/Rwanda</td>
<td>10,500</td>
</tr>
<tr>
<td>Others (including EU)</td>
<td>12,800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>72,100</td>
</tr>
</tbody>
</table>

Table 10: Zambian sugar exports (1995)

Access to potential regional export markets will be greatly influenced by the regional peace and security situation, as well as trade and commercial agreements. The picture at present is clouded with uncertainties due to unresolved regional conflicts. However, the market that has already been established in the Shaba Province of Congo DR is expected to continue to develop. The Namibian Government has also pronounced its intention to purchase sugar from nearby sources such as Zambia. Namibia is expected to import approximately 50,000 tonnes of sugar per year (Ministry of Trade, 1999).

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic Consumption (1000 tonnes)</th>
<th>Population (1000)</th>
<th>Per Capita consumption (kg/person)</th>
<th>Exports (1000 tonnes)</th>
<th>Per Capita GDP (1000 ZMK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>104.0</td>
<td>-</td>
<td>-</td>
<td>6.4</td>
<td>-</td>
</tr>
<tr>
<td>1990</td>
<td>107.5</td>
<td>7,383</td>
<td>14.56</td>
<td>3.5</td>
<td>-</td>
</tr>
<tr>
<td>1991</td>
<td>110.2</td>
<td>7,624</td>
<td>14.45</td>
<td>11.7</td>
<td>-</td>
</tr>
<tr>
<td>1992</td>
<td>98.2</td>
<td>7,873</td>
<td>12.47</td>
<td>5.3</td>
<td>-</td>
</tr>
<tr>
<td>1993</td>
<td>102.3</td>
<td>8,131</td>
<td>12.58</td>
<td>53.3</td>
<td>-</td>
</tr>
<tr>
<td>1994</td>
<td>80.3</td>
<td>8,397</td>
<td>9.56</td>
<td>57.5</td>
<td>255.8</td>
</tr>
<tr>
<td>1995</td>
<td>71.0</td>
<td>8,671</td>
<td>8.19</td>
<td>72.1</td>
<td>240.4</td>
</tr>
<tr>
<td>1996</td>
<td>85.3</td>
<td>8,958</td>
<td>9.52</td>
<td>69.8</td>
<td>247.0</td>
</tr>
<tr>
<td>1997</td>
<td>80.4</td>
<td>9,255</td>
<td>8.69</td>
<td>79.0</td>
<td>246.6</td>
</tr>
<tr>
<td>1998</td>
<td>74.8</td>
<td>9,561</td>
<td>7.82</td>
<td>86.8</td>
<td>234.1</td>
</tr>
</tbody>
</table>

Table 9: Domestic consumption and exports of sugar

Source for sugar consumption and exports: Zambia Sugar Annual Report, 1998
Among these regional markets, the Shaba Province of the Democratic Republic of Congo offers the greatest potential because of its proximity to Zambia. The distance from Luena through the Pedicle Road to Mufilira, Kitwe and Lubumbashi (the Provincial capital of Shaba) is 570 km. The Shaba Province, which is the second largest province in the Congo DR, includes the rich mining towns of Lubumbashi, Kipushi, Likasi, Kolwezi, Kamina and Kalemí, and has an estimated population of 15 million people. In view of the lack of data on per capita sugar consumption from the Shaba Province, a moderate per capita consumption of 8.0 kg per person has been assumed in this study. With a modest increase in population of 2.5% per year, the market potential by the year 2010 is expected to reach 120,000 tonnes. Assuming that Zambia can increase its market share from the current 30% to 50%, the potential export market to Congo DR for Zambia would be 60,000 tonnes per year. This market share is possible in view of the proximity of the Shaba Province to Zambia, and the absence of reliable road and rail transport connecting the Shaba Province to the rest of Congo DR and neighboring countries like Tanzania and Kenya. The recent entry of Congo DR into the SADC is expected to enhance this market.

Assuming a growth rate of 5% on current exports to Northern Tanzania, Burundi and Rwanda, the potential market to these countries would reach 60,000 tonnes per year by 2010. Reliable road, rail and water transport, connecting Zambia, Tanzania, Burundi and Rwanda already exist. Other potential regional markets include border areas of Botswana, Namibia and Angola, where with aggressive marketing strategies, a potential of 70,000 tonnes could be realized by 2010. With the planned improvement of the road network from Livingstone to Seshake, Zambia would have a geographical advantage for transporting sugar to such neighboring areas, as they are currently served by sugar refineries that are located further away.

Zambia failed to supply its 13,000 metric tonnes sugar quota to the EU in 1998. The future EU market depends on the EU Special Preferential Sugar quota, which we assume will increase to at least 20,000 tonnes per year. Attainment of this figure will largely depend on the re-negotiation of the Lomé Convention, which will occur in the year 2002. It is expected that the African-Caribbean-Pacific (ACP) countries will aim to increase their quotas during these negotiations.

The total estimated market potential for Zambian sugar in the years 2010, 2015 and 2020 is summarized in Table 11. Sugar consumption for Congo DR is projected based on a population of 17.4 million and 20.2 million in the years 2015 and 2030 respectively, and a per capita consumption of 8.0 kg/person. Exports to Tanzania, Burundi and Rwanda, and Angola, Namibia and Botswana for 2015 and 2020 are projected based an export growth rate of 3% per year, assuming that sugar consumption grows at that rate and Zambia’s market share remains constant.

<table>
<thead>
<tr>
<th>Source</th>
<th>1998</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>74,800</td>
<td>190,000</td>
<td>240,000</td>
<td>265,000</td>
</tr>
<tr>
<td>Congo DR</td>
<td>50,000</td>
<td>60,000</td>
<td>70,000</td>
<td>80,000</td>
</tr>
<tr>
<td>Tanzania</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burundi and Rwanda</td>
<td>21,800</td>
<td>60,000</td>
<td>70,000</td>
<td>80,000</td>
</tr>
<tr>
<td>Angola, Namibia and Botswana</td>
<td>0</td>
<td>70,000</td>
<td>80,000</td>
<td>90,000</td>
</tr>
<tr>
<td>EU</td>
<td>15,000</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Total</td>
<td>161,600</td>
<td>400,000</td>
<td>480,000</td>
<td>535,000</td>
</tr>
</tbody>
</table>

Table 11: Estimated market potential for Zambian sugar (tonnes)

The existing Nakambala sugar estate has the capacity to produce up to 200,000 tonnes of sugar per year. It is expected that with agricultural investments, sugar production at Nakambala can increase to 250,000 tonnes by the year 2010 (Hart, 1999). However, attainment of the latter figure is likely to be hampered by the restriction of irrigation water supply from the Kafue River under the Water Board Water Right quota system used to insure availability of water for power generation at Kafue Gorge. Assuming that Nakambala produces 250,000 tonnes of sugar per year and that production from a future sugar plant in Luena would complement rather than compete with Nakambala’s, the total potential sugar market for Luena is estimated at 150,000 tonnes in 2010; 230,000 in 2015; and 285,000 in 2020.

To capture export markets, however, an estate in Luena would have to be able to produce and deliver sugar at a competitive price. The cost of transporting sugar from the factory to the market (particularly for markets in Congo DR, Northern Tanzania, Burundi and Rwanda) is an important determination of the cost-competitiveness of Zambia’s regional sugar exports.

The price of sugar on the international market may be of increasing importance in determining Zambia’s export potential. Currently, bilateral contracts, quotas, and/or other arrangements govern a great deal of the world’s sugar trade. Such special trading arrangements have led to prices that are
above the international trading price. These preferential arrangements, such as the EU quota system, could give way to more open markets in the future, in which case the international sugar price will carry more weight than it does today.

International sugar prices fluctuate considerably. The unstable international price of sugar is one of the greatest difficulties faced by sugar companies and is a primary motivation for diversifying into other cane co-products. Threats to the sugar market include the planned abolishing of the preferential trade arrangement under the World Trade Organization (WTO). Under such a scenario, it is likely that many developing countries, including Zambia, would lose out as prices fall.

### 5.5.2 Ethanol

There are three main markets for ethanol: the fuel market, the industrial alcohol market, and the potable alcohol market. Where it exists, the fuels market is always the largest of the three in volume terms. The market for ethanol as an industrial feedstock is smaller in volume, and also faces competition from alcohol that is produced synthetically rather than through fermentation. Potable alcohol markets are also much smaller in volume terms, but can attract a price premium based on high quality. Potable alcohol is subject to much more stringent standards, and fermented sources are exclusively preferred in this market. Consequently, ethanol production based on sugarcane has comparative advantages to synthetically produced ethanol if a potable alcohol market exists.

Ethanol that is produced for the fuels market is sold in two forms: hydrous and anhydrous. Hydrous ethanol contains approximately 5% water, whereas anhydrous ethanol is nearly 100% pure. Hydrous ethanol cannot be blended with gasoline. It can be used in dedicated ethanol vehicles (so-called neat engines), which have been used extensively in the Brazilian ethanol program. Anhydrous ethanol can be blended with gasoline to produce gasohol, which can be used in standard internal combustion engines.

A typical blending ratio for gasohol is 15% ethanol and 85% gasoline. Car manufacturers and oil companies often prefer lower levels because the alcohol in gasohol can be corrosive. Recommendations vary for different auto manufacturers, but in general they have suggested figures of 10%. Nevertheless, well-tuned and maintained engines can run at blends up to 20 or 25%, ratios that have been common in Brazil. In the Malawi ethanol program, 22 to 24% has been fairly common, in part because the pricing system has favored ethanol over imported oil, resulting in an economic advantage to increasing the ethanol content. In the scenarios including gasohol in this study, an ethanol content of 15% has been assumed.

The Brazilian ethanol program has highlighted the possibilities as well as the difficulties of creating markets for ethanol. Brazil is the world’s largest producer of ethanol today, producing about 16 billion liters in 1998, or roughly half of estimated world production. Brazil’s ethanol program was initiated in 1975 after the oil crisis as a means of improving the domestic resource base and supporting the sugarcane industry. Widespread substitution for gasoline in motor vehicle engines has had considerable environmental benefits, and has created a domestic industry based on a renewable resource. A significant expansion of the industry in the early 1980s led to widespread production and adoption of neat (100%) ethanol engines for automobiles, which assured ethanol producers of a large market.

Lower oil prices in the mid-1980s and the trend toward deregulation of the sugar and ethanol industries in Brazil have made the Brazilian program more responsive to market forces. The significant size of the ethanol vehicle fleet in Brazil in the late 1980s required a stable supply of ethanol. Difficulties in maintaining sufficient supply eroded public confidence in the program. This coincided with the lower gasoline prices and the government’s decision in 1990 to slash taxes on small gasoline-engine cars (Vyas, 1999). These factors led to a collapse in the market for neat ethanol vehicles in the 1990s, as manufacturers did not produce ethanol-only engines for the smaller cars, while ethanol producers began to emphasize anhydrous ethanol production for blending. Ethanol production also became more dependent on the price of sugar, with sugar producers increasing or decreasing sugar production (thereby decreasing or increasing the available feedstocks for ethanol production) in response to sugar prices. The outlook for the ethanol market in Brazil is fairly stable or modestly increasing in the near-term. Production costs are expected to decline further and efforts to increase the percentage of ethanol used for blending are ongoing (Macedo, 1999).

Several countries in Southern Africa — including Kenya, Malawi, and Zimbabwe — have experimented with gasohol. South Africa produces a significant amount of ethanol synthetically from coal (as opposed to fermentation from cane) that is sold primarily for industrial applications. Zimbabwe previously had a gasohol program using
ethanol produced domestically from sugarcane, but support for this program declined. Ethanol is still produced in Zimbabwe, but is exported and sold on the potable alcohol market. Malawi is currently the only country in the region that still blends ethanol on a large scale. The Brazilian experience and the experience in Malawi suggest that emphasizing anhydrous ethanol for blending poses less risk for a country seeking to create a new domestic fuel market for ethanol.

The option of installing an ethanol plant at the Nakambala sugar plant in Zambia has been explored several times, as part of efforts to explore alternative uses for molasses. Producing gasohol, potable and industrial alcohol, cattle fodder and yeast have been explored (Kaoma, 1991). These ideas were abandoned due to uncertainties or difficulties including:

- Insufficient availability of molasses;
- Reluctance by farmers to utilize concentrated molasses stillage (CMS) that was to replace molasses (for cattle fodder);
- Negative impacts on the Indeni Oil refinery operations due to a declining gasoline market; and
- A low anticipated rate of return on investment.

A new ethanol plant in Luena would differ from the options explored for Nakambala in important ways that would affect the potential to attract a market and achieve financial viability. First, there are economic advantages to co-designing a sugar factory and ethanol distillery rather than adding a distillery to an existing sugar plant. Second, the flexibility of producing some combination of the three outputs — sugar, ethanol, and electricity — results in advantages with respect to financial risk. Third, the development context of the project could make it eligible for tax/fee reductions and/or attract funds that would otherwise be unavailable. Finally, given international efforts to reduce carbon emissions and the flexible financial mechanisms being negotiated under the Kyoto Protocol, the carbon reduction potential of ethanol (if earmarked to produce gasohol, thereby replacing fossil fuels) could open up sources of investment and financial support that would otherwise be unavailable.

In addition to anhydrous ethanol for fuel blending, there is a demand in Zambia for commercial grade ethanol for industrial uses, estimated at 1.0 million liters per year. Fermented (as opposed to synthetic) alcohol also has a preferred international market, both for alcoholic beverages and a wide range of commercial applications, especially in the food and pharmaceutical industries. Therefore, ethanol from sugarcane would have some additional export potential beyond that required for fuel blending. Although these commercial markets would be much smaller in volume than the fuels market, they tend to obtain a price premium if high quality production standards can be maintained at the distillery. We have not analyzed these markets in this study since their contribution to the total ethanol market would be small. Only the potential markets for ethanol to be blended with gasoline have been explored here. Nevertheless, an investor looking at potential ethanol production might consider these other markets due to the price premium and/or market expansion possibilities.

Zambia currently has one petroleum refinery: the Indeni refinery, located in the industrial region of Ndola. Introducing ethanol into the transportation fuel market in Zambia has implications for the cost-effectiveness of operations at Indeni. As the refinery is designed to meet diesel demand, there is a minimum production level (and a resulting minimum output of gasoline) for the refinery operation to remain cost-effective. If demand for gasoline from the refinery fell below that level, then the refinery would incur economic losses. Given that significant increases in gasoline demand are forecasted (Table 13), it appears unlikely that this constraint would be reached in most of the scenarios that include ethanol production. Furthermore, the continued operation of the Indeni refinery is not guaranteed. Nevertheless, policymakers in Zambia would likely consider the operational constraints of the Indeni refinery if evaluating alternative options for the level of ethanol production.

5.5.2.1 Blending with gasoline

Domestic gasoline consumption has declined with the economic recession, as shown in Table 12. The rising price of gasoline and the devaluation of the Zambian Kwacha have been major factors behind the steep decline in consumption. The price of gasoline in dollar terms reached a low of 0.41 USD in 1995, and returned in 1997 to levels of 0.7 to 0.8 USD, as was the case in 1990 from 1992.

Projections of future gasoline consumption levels (after 1998) are given in Table 13, assuming an annual growth rate of 4% for gasoline consumed domestically (CEEEZ, 1998) and that exports will roughly equal 13% of domestic consumption (ZNOC, 1999). The assumed growth rate for domestic consumption is somewhat lower than the 5% annual growth rate estimated by ZNOC. The real market price projections for gasoline are based
on the assumption that current price controls are removed and all players in the petroleum industry have a reasonable return on their investment (ZNOC, 1999).

Table 12: Historical gasoline consumption and prices in Zambia

<table>
<thead>
<tr>
<th>Year</th>
<th>Gasoline Consumption (1000 Liters)</th>
<th>Local Exports Total</th>
<th>Fuel Price ZK/Liter</th>
<th>Average Exchange Rate (ZK/USD)</th>
<th>Equivalent Price (USD/Liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>160,730</td>
<td>16,147</td>
<td>185,877</td>
<td>29</td>
<td>40.7</td>
</tr>
<tr>
<td>1991</td>
<td>212,973</td>
<td>16,938</td>
<td>229,911</td>
<td>52</td>
<td>64.6</td>
</tr>
<tr>
<td>1992</td>
<td>179,459</td>
<td>220</td>
<td>179,679</td>
<td>121</td>
<td>172.2</td>
</tr>
<tr>
<td>1993</td>
<td>154,181</td>
<td>90</td>
<td>154,271</td>
<td>257</td>
<td>452.8</td>
</tr>
<tr>
<td>1994</td>
<td>185,000</td>
<td>694</td>
<td>185,694</td>
<td>399</td>
<td>669.4</td>
</tr>
<tr>
<td>1995</td>
<td>197,027</td>
<td>16,142</td>
<td>213,169</td>
<td>558</td>
<td>1,364.1</td>
</tr>
<tr>
<td>1996</td>
<td>123,693</td>
<td>123,693</td>
<td>123,693</td>
<td>695</td>
<td>1,207.0</td>
</tr>
<tr>
<td>1997</td>
<td>107,527</td>
<td>4,646</td>
<td>112,173</td>
<td>986</td>
<td>1,314.0</td>
</tr>
<tr>
<td>1998</td>
<td>98,368</td>
<td>9,323</td>
<td>107,691</td>
<td>1,300</td>
<td>1,861.0</td>
</tr>
</tbody>
</table>

*Retail price, including taxes.

Table 13: Projected gasoline consumption and market price

Source: ZNOC, 1999

The market for ethanol has been estimated based on these projections, and assuming — as motivated in the discussion in section 5.5.2 — that anhydrous ethanol and gasoline would be blended and 15% of the domestic gasoline market would be replaced with ethanol. The resulting estimates of the potential domestic anhydrous ethanol market in 2010, 2015 and 2020 are presented in Table 14.

Table 14: Potential domestic anhydrous ethanol market

<table>
<thead>
<tr>
<th>Year</th>
<th>Market (1000 Liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>23,620</td>
</tr>
<tr>
<td>2015</td>
<td>28,740</td>
</tr>
<tr>
<td>2020</td>
<td>34,970</td>
</tr>
</tbody>
</table>

Blending ethanol with gasoline would eliminate the necessity of adding lead (as is current practice) or MTBE (methyl tertiary butyl ether, a common lead substitute) as an octane enhancer. Lead gasoline is currently used in Zambia. However, following the growing trend in the region, the government does plan to introduce unleaded fuel. If a policy of phasing out leaded gasoline is implemented, it is not clear whether MTBE or ethanol would be preferred for use as an octane-enhancing additive.

MTBE is not currently used in Zambia, and its use in industrialized countries — where pressure to ban its use has been rising because it was found to leak from underground fuel tanks and contaminate drinking water and to possibly be carcinogenic — has come into question. International spot prices are lower for MTBE suggesting that if both additives were imported, MTBE would be the preferred alternative. However, from a national perspective, a blending strategy using domestically produced ethanol would have the added benefit of saving foreign exchange (as all petroleum in Zambia is imported) whereas importing MTBE would result in a foreign exchange cost.

5.5.3 Electricity

The market for electricity exported from an industrial facility such as a sugar plant depends on the regulations for Independent Power Producers (IPPs). In countries where the institutional environment has been reformed and subsidies for large energy producers have been removed, opportunities tend to arise for cost-effective independent power production. An independent producer could supply electricity on a bilateral contract basis to a neighboring industry or a group of small users. Such market opportunities can certainly arise in rural areas such as Luena, where grid connections are expensive and/or unreliable. But it is generally more advantageous for an IPP to sell to established utilities or distributors, wheeling their product on a national or regional electricity grid. To do so requires national policies that allow wheeling as well as independent production.

Current plans for privatizing electricity supply include de-coupling production and distribution, indicating that wheeling will be an option in the near term. In addition, a Policy Framework of
Incentives for Private Sector Investment in Hydropower Generation and Transmission exists, offering attractive incentives for independent power producers harnessing hydropower resources. Although use of other renewable energy sources such as biomass are not specifically mentioned in this policy, discussions with relevant authorities indicate that bagasse cogeneration could qualify for consideration under this framework (ERB, 1999).

5.5.3.1 The electricity market

Domestic and export electricity demand for 1995 and five-year projections from 2000 to 2020 are given in Table 15. The average annual growth rate for domestic electricity consumption is expected to be 4% (CEEEZ, 1998). Projected growth in exports was based on annual assumed growth rates for two major marketing regions: Congo DR at 2.5%, and Northern Tanzania, Burundi, and Rwanda at 5% (CEEEZ, 1998).

Table 15: Electricity demand, 1995 to 2020

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic (1000 GWh)</th>
<th>Export (1000 GWh)</th>
<th>Total (1000 GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>6.22</td>
<td>1.18</td>
<td>7.40</td>
</tr>
<tr>
<td>2000</td>
<td>7.60</td>
<td>1.56</td>
<td>9.16</td>
</tr>
<tr>
<td>2005</td>
<td>9.17</td>
<td>2.15</td>
<td>11.32</td>
</tr>
<tr>
<td>2010</td>
<td>10.90</td>
<td>3.07</td>
<td>13.97</td>
</tr>
<tr>
<td>2015</td>
<td>13.18</td>
<td>4.39</td>
<td>17.57</td>
</tr>
<tr>
<td>2020</td>
<td>16.40</td>
<td>5.76</td>
<td>22.16</td>
</tr>
</tbody>
</table>

Currently, the total firm power supply in Zambia is 1,500MW (from both Zambian Electricity Supply Company (ZESCO) and Kariba North Bank). Of this, 1,000MW are dedicated to meeting domestic electricity demand. An additional 200MW of capacity is used to produce electricity for export to neighboring countries, leaving 300MW unused or as reserve power.

With the growth in electricity demand shown in Table 15, the current capacity surplus is estimated to be exhausted in the year 2006, so plans for new production capacity need to be developed and implemented over the next five years. The proposed or expected capacity investment alternatives to meet future demand are given in Table 16. Current plans include an 80MW hydropower plant at Itzexi-Tezzi, followed by a 450MW plant on the lower Kafue River. Another option being considered is an 800MW plant at Batoka. In addition, the overall average capacity factor (excluding the 300MW of capacity not in use) is currently low — approximately 70% — and is assumed to rise to nearly 85% by 2020, a level that is more acceptable for a hydro-based system.

Table 16: Current and projected electricity supply and demand (MW)

<table>
<thead>
<tr>
<th>Source</th>
<th>1995</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing capacity</td>
<td>1,500</td>
<td>1,500</td>
<td>1,500</td>
</tr>
<tr>
<td>With planned additions (Itzexi-Tezzi, Kafue Lower)</td>
<td>2,030</td>
<td>2,030</td>
<td></td>
</tr>
<tr>
<td>With additional option being considered (Batoka)</td>
<td>2,830</td>
<td>2,830</td>
<td></td>
</tr>
<tr>
<td>Projected Domestic demand</td>
<td>1,665</td>
<td>2,200</td>
<td></td>
</tr>
<tr>
<td>Balance (available for export)</td>
<td>500</td>
<td>1,165</td>
<td>630</td>
</tr>
</tbody>
</table>

The proposed capacity additions listed above would guarantee a significant surplus available for export. On the other hand, these additions, particularly Batoka (800 MW), come in very large increments and could leave even larger surpluses if demand grows more slowly. Furthermore, given Zambia’s high dependence on hydropower (over 90% of electricity supply), it would appear advantageous to diversify supply in the future. Independent power production from a sugar factory should pose less financial risk than a large hydro plant due to the smaller scale. Risk would also be reduced because the financial viability of the investment would be linked to several products, rather than only to electricity as is the case with a new hydro plant.
6 Producing sugarcane

6.1 The sugarcane plant
Sugarcane is a perennial grass with tillers or stems, bunched into stools that are usually erect. It has a sucrose content of 10 to 18 percent and a fiber content of 10 to 15 percent at harvest (Fauconnier, 1993). The stems or stalks develop from buds, and are ready for harvesting 10 to 24 months later. Sugarcane is grown in the tropics and subtropics between latitudes 37°N and 31°S. It is essentially a plant of the warm tropics and grown best when frequent heavy rainfall is interspersed with bright sunshine. It is very sensitive to temperature: below 15°C growth is very slow and growth ceases when temperatures exceed 35°C. The optimum temperature range for sugarcane growth is 20 to 30°C (Hunsigi, 1993).

Sugarcane grows well on a variety of soil types. It is tolerant to wide variations in acidity and alkalinity. The most important constraints are frost and water availability. Problems related to lack of nutrients and to the presence of weeds, pests and disease are more easily overcome. The environmental impacts of methods for abating such problems are discussed in chapter 13.

6.2 Area suitable for sugarcane production
About 40,706 ha of dry land in the study area are considered suitable for sugarcane production, although the maximum extent of cane fields is estimated at 32,565 ha (Table 17). In this study, 6,650 hectares are proposed for initial sugarcane production, leaving a significant potential for future expansion.

<table>
<thead>
<tr>
<th>Block</th>
<th>Area in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gross</td>
</tr>
<tr>
<td>Mushota</td>
<td>7,930</td>
</tr>
<tr>
<td>Luena</td>
<td>12,061</td>
</tr>
<tr>
<td>Lufubu</td>
<td>8,106</td>
</tr>
<tr>
<td>Pambashye</td>
<td>2,650</td>
</tr>
<tr>
<td>Luwo</td>
<td>3,032</td>
</tr>
<tr>
<td>Luongo</td>
<td>6,927</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40,706</strong></td>
</tr>
</tbody>
</table>

Table 17: Location and size of the potential sugarcane fields in Luena (See also Figure 3)

6.3 Factors affecting sugarcane production potential

6.3.1 Choice of sugarcane variety
The choice of cane variety is one of the most important factors in cane production. Different varieties have different yield potentials, pest and disease resistance and are bred for different ecological and economic conditions. Therefore, the choice of the varieties to be grown in Luena is of paramount importance. A wrong decision could lead to total production failure. Varieties are considered in view of a number of properties, including:

- Percentage pol: a term used in the laboratory determination of sucrose content (polarimetrically determined sucrose). It indicates the percentage sucrose (sugar) in the cane (Fauconnier, 1993). This is important because the economic value of a sugarcane crop depends on the amount of sugar obtained per hectare. To optimize pol content one needs a good variety, good climatic conditions and good control of ripening conditions.

- Biomass yield: is important because high levels of vegetative material (which act as the plant’s sucrose factory) are needed for sucrose production.

- The growing period from planting to maturity for sugarcane ranges from one to two years depending on the variety. This is important because harvesting has to be synchronized with the ripening conditions, planting time and milling operations. Harvesting under Zambian conditions has to be done in winter (during the dry season).

- Resistance to pests and diseases are very important factors in sugarcane production. While production can be maintained at high levels using chemicals (pesticides and herbicides), it is better to use resistant varieties. This reduces sugar production costs and protects the biophysical environment and humans from possible negative effects of the use of agro-chemicals.
The right varieties for Luena cannot be chosen purely on the basis of the above properties. They must also be adaptable to the soil and climatic conditions of the area. Examining the varieties grown at Nakambala Sugar Estate provides a good starting point in the process of scrutinizing varieties to be grown at Luena. Nakambala is the nearest sugar growing area to Luena and therefore it should be the point of reference despite the differences in rainfall, sunshine hours and soil qualities.

The main variety grown at Nakambala is NCO 376. This variety is recommended for trial at Luena because of its proven good performance in several countries in the southern African region. NCO 376 can be tried at Luena despite the fact that it is susceptible to smut (Ustilago Scitaminea), a fungal disease. It is possible that the incidence of smut in Luena may be higher than at Nakambala because of higher rainfall. However, this disease can be controlled with agricultural practices. These include selecting healthy seed material, avoiding ratooning, thermo-therapy of seed material and roguing and destruction of smutted clumps. Although NCO 376 is a high yielding variety, there are other varieties — such as N19, N14, N22 and CP66 — that have much higher yields than NCO 376. The other varieties recommended are N14 (a variety that is resistant to smut (TECNOAZUCAR-IPROYAZ, 1991)) and N19 (a variety that has demonstrated high yields at Nakambala (Zambia Sugar Company, 1996)). All of the three varieties recommended have a high percentage pol and about the same growing period to maturity of 12 months.

6.3.2 Climatic conditions

Temperature is the most critical of the uncontrolled factors in sugarcane growing. The minimum mean air temperature for active growth is 20°C. Depending on varieties and agricultural practices, this may vary from 18 to 22°C (Blackburn, 1984; Landon, 1984). The length of the period when temperatures are significantly below 20°C influences both the growing season and the ripening period. Sugarcane ripening is a stage of cane growth at which the sucrose level in the stem increases, with decreases in moisture, glucose and acidity. Temperatures below 10°C and above 35°C are detrimental to sugarcane growth (Blackburn, 1984; Landon, 1984). Hunsigi (1993) reported that temperatures below 10°C reduce water uptake. It is important to note that low temperatures (but not below 10°C) have been found to be the best conditions for ripening sugarcane.

Temperature is not likely to be a limiting factor for growing sugarcane in Luena, especially if planting and harvesting activities are synchronized with the temperature pattern. The low winter temperature will help ripen the crop without employing artificial ripening measures (e.g., spraying the crop with a contact herbicide). In fact, the climatic conditions in the dry season in Kawambwa are ideal for the ripening requirements of sugarcane.

Sunshine (insolation) is the other important factor in growing sugarcane. The photosynthetic rate of the sugarcane plant is affected by natural light intensity, so that the greater the incident radiation, the higher the expected yields. This factor is likely to be the main limitation in the Luena area. The dry season (May to October) is a time of high insolation, with an average of 5.1 hours of sunshine per day. Daylight, although difficult to evaluate because of winter-summer temperature changes, is another important factor in sugarcane production (Blackburn, 1984; Landon, 1984).

Very little is known about the combined effects of multiple climate factors on sugarcane growth in Zambia. In order to assess the potential impact of multiple climate factors, a general model was developed based on the growth pattern of vegetation at Mpika in northern Zambia, using monthly increments in the Normalized Difference Vegetation Index (NDVI, a measure of vegetation greenness) (Fuller 1994). The climate variables used in the analysis were temperature, sunshine hours, rainfall patterns and cumulative rainfall. The analysis revealed that the most significant factors affecting plant growth were cumulative rainfall and minimum, maximum and average temperature (Table 18). The plant growth model was applied using climate data for Kawambwa and Kafue Polder to predict plant growth patterns in Luena and at Nakambala, respectively (Figure 9). The results suggest that plant growth in Luena would generally be lower than that at Nakambala. If sugarcane behaves similarly, then lower yields would be expected in Luena compared to Nakambala.

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Coefficient</th>
<th>Significance level (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.23246</td>
<td>0.0183</td>
</tr>
<tr>
<td>Cumulative rainfall</td>
<td>-0.00003</td>
<td>0.1674</td>
</tr>
<tr>
<td>Minimum temperature</td>
<td>-0.04018</td>
<td>0.0570</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td>0.03132</td>
<td>0.0613</td>
</tr>
<tr>
<td>Average temperature</td>
<td>0.04926</td>
<td>0.0115</td>
</tr>
</tbody>
</table>

Table 18: Predictor variables used in modeling vegetation growth as measured by NDVI
6.3.3 Soil conditions

Sugarcane is a highly versatile crop that can be grown successfully under a wide range of soil conditions (Fauconnier, 1993). The physical properties (such as porosity, depth, bulk density, permeability and moisture retention) of the soil are more critical for successful sugarcane production than the chemical characteristics, because the physical properties are more difficult to modify. The analysis below of soil treatments necessary in Luena is based on the assumption that the soil measurements taken at the site for Tate & Lyle in 1978 (Tate and Lyle, 1978) accurately reflect the state of the soils today.

Soils identified as suitable for growing sugarcane still need to be properly managed to produce good crops. Soil acidity is one of the important constraints that must be addressed. It does not in itself reduce growth, but it affects the associated chemical environment. Some nutrients become more soluble at low pH and end up being leached down through the soil profile and into the water supply. The acid conditions will also make aluminum (Al) more soluble. Aluminum is toxic to sugarcane when its presence on the soil exchange complex exceeds 60 percent. High amounts of manganese are also toxic to sugarcane. Low pH may also affect microbiological activity in the soil, hence nutrient cycling.

Sugarcane tolerates a pH range of 4.5 to 8.5 but has an optimum pH range of 6.0 to 7.5. The mean pH of the dry land soils in Luena area is 4.5 for topsoil and 4.2 for subsoil. These values would need to be raised to 5.5 to 6.0. To do so, it is recommended that finely ground lime be applied initially a month before planting at a rate of two tonnes per ha. Lime application should be repeated every two years. The pH should be monitored every year and the liming schedule adjusted as necessary depending on the actual pH levels. The liming material should be either dolomitic or calcitic. Dolomitic lime is available in Lusaka and Kabwe while calcitic lime is available in Ndola. The nearest deposit with dolomitic lime is at Matanda, in the Mansa district (Oygard, 1987) but production has not started at this site. When applying lime it is important to monitor the levels of micronutrients (zinc, copper, boron, manganese and iron) and to apply required amounts to avoid deficiencies.

The Luena soils have low cation exchange capacity (CEC). This is because they contain low levels of organic matter and the clay minerals in the soils are of low activity (i.e., clays composed of minerals that have a low cation exchange capacity, such as kaolinite and oxides and hydrated oxides of iron and aluminum). In low activity clay soils, organic matter usually contributes significantly to the CEC of the soils. The desired level of organic matter in soils is difficult to quantify. Generally, values of between two and four percent are considered adequate. The soils in Luena currently contain less than one percent organic matter. Soils with low CEC have low capacity to retain added nutrients against the leaching effect of the heavy rainfall. The dry-land soils in the Luena area have CECs of less than ten meq per 100g soil (Tate and Lyle, 1978). This is lower than the critical value of 15 meq per 100g soil considered necessary for growing sugarcane. Nutrient leaching losses lead to economic losses and reduce the freedom of choice in the method of applying fertilizers (Blackburn, 1984).

To improve the organic matter content and CEC, solid residues from sugar production should be applied to the soil. The cultivation of green manure crops can also help to raise the organic matter content. Leguminous green manure crops can be grown in the period between the removal of the last ratoon crop and replanting with new cane. These crops have the advantages of protecting the soil and of supplying nitrogen and organic matter when ploughed in. Incorporating green manure improves cane yield quality (Hunsigi, 1993). Legumes that can be used in this way include pigeon peas (Cajanus indicus Spreng), sunnhemp (Crotalaria juncea L.) and related species, and cow peas (Vigna spp.), and winter crops such as soybeans, lupines, field peas and vetches (Halliday, 1956).

The levels of nitrogen, phosphorus, calcium and magnesium in the soils at Luena were found to be low (Tate and Lyle, 1978). Potassium was the only element of those measured that was available in adequate amounts. It is therefore imperative to regularly apply fertilizers, in correct quantities. There are a number of factors to consider when
deciding on the types of fertilizers, amounts and methods of application. Some of the factors to consider in the case of Luena area:

- Leaching potential
- Fertilizer release rate
- Effect on soil pH
- Nutrient mobility in the soil
- Cane varieties used
- Ratoon or plant crop (to be considered after first year)
- Cost per unit nutrient (to be considered at the time of purchase).

Nitrogen (N) is necessary for vigorous vegetative growth. However, if applied in excess, N can slow down the ripening process, especially under wet conditions. It is recommended that N be applied in the form of urea at 130 kg N/ha. Ammonium sulphate should be avoided because of its acidifying effect. It is important that the urea is covered. In case of plant cane, urea should be placed in bands parallel with the rows of setts and roughly five centimeters from them. The second split (half the amount) should be applied four months after planting for plant crop, and three months after harvesting for ratoon crop (the first split having been applied soon after harvesting). All nitrogen must be applied five months before the cane is harvested. If the application is too heavy or unduly delayed, the sucrose content of the juice can be depressed.

Phosphorus is especially important for cane growth. Deficiencies retard the development of the root system. Phosphorus is applied as single superphosphate (SSP) or triple super-phosphate (TSP) at a rate of 100 kg P$_2$O$_5$/ha. It is applied at the time of planting in case of plant crops or soon after harvesting in the case of ratoon crops. Phosphorus should be placed close to the plant because of its low mobility in the soil.

Moderate levels of potassium (K) are available in the soil but it is still necessary to apply more. Apart from its well-known general functions in plant growth, K plays an important role in sugarcane production by counteracting the effects of N on the sucrose content of the cane juice. It must be available, therefore, in adequate amounts. There is no risk of over fertilizing, as high levels of K have no detrimental effect on the crop and contribute to the K reservoir in the soil. Potassium chloride (muriate of potash) should be applied to supply 80 kg K/ha. Potassium can be applied on its own or in combination with other fertilizers. As there is no need for special placement, the cheapest method of application should be used.

The levels of calcium (Ca) and magnesium (Mg) are very low in the upland soils of Luena. The Ca and Mg levels would be improved by the application of dolomitic liming material. If calcitic lime material is used to raise the soil pH, magnesium sulphate should be applied. Micronutrients in the soil were not analyzed or reported in the Tate and Lyle (1978) report. It is strongly recommended that these be analyzed, because micronutrients are likely to be available in low amounts under the acid and leaching conditions described above. The recommended liming program could further contribute to micronutrient deficiencies in the soil.

The above fertilizer recommendations should be considered provisional. It is necessary to carry out fertilizer trials on site to determine the right amounts of fertilizer. A nutrient monitoring program should also be introduced from the beginning, with plant and soil analyses conducted annually.

6.3.4 Availability of water

Although drought tolerant, sugarcane is a highly water demanding crop (especially during the peak-growing phase) (Hunsigi 1993). The mean annual rainfall of 1,294 mm at Kawambwa is adequate for growing sugarcane because it is well distributed throughout the year. This is not the case at Luena, where rainfall is seasonal, occurring from November to April. To successfully grow sugarcane in Luena would require irrigation from April to October.

The possibility of expanding the existing sugarcane estate at Nakambala rather than establishing a new estate at Luena has been considered. However, although irrigation requirements at Nakambala are lower than at Luena (Figure 10), expansion of the Nakambala estate is severely constrained by water supply from the Kafue River. Even with the existing estate size, Nakambala uses its entire water extraction quota during the peak month of October (Figure 11). Therefore, expanding the estate by another 6,650 ha (the proposed size of Luena estate) is not feasible with the present allocation of water rights from the Kafue River. High water losses as a result of evapotranspiration by the water hyacinth weed will further constrain water supply from Kafue River. The weed currently covers a stretch of 75 km on the Kafue River, from Nakambala down to the Kafue gorge hydropower station (ADS Groupe-Conseil Inc., 1995).
For water resources alone, it would be advantageous to choose the Luena site over expansion of Nakambala if one chose to expand Zambia’s sugarcane production capacity to the extent explored in this study. In fact, it would be possible to expand an estate in Luena beyond the initial 6,650 ha analyzed in this study, especially if the proposed higher capacity reservoir at Luongo can be constructed to irrigate the nearly 10,000 ha in Pambashye, Luwo and Luongo blocks (see Figure 3). Currently, the only known constraint to the development of the Luongo reservoir is the potential impact on the five-megawatt hydropower station at Musonda Falls, further downstream. The impacts of such a larger reservoir were not assessed in this study.

Approximately 87 to 95 million m$^3$ of irrigation water would be needed for cane production at Luena. Three to four thousand hectares in the Lufubu block of the Estate would be irrigated directly from the Lufubu River and the water conveyed to the fields by gravity after overnight storage (see Figure 3). The volume of water necessary for irrigating Lufubu block is 20.7 million m$^3$. River-flow in the Lufubu River is sufficient, even during periods when river flow is at a minimum (Figure 12).

Irrigating the 6,000 to 7,000 ha of sugarcane in the Luena block would require about 80 million cubic meters of water. The Pambashye River, which runs from south to north, is located in the middle of the project site, with a watershed of 380 km$^2$. River flow in the Pambashye River from May through October is too low to meet the irrigation needs of Luena block by direct extraction from the river (Figure 13). Therefore, water for irrigating this block would have to come from a storage facility. A dam would be constructed across the Pambashye River and swamp to create a reservoir covering about 4,000 ha and with a storage capacity of about 110 million m$^3$ of live storage (Tate and Lyle, 1978). Water would be conveyed from the reservoir to night storage dams for use during the following day. Night storage would be essential because irrigation demands would often exceed the capacity of direct pumping from the main dam which would be located further away from the cane fields.

Furrow irrigation is recommended for the Luena Estate because it is simple to operate and maintain and is suitable for the landscape and soils of the site (Booker Tate Ltd., 1992). The main irrigation infrastructure would consist of:

- Twenty night storage dams with a capacity of 38,500 m$^3$ each;
- Concrete lined primary canals with a total length of 35 km;
- Concrete lined secondary/tertiary canals serving 8,360 ha; and
- Drains and culverts in 9,900 ha.

![Figure 10: Sugarcane irrigation water requirements (per ha) at Nakambala (Mazabuka) and Luena.](image)

![Figure 11: Irrigation water use at Nakambala Sugar Estate.](image)

![Figure 12: Lufubu river flow and irrigation requirements in Lufubu block.](image)
6.3.5 Weed, pest and disease control

Sugarcane requires a weed-free environment for the first three months after planting. Weeds can drastically reduce sugarcane yields. This is because they compete with the cane for water and nutrients. Weeds also harbor pests, which in turn affect sugarcane productivity. They can be controlled manually, mechanically or chemically. The method chosen depends on the type of weed, degree of infestation, the weather conditions, cost and environmental considerations.

To assess the specific measures necessary for weed control requires an analysis of the local situation under planted conditions. The type of herbicides to be used depends on the important weed(s) present and how these relate to the environment (soil, climatic conditions and cane variety). The type of weeds encountered depends on the climate, soils and agricultural practices. In addition, specific control-measure recommendations are better developed on site because in some cases the control of one major weed may lead to the emergence of a less important weed to a higher degree of infestation. Therefore, it is difficult to predict what types of weed control would be needed in Luena. Hunsigi (1993) has briefly discussed the most important weeds in sugarcane growing areas and has listed the most commonly used herbicides in cane culture as atrazine, TCA, metribuzin, diuron, cyanazin, ametryne, trifluralin, alachlor, hexazinones, paraquat and phenoxy-acetic compounds. Despite the differences in climate and the soils, one could expect to get a general idea of the weed conditions that could be expected in Luena by examining conditions at Nakambala. Weeds are not a serious problem at Nakambala and therefore, there are no specific weed control recommendations. Contact herbicides are sometimes used to artificially ripen the sugarcane.

The major pests that affect sugarcane globally are moth borers, froghoppers, termites, white grubs and rodents. The main pests at Nakambala, although of no economic importance, are Eldana borer, Lepidopterus stem borer and the Black maize beetle (Heteronychus licus). Their attacks are not very serious. These pests have been controlled with agricultural methods without applying chemicals. H. licus has been controlled at Triangle Sugar Estates in Zimbabwe using integrated pest management (Musikavanhu, 1996).

If the experiences of other sugarcane growing areas in southern Africa are applicable to Luena, it can be inferred that there may be little or no need to use chemicals in the first two or three years of sugarcane production. However, it would be necessary to establish a pest-monitoring program from the first year of sugarcane production.

Sugarcane is susceptible to about 100 diseases (Hunsigi, 1993). Some of the most important are smut (Ustilago scitaminea), downy mildew (Sclerospora sacchari), red rot (Colletotrichum falcatum), rust (Puccinia melanocephala), leaf scald (Xanthomonas albilineans) and sugarcane mosaic virus. The most important disease in the southern African region is smut. The recommended variety, NCO 376, is also susceptible to smut. Smut can be controlled using hot-water treatment, fungicides, removing diseased stools or by growing only plant cane. However, the most economic and satisfactory method is the replacement of susceptible varieties with resistant ones (Blackburn, 1984).

6.4 Anticipated sugarcane yields

It is not easy to predict sugarcane yields without detailed information about many critical case-specific factors that affect sugarcane yield. Reasonable estimates of anticipated yields for the Luena area can be made by comparing yields from existing plantations in other areas with similar agro-ecological conditions and management practices. Landon (1984) reports cane yields ranging from 70 to 150 tonnes per hectare (t/ha) for tropical regions, while at Nakambala average sugarcane yields for different varieties during 1968-1997 have ranged from 88 to 126 t/ha, with an overall average of 111 t/ha. Nakambala is located in an area that has soils and climatic conditions that are better suited for sugarcane growing than Luena (see also Figure 9). Therefore, a more conservative cane yield assumption of 100 t/ha has been used for Luena in this study. However, cane trials to determine the appropriate variety(ies) and their yields would have to be made if plans to establish an Estate progressed further.
The cane quality input assumptions for the technical analysis are as follows:

- **Fiber**: 13.0 – 15.0% of cane
- **Pol**: 13.5% of cane
- **Tonnes Cane/Tonnes Sugar**: 8.7
- **Molasses Production**: 4.5% of Cane

### 6.5 Manual versus mechanized harvesting

There are three primary methods of harvesting sugarcane: manual (no mechanization), semi-mechanized, and fully mechanized harvesting. Semi-mechanized harvesting generally means that the cane is cut manually, but loaded mechanically. In most countries today, either semi-mechanized or mechanized harvesting operations are used, with exceptions found in very poor countries and/or in very remote areas. In most of the poorer developing countries cane is still cut manually. In wealthier developing countries (such as Brazil), mechanized cane cutting has become much more common. Most African cane estates practice semi-mechanized harvesting, and this appears to be the most likely choice for Luena. However, it should also be noted that outgrowers or small farmers generally practice fully manual harvesting because they do not have access to loading equipment and are unlikely to harvest sufficient volumes to make investments in such equipment cost-effective.

Manually cut cane is burned first to clear out weeds, animals, and debris that would otherwise complicate the cutting. Sugarcane that is harvested fully mechanically can generally be cut green. The equipment used for cutting green cane mechanically differs from that designed for cutting burnt cane. Green cane harvesting results in a significant quantity of leftover biomass, sometimes referred to as cane trash. Where the biomass supply has market value for fuel or other uses, cane trash represents a significant resource. The total quantity of cane trash is roughly equal to the bagasse supply, so green cane harvesting effectively doubles the total size of the biomass resource. Harvesting cane green sometimes reduces cane yields slightly and presents other problems. Nevertheless, green cane harvesting is becoming standard practice in many countries because of its overall efficiency and its environmental benefits (Schembri and Carson, 1997).
7 Producing sugar, ethanol and electricity

Efforts to improve production efficiency and economic viability in the sugar industry have traditionally focused on maximizing sugarcane yield per hectare of agricultural land and sugar produced per tonne of sugarcane grown. Although some cane co-products (such as bagasse and molasses) are utilized in this process, priority is accorded to sugar production. The traditional focus on sugar has made the industry vulnerable to changing market prices and weather patterns and prone to financial instability. There have been few attempts by sugar companies to consider all sugarcane resources as a bundle of potential products and services whose value could be maximized together. Co-production strategies present attractive options as they offer flexibility in producing varied quantities of sugar, ethanol and electricity depending on prevailing market conditions.

Figure 14: Sugarcane resources

![Diagram of sugarcane resources]

Figure 14 provides a characterization of sugarcane resources, broken into three types of product streams: sugar/solids, molasses/juice, and crop residues. There are a variety of products that are feasible and marketable within each category. This study focuses on sugar, ethanol, and steam/electricity. The sugar/solids category includes various feedstocks and intermediate products in addition to sugar. Molasses and/or cane juice are valued for the fermentable sugars that can be converted into ethanol, as well as being used as industrial and agricultural inputs. Cane residues, namely bagasse and cane trash, are valued for their fiber content and organic residues as well as their use as fuel in cogeneration plants. The useful cycle of by-products and co-products continues after ethanol production, with stillage serving as input for production of fertilizers and methane gas.

The concept of co-production is based on biophysical, industrial and economic principles. The biophysical basis lies in the special properties of the sugarcane plant, which contains large quantities of biomass along with digestible and fermentable sugars. The industrial facilities that have been designed for co-production have a spatial advantage, because key co-products of one industrial process, such as bagasse, are available on-site for use as raw materials for the additional production processes. A business that wishes to stay competitive in today’s global economy must attain flexibility and diversity in adapting to changing markets. The ability to sell three major products such as sugar, ethanol, and electricity is therefore a major asset from an economic perspective. Consequently, a variety of co-products have emerged and found markets during the historical evolution of the cane-based sugar industry.

7.1 Sucrose utilization strategies

Four primary strategies for utilizing the sucrose resource have been explored in this study:

1. the traditional strategy of only producing sugar;
2. only producing ethanol;
3. producing sugar and ethanol in fixed proportions; and
4. producing sugar and ethanol in flexible proportions.

7.1.1 Sugar

The modern sugar industry has evolved into a rather complex agro-industrial activity, with three distinct phases: (1) the harvesting of the sugarcane plant; (2) the conversion of sugarcane into small crystals of raw sugar; and (3) the refining of raw sugar. Refined sugar can be brown or light brown, or it may be whitened from its naturally brown form through bleaching. Sugar refining is often spatially separated from the other two steps. Many purchasers in industrialized countries demand raw sugar for processing at their own refineries. It is also possible to make white refined sugar directly in a sugar factory through a bleaching process that

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3 From the perspective of sugar production, it is the sucrose that is the valued end product, whereas for ethanol production, all fermentable sugars are useful as feedstock. A decision to produce more sugar (sucrose) reduces the available fermentable sugars for ethanol production. We have adopted the terminology of “sucrose utilization” to simplify the discussion.
uses sulfur dioxide as bleaching agent. The resulting sugar is known as plantation white. Producing sugar from sugar beets, which grow in temperate climates, is an equivalent and competing source of raw sugar for input to refineries. The sugar beet, however, has neither the biomass content nor the solar conversion efficiency of the sugarcane plant.

Sugarcane stalks contain the cane juice from which sucrose is extracted. They are shipped to the sugar factory by truck or rail. The sucrose content in cut cane stalks rapidly decreases, so the time between harvest and processing at the factory must be minimized to maximize sugar yield. Therefore, most sugar factories are integrated with nearby cane fields. Most sugar factories are configured with mills to crush the cane as part of the many processes needed to extract the cane juice. Once the cane is crushed and separated, conveyor belts carry the bagasse to the boiler furnaces to provide process steam and electricity.

A typical sugar factory produces brown granulated sugar known as raw sugar, with a sucrose content (or purity) varying from 94 to 99%. Factories configured to produce a final product for sale to the end-user tend to operate towards the upper end of this purity range, while factories configured primarily for export to a refinery operate at the lower end. Sugar refining generally increases the purity to 99.5% or higher. From a health and environmental point of view, it is interesting to note that the purification or refining of sugar reduces its nutritive value and alters its natural taste. Naturally occurring minerals are removed in the process, chemicals are added in trace amounts, and there is additional expenditure of energy and resources in production. In developing countries such as Zambia, brown sugar is generally preferred if it is cheaper. Vitamins are sometimes added as dietary supplements at the factory to sugars intended for the domestic market.

Some sugar factories have adopted a system known as diffusion instead of using milling to extract the cane juice. Diffusion requires a series of successive “washings” with water and related processing in order to extract the juice. It generally requires less mechanical energy, but does require large quantities of water and steam. More importantly, it is not flexible in terms of upgrading. Whereas a mill can be upgraded to crush as much as twice the amount of cane per hour, a diffuser is fairly fixed in its processing capacity (Hunsigsi, 1993). Thus the opportunities for future expansion when a diffuser is adopted are limited. Milling is

still the preferred method around the world and has been assumed in this analysis.

### 7.1.2 Ethanol

Ethanol is produced through biochemical processes based on fermentation using cane juice or molasses as a feedstock (or a mixture of cane juice and molasses). After preparation of a mash with the appropriate concentration of sugars and solids, the sugars are transformed into alcohol using yeasts as the catalyst. Fermentation takes four to 12 hours. The chemical reaction liberates a significant amount of CO$_2$ and heat. The fermentation process can be conducted in batch or continuously, using open or closed fermentation tanks. Cooling is applied to maintain the resulting fermented wine mixture. Much of the CO$_2$ liberated can be captured and converted into marketable products, such as dry ice, liquid CO$_2$ for soft drinks, fire-fighting foams, filtration products, and various industrial uses.

After fermentation, the ethanol is distilled from other by-products, resulting in a level of purity of approximately 95%. This is often referred to as hydrous ethanol because it contains 5% water. This mixture of ethanol and water is azeotropic, so that the compounds cannot be separated by simple addition of heat, as is done in the distillation process. Hydrous ethanol can be commercially used, but cannot be blended with gasoline. An additional reactant, such as cyclohexane, is needed in order to dehydrate the ethanol, by forming a tertiary azeotropic mixture with water and alcohol. Anhydrous ethanol is nearly 100% pure and can therefore be blended with gasoline.

Several technological advances are important to consider in configuring an ethanol factory. The first is continuous fermentation (through increased yeast concentration), which has become a valued alternative to batch processing. Continuous processing increases the productivity of fermentation, *i.e.* the amount of ethanol fermented per liter volume per hour. High productivity reduces the volume capacity required for fermentation tanks, thereby reducing costs. In distilleries (as well as in sugar factories), low steam utilization technologies have been introduced through heat integration (Williams and Larson, 1993) using waste heat in heat exchangers, which is then re-used to increase the temperature and/or pressure of other processes. Such an approach uses less steam and leaves more steam for electricity generation, thereby improving the economics of production.

Assuming that there is no existing capacity for sugar and/or ethanol production (as is the case in
this study), a decision must be made whether to focus only on ethanol production or to engage in co-production of sugar and ethanol. Stand-alone production of ethanol is accomplished with an autonomous distillery that takes cane juice as the feedstock. The high capital cost of the sugar factory is thereby avoided.

7.1.3 Co-producing sugar and ethanol

The decision for or against co-production should be based on the relative economic value of sugar vs. ethanol, along with the size of the two product markets. Where ethanol is highly valued and a sufficiently high volume market appears likely, then an autonomous distillery would be favored. Where sugar is highly valued and the market for ethanol is somewhat uncertain, then co-production would be favored.

Co-producing sugar and ethanol is often accomplished by co-locating (annexing) the distillery with the sugar factory. Molasses or a mixture of cane juice and molasses is used as the primary feedstock. The value of molasses from a sugar factory is generally much greater as an ethanol feedstock on-site than the value of exporting the molasses to a separate distillery. A distillery without access to a sugar factory must obtain feedstock from another source, thereby incurring transportation costs and transaction costs. In addition, the ethanol distillery often supplies fertilizer for the cane fields. Thus co-location offers synergistic advantages to both industries. As a result, ownership of the sugar plant and ethanol distillery is often unified. The choice of unified ownership over other organizational forms has been found in a number of industries that exhibit such synergies. The economic rationale for doing so is that it minimizes transaction costs (Williamson, 1985). In this analysis, given the remoteness of the site and the lack of transportation infrastructure, we have assumed that co-location with unified ownership of the sugar factory and ethanol distillery is the only feasible option.

There are different economic strategies for co-producing sugar and ethanol. The main choice is whether to produce in fixed or flexible quantities. Fixed quantity production generally means reserving all of the economically extractable sugars for sugar production and using “C” molasses or “final” molasses for ethanol production. C molasses is not valuable for sugar production because sugar extraction has reached a point of diminishing returns. Such a strategy would be chosen when the market value of sugar is generally higher than that of ethanol in production-equivalent terms, and is expected to remain higher for the foreseeable future.

Alternatively, sugar extraction can be halted after the first or second stages, resulting in “A” or “B” molasses, respectively. These molasses streams will have fermentable sugars that can still be economically extracted. However, the presence of additional fermentable sugar increases the efficiency of ethanol conversion. Consequently, if ethanol is expected to have a market value close to or greater than that of sugar, then it makes economic sense to prioritize ethanol production over some sugar production, by using A or B molasses as the ethanol feedstock.

If market prices are fluctuating over time, a producer can benefit from having the flexibility to switch among these alternative balances of molasses use. The capital and operating costs of the additional processing stations for B and C molasses are not significant compared to the overall production costs. Consequently the decision as to whether to emphasize sugar or ethanol production can be made at the margin.

7.2 Bagasse utilization strategies

When cane is processed at a sugar factory, the cane stalks are shredded and crushed to extract the cane juice while the fibrous outer residue, known as bagasse, is sent to the boiler to provide steam and electricity for the factory. The fact that the sugarcane plant provides its own source of energy for sugar production in the form of bagasse has long been a special feature of the sugar industry. In the traditional approach, sugar factories and distilleries cogenerate just enough steam and electricity to meet their on-site needs. Boilers and steam generators are typically run inefficiently in order to dispose of as much of the bagasse produced from crushing the cane as possible. Some older factories purchase oil or electricity, because their steam generating technologies and boilers are extremely inefficient. Any factory designed and constructed today would be at least efficient enough to cover its own energy needs. With the availability of advanced cogeneration technologies, sugar factories today can harness the on-site bagasse resource to go beyond meeting their own energy requirements and produce surplus electricity for sale to the national grid or directly to other electricity users.

There are two main options for selling surplus electricity from a sugar factory. One is to sell to local off-grid customers, such as local industries or rural electricity cooperatives, thereby providing electricity services without the costs (both actual
and organizational) that accompany grid connections. Sugar factories, which are almost always located in rural areas in proximity to the cane fields, can be excellent resources for electrifying rural areas and small towns. This option has not been explored for Luena in this study due to the low levels of local demand and the need for a guaranteed market for an investment in a cogeneration plant to be viable. The second option is to sell surplus electricity to established utilities or distributors, contracting as an independent power producer and transporting the electricity over the national grid. This option has been assumed in the scenarios including surplus electricity production in this study.

Bagasse is already used to produce surplus electricity in sugar factories in several developing countries. For example, India (the world’s largest sugar producer) has initiated an aggressive program aimed at installing as much as 3,500MW of electricity-generating capacity at its sugar mills (Khuller, 1999). Mauritius is the African country that has come the furthest, with modern efficient Condensing Extraction Steam Turbines (CEST) at sugar mills producing a significant share of the island’s electricity (Beeharry, 1996). The potential exists in many other sugar factories in Africa and around the world. An analysis in Tanzania showed that a cogeneration plant using bagasse and cane trash could produce surplus electricity for six US¢ per kWh, a very competitive price (Gabra and Kjellström, 1995).

7.2.1 Electricity
In the traditional approach, sugar factories and distilleries use medium pressure (1.5-2.5 MPa) bagasse-fired boiler/steam turbine systems to cogenerate just enough steam and electricity to meet the on-site needs. More efficient steam turbines operating at higher pressures can significantly increase electricity production at sugar factories. A typical Condensing Extraction Steam Turbine (CEST) operates at 4.0 to 6.0 MPa. These systems produce enough steam to supply a typical sugar factory and distillery and export 30 to 100 kWh of electricity per tonne of cane (kWh/tc) to other users or to the national grid (Williams and Larson, 1993). CEST systems represent the state-of-the-art for bagasse cogeneration in terms of mature technologies that are fully commercialized in the marketplace.

Gasification of biomass for use in a high-efficiency gas turbine is a more advanced approach to bagasse cogeneration. This approach is based on the marriage of two technologies: a biomass gasifier unit with a gas turbine. There are a number of possible configurations, of which two have been extensively analyzed and undergone experimentation. The first is the Biomass Integrated Gasifier-Combined Cycle (BIG-CC) and the second is the Biomass Integrated Gasifier/Steam Injected Gas Turbine (BIG/STIG). A BIG-CC system adds a separate steam turbine bottoming cycle to an industrial gas turbine. The BIG/STIG employs steam not needed for process uses and injects it in order to boost the power output of the gas turbine. The economic value arises in that these systems increase electricity production, which is a higher-value export product, once factory steam needs are met.

BIG-CC and BIG/STIG systems would produce over twice as much power per tonne of cane as CEST systems. However, unlike CEST systems, BIG-CC and BIG/STIG systems are not commercially mature at present. In addition, they are expected to have significantly higher capital costs. Nevertheless, Combined Cycle systems using natural gas are widely available. Because combined-cycle gas turbines represent one of the most energy-efficient power generation choices on the market, and one of the most promising emerging technologies for utilizing biomass energy resources, we have included BIG-CC in this study. For each sucrose strategy, three different cogeneration systems have therefore been analyzed:

- Conventional Back-pressure Steam Turbines (reference);
- High Pressure Condensing Extraction Steam Turbine Systems (CEST); and
- Biomass Integrated Gasifier/Combined Cycle (BIG-CC).
8 Technological specifications

This section describes the full set of scenarios analyzed and the design specifications for production. First, the choice of scenarios using combinations of technical options for sugar, ethanol, and electricity production are described. Then the design specifications for expected product yields and energy requirements for the sucrose utilization strategies are provided. Next, additional co-products, with emphasis on stillage from ethanol production, are discussed. Finally, the detailed process energy requirements and accounting for the bagasse utilization strategies are listed.

8.1 The full set of scenarios

The number of combinations was increased in order to address some technical issues, resulting in a total of twenty-five distinct scenarios based on relevant and feasible combinations of the technological options. These are given in Table 19. The scenarios in the table are grouped by cogeneration option. Some additional minor distinctions required additional scenarios to be explored.

One such addition was made in order to allow a distinction between the choice of A and B molasses as feedstock for ethanol production, which affects

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</tr>
<tr>
<td>CEST4BF</td>
</tr>
<tr>
<td>CEST4AP</td>
</tr>
<tr>
<td>CEST4AF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BIOMASS INTEGRATED GASIFIER/COMBINED CYCLE (BIG-CC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
</tr>
<tr>
<td>BIG1A</td>
</tr>
<tr>
<td>BIG1G</td>
</tr>
<tr>
<td>BIG2A</td>
</tr>
<tr>
<td>BIG2G</td>
</tr>
<tr>
<td>BIG3A</td>
</tr>
<tr>
<td>BIG3G</td>
</tr>
<tr>
<td>BIG4BA</td>
</tr>
<tr>
<td>BIG4BG</td>
</tr>
<tr>
<td>BIG4AA</td>
</tr>
<tr>
<td>BIG4AG</td>
</tr>
</tbody>
</table>

Table 19: Scenarios, grouped by cogeneration option
the sugar and ethanol yields. This choice effectively represents the likely boundaries for flexible production strategies, since the key economic tradeoff between sugar and ethanol production would occur in this range. The scenarios added to reflect this distinction are designated by A or B in the scenario titles below. The lack of an A or B designation where ethanol is being produced means that the configuration is based on ethanol-only or fixed-quantity sucrose strategies, the latter case implying that C molasses is being used.

Another distinction arises with respect to mechanical power demand at the factory, which can be based on partial or full electrification. The scenarios designated by P or F in the scenario titles below reflect this distinction. Older factory designs have used exhaust steam turbines to run knives, shredders, and other equipment needed for processing. Redesigning the factory to be fully electrified and running these processes with electric motors can improve the overall efficiency of these plants. Full electrification would always be optimal where the sugar factory is well integrated into the national electricity grid and the option to buy and sell from/to the grid is relevant. In the conventional case where back-pressure steam turbines are used, full electrification need not be considered since the advantages would be insignificant and not exploitable, because there is no surplus electricity. The option of full factory electrification is quite relevant where advanced cogeneration technologies like CEST are employed. Consequently, the CEST configurations were split into two cases. In the case of BIG-CC, only full electrification should be considered because of the high efficiency of electricity production.

A final distinction was based on two possible techniques for the biomass gasifier unit: atmospheric pressure or pressurized gasification. The pressurized unit would be more efficient but it is not fully commercially tested and would also come at a higher capital cost. It should also be noted that the integration of a BIG-CC unit of either type would require some redesign in the factory for steam extraction. The cost of such design changes is very small in comparison to the high cost of the BIG-CC unit itself, and thus has not been included in capital cost estimates.

The scenario designations in Table 19 indicate: the cogeneration option; the sucrose strategy (1-4); the molasses used for ethanol production (for the flexible production scenarios); whether partial or full electrification is adopted (for the CEST option scenarios); and whether atmospheric pressure or pressurized gasification is adopted (for the BIG-CC scenarios).

### 8.2 Product yields
Sugar and alcohol yields for the main product strategies are given in Table 20. Sugar yields depend on both agronomic and industrial factors, while ethanol yields depend mainly on the fermentable sugar content of the feedstock used. Where cane juice is used in the Ethanol Only sucrose strategy, essentially all of the potential fermentable sugars are being utilized, and the maximum ethanol yield is 75.8 liters per tonne of cane (tc). The remaining strategies differ in yield as a result of stopping at the first, second, or third strike in sugar production, the outputs of which are A, B, or C molasses, respectively. The Sugar plus Ethanol strategy is equivalent to the fixed production strategy eluded to earlier. A producer would pursue such a strategy when sugar is the higher-valued product, and the remaining sugars in the final or C molasses cannot be economically extracted. A producer would pursue flexible production strategies when the relative market values of sugar and ethanol are fluctuating and/or deemed uncertain.

![Table 20: Sugar and alcohol yields by sucrose strategy](image-url)

*Note that the feedstock here is cane juice rather than molasses.

### 8.3 Energy requirements and outputs
Steam and electricity production are shown by sucrose strategy in Table 21. The main differences arise from the steam and electricity requirements of cane preparation and sugar production, since ethanol production requires very little external energy input due to the exothermic (heat-producing) nature of the fermentation process. Therefore, the Sugar Only strategy has the highest energy requirements: 460 kg steam and 15 kWh of electricity per tonne of cane (tc) processed. Sugar plus Ethanol and Flexible Production strategies have lower electricity needs because ethanol production itself contributes positively to the overall energy balance. The energy requirements for the Ethanol Only strategy are attributed to extracting cane juice from the cane stalks.
The energy characteristics of the factory are summarized in Table 22, Table 23 and Table 24 for the three basic cogeneration options (bagasse strategies) under the sugar plus ethanol sucrose strategy scenarios (fixed quantities of sugar and ethanol from C molasses). For the Reference (low-pressure) and CEST cases, the analysis was conducted for two alternative mill sizes (250 or 300 tonnes/hour), the choice of which would depend on the length of the harvest season and related parameters.

The most significant parameter for comparison across the three cases is the surplus power available. In the conventional case, less than one MW of surplus capacity is available and this would not be sufficient to justify export sales. In the case of CEST, the surplus is 31 to 34 MW, while with BIG-CC it is 60 to 76 MW. This means that with BIG-CC, electricity generation will be nearly two orders of magnitude higher than in the conventional case. There would even be a surplus of bagasse during the harvest season, which might be sold if there were other market options.

![Table 21: Steam and electricity consumption by sucrose strategy](image)

<table>
<thead>
<tr>
<th>Mill Size</th>
<th>300 Tonnes of Sugarcane per Hour</th>
<th>250 Tonnes of Sugarcane per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam demand (kg/tc)</td>
<td>460</td>
<td>460</td>
</tr>
<tr>
<td>Steam demand (t/h)</td>
<td>138</td>
<td>115</td>
</tr>
<tr>
<td>Steam raised (t/h)</td>
<td>141</td>
<td>118</td>
</tr>
<tr>
<td>Boilers capacity (t/h)</td>
<td>150</td>
<td>120</td>
</tr>
<tr>
<td>Mechanical power demand (kW/tc)</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Mechanical power (kW)</td>
<td>4,500</td>
<td>3,750</td>
</tr>
<tr>
<td>Electricity demand (kW/tc)</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Power requirement (kW)</td>
<td>3,750</td>
<td>3,125</td>
</tr>
<tr>
<td>Power capacity (kW)</td>
<td>4,708</td>
<td>3,708</td>
</tr>
<tr>
<td>Surplus of power (kW)</td>
<td>958</td>
<td>583</td>
</tr>
<tr>
<td>Annual bagasse consumption (t/year)</td>
<td>227,023</td>
<td>195,972</td>
</tr>
<tr>
<td>Bagasse availability (t/year)*</td>
<td>299,520</td>
<td>249,600</td>
</tr>
<tr>
<td>Surplus of bagasse (t/year)</td>
<td>72,497</td>
<td>53,628</td>
</tr>
</tbody>
</table>

*13% fiber content, 50% moisture, no losses

![Table 22: Energy characteristics with Low-Pressure Steam Turbine (REF3)](image)

<table>
<thead>
<tr>
<th>Mill Size</th>
<th>300 Tonnes of Sugarcane per Hour</th>
<th>250 Tonnes of Sugarcane per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam demand (kg/tc)</td>
<td>350</td>
<td>0</td>
</tr>
<tr>
<td>Steam demand (t/h)</td>
<td>105</td>
<td>0</td>
</tr>
<tr>
<td>Steam raised (t/h)</td>
<td>220</td>
<td>110</td>
</tr>
<tr>
<td>Boilers capacity (t/h)</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>Mechanical power demand (kW/tc)</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Mechanical power (kW)</td>
<td>4,500</td>
<td>0</td>
</tr>
<tr>
<td>Electricity demand (kW/tc)</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Power requirement (kW)</td>
<td>3,750</td>
<td>0</td>
</tr>
<tr>
<td>Power capacity (kW)</td>
<td>40,055</td>
<td>23,016</td>
</tr>
<tr>
<td>Surplus of power (kW)</td>
<td>31,805</td>
<td>23,016</td>
</tr>
<tr>
<td>Annual bagasse consumption (t/year)</td>
<td>299,520</td>
<td>249,600</td>
</tr>
<tr>
<td>Bagasse availability (t/year)*</td>
<td>299,520</td>
<td>249,600</td>
</tr>
<tr>
<td>Surplus of bagasse (t/year)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trash Availability (t/year)</td>
<td>225,000</td>
<td>—</td>
</tr>
<tr>
<td>Hours of Operation off-season</td>
<td>3,237</td>
<td>2,198</td>
</tr>
</tbody>
</table>

*13% fiber content, 50% moisture, no losses

![Table 23: Energy characteristics with Condensing Extraction Steam Turbine (CEST3P)](image)
8.4 Installed Capacity

The installed capacities assumed for sugar, ethanol, and electricity production are given in Table 25. The choice of capacity was based on the design product output specifications and the discrete sizes of available units. In the case of ethanol production, there will be considerable excess capacity, particularly for the annexed distillery. However, the capital cost of the distillery is small in relation to overall costs, so the over-sizing effect is unlikely to have much impact. Only the estimated installed capacity for surplus electric power is listed here, since that is the relevant figure for sales. On-site power demand varies from four to eight MW, depending on whether the factory is partially or fully electrified. The actual sugar, ethanol, and electricity production volumes in a given year will depend on the production strategy. These volumes are given in the analysis provided in chapter 12.

---

**Table 24: Energy characteristics with Biomass Integrated Gasifier/Combined Cycle (BIG3A)**

<table>
<thead>
<tr>
<th>Mill Size - 300 Tonnes of Sugarcane per Hour</th>
<th>Harvest</th>
<th>Off-season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam demand (kg/tc)</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>Steam demand (t/h)</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>Steam available to process (t/h/unit)</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Number of units to match steam demand</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total BIG net power</td>
<td>22,410</td>
<td>25,250</td>
</tr>
<tr>
<td>Mechanical power demand (kWh/tc)</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Mechanical power (kW)</td>
<td>4,500</td>
<td>0</td>
</tr>
<tr>
<td>Electricity requirements (kWh/tc)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Power requirements (kW)</td>
<td>3,750</td>
<td>0</td>
</tr>
<tr>
<td>Power capacity (kW)</td>
<td>58,980</td>
<td>75,750</td>
</tr>
<tr>
<td>Harvest bagasse consumption (t)</td>
<td>232,934</td>
<td></td>
</tr>
<tr>
<td>Bagasse availability (t/year)*</td>
<td>299,520</td>
<td></td>
</tr>
<tr>
<td>Trash Availability (t/year)</td>
<td>66,586</td>
<td></td>
</tr>
<tr>
<td>Hours of Operation off-harvest</td>
<td></td>
<td>225,000</td>
</tr>
</tbody>
</table>

*13% fiber content, 50% moisture, no losses

---

8.5 By-product and co-product streams

Sugarcane, sugar, and ethanol production result in a wide variety of by-products and co-products, due to the significant quantities of biomass, the fiber content of the cane plant, and the rich array of organic materials that enter into the production stream. These many by-products and co-products have not been assessed in this study, due to resource limitations and the fact that they represent much smaller product streams in commercial terms than sugar, ethanol, and electricity. However, some of these by-products naturally find internal uses within the cane industry or external commercial markets. Therefore, two of the most significant ones deserve mention here: filter cake and vinasse (stillage).

Filter cake is a thick mud-like substance that includes a mixture of minerals and organic components that result from factory cane processing and extracting the fermentable sugars. Some of the many uses of filter cake are as a fertilizer or lubricant, as an industrial input in the production of waxes, as a fuel, or as an input to cattle feed production. In volume or material balance terms, filter cake is about 3 to 4% of the cane that enters the factory.

Vinasse or stillage results from the distillation process in ethanol production. It is a highly organic wastewater stream that is approximately ten to 15 times the volume of ethanol produced. The sheer volume of this waste product and its organic content make it both a potential environmental hazard and a business opportunity. Stillage poses the main difference between ethanol and non-ethanol strategies in terms of potential environmental impacts. Improper handling can result in harmful soil runoff and/or organic pollution of water supplies. There are two main opportunities for using stillage productively. One is as a fertilizer for the cane fields. As a major source of potassium...
and other nutrients, it can substitute for fertilizers that would otherwise have to be purchased. The second is as an energy input. Stillage can be processed in an anaerobic digester to produce methane, which can then be used directly or for electricity production. This latter option has not been analyzed in this study. Instead, it is assumed that the stillage would be used as fertilizer.
9 Human resource requirements

The human resource requirements do not vary significantly across the four basic strategies analyzed. Estimates for the number of employees required for running the estate, factory and ethanol plant have been categorized into agricultural and industrial (including electricity generation) and management components. The general estate personnel (to provide financial, purchasing and supply and personnel services) are included in the industrial category. The human resource requirement estimates for running the estate and plant are summarized in Table 26. Executive positions include the leadership positions directly supporting the Managing Director as well as some of the supervisory positions in the agricultural and industrial categories. The remaining supervisory positions are classified as skilled labor. The labor requirements for each component are described in more detail below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Executive</th>
<th>Skilled</th>
<th>Unskilled</th>
<th>Seasonal Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>5</td>
<td>159</td>
<td>1,000</td>
<td>2,500</td>
</tr>
<tr>
<td>Industrial</td>
<td>9</td>
<td>245</td>
<td>60</td>
<td>314</td>
</tr>
<tr>
<td>Managerial</td>
<td>5</td>
<td>31</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>435</td>
<td>1,060</td>
<td>2,500</td>
</tr>
</tbody>
</table>

Table 26: Total human resource requirement

9.1 Agricultural

Human resource requirements for growing the sugarcane have been determined for several categories of operations. These requirements are given in Table 27. Out of a total of 3,664 employees, the 2,500 categorized under manual harvesting are cane cutters and are seasonal workers. The cane cutters would be required during the harvest season, which is 160 days per year.

<table>
<thead>
<tr>
<th>Position</th>
<th>No. Per Shift</th>
<th>No. of Shifts</th>
<th>Total Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Harvesting</td>
<td>1,250</td>
<td>2</td>
<td>2,500</td>
</tr>
<tr>
<td>Cane Loading</td>
<td>15</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>Transportation/</td>
<td>25</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>Cultivation</td>
<td>500</td>
<td>2</td>
<td>1,000</td>
</tr>
<tr>
<td>General Purpose</td>
<td>40</td>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>Supervisor</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Manager</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Agriculture Specialists</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>3,664</td>
</tr>
</tbody>
</table>

Table 27: Agricultural personnel requirements

9.2 Industrial

There are only minor differences in the number of employees required at the factory for each of the scenarios. Estimates of the industrial personnel requirements by employment category are given in Table 28. These persons would be employed year round. The estimates assume a sugar factory, including electricity generation and annexed distillery, with a crushing capacity of 300 tonnes of cane per hour. The estimates in each employment category are based on factory requirements as specified by equipment manufacturers and the experience of other sugar estates in the region, namely: Nakambala (Zambia), Triangle (Zimbabwe) and Dwangwa (Malawi).

<table>
<thead>
<tr>
<th>Position</th>
<th>No. Per Shift</th>
<th>No. of Shifts</th>
<th>Total Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators</td>
<td>50</td>
<td>3</td>
<td>150</td>
</tr>
<tr>
<td>General Workers</td>
<td>20</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>Engineers</td>
<td>20</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Analysts</td>
<td>18</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Sugarcane Wet Controls</td>
<td>10</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Laboratory Sugarcane Controllers</td>
<td>12</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Maintenance</td>
<td>35</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>Supervisors</td>
<td>8</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Manager</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>314</td>
</tr>
</tbody>
</table>

Table 28: Industrial personnel requirements

9.3 Managerial

A Managing Director superintending over agriculture, industrial, financial and personnel functions would head the company. The managerial human resource requirements are given in Table 29.

<table>
<thead>
<tr>
<th>Position</th>
<th>Number</th>
<th>Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing Director</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Financial Manager</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Human Resource</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lawyer</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Public Relations Personnel</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Accounting</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Finance Officer</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Purchasing and Supply</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Stores</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Secretaries</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Social Scientists</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Personnel</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Drivers</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Table 29: Managerial personnel requirements
9.4 Ethanol plant

The above estimates include the personnel requirements for an annexed ethanol distillery. Because the additional personnel requirements for the distillery are quite low, these have not been demarcated here. In general, an ethanol plant requires very few personnel. Unlike the sugar factory, there are not a wide variety of moving parts and production processes that require monitoring and evaluation. A typical shift might have only five employees monitoring the plant operations. Personnel responsible for cane and sugar processing can carry out many of the functions. Consequently, it is not necessary to distinguish between the industrial human resource requirements of the ethanol and non-ethanol scenarios.
10 Investment costs

In the sections below, the existing infrastructure is described and cost estimates are provided for four categories of required investment. Because of the remoteness of the Luena project site, considerable infrastructure investments would be needed in addition to the infrastructure and equipment needed for the estate and factory. The investment costs for public infrastructure are discussed separately from the estate and factory investments, since these would be needed for any industrial development and would likely be funded through the public sector. The public infrastructure investments would not differ across the scenarios. The private sector investment costs have been divided into three categories: estate development, agricultural development, and industrial development. The industrial development costs differ across the scenarios.

10.1 Existing infrastructure

There is no modern infrastructure in the vicinity of the project site. The only access is a dirt road that is in poor condition; in fact, in the rainy season it is unusable. The nearest asphalt road and power line are at the Kawambwa Tea Company, approximately 40 km from the project area (see Figure 4). The nearest rail connection is in Kasama, approximately 250 km through Luwingu on a laterite road. A 132 kV power line runs from Mansa through Kawambwa Tea Estate to Kasama. The nearest point for telecommunications is Kawambwa, which is connected to the rest of the country through a microwave telephone link (see Figure 2). The status of the important road links to Luena for supply lines and trade routes in the region is summarized below.

• The Ndola - Mansa Road through the Pedicle (Democratic Republic of Congo) covers a distance of approximately 200 km, passing over the Luapula River. The river crossing relies on an aged pontoon with a capacity of 30 tonnes. The road is tarred from Mansa to Chembe at the Luapula River. The rest is gravel all the way through to the Congo.
• Serenje - Samfya - Mansa asphalt road passing through the Bangweulu swamps is in good condition.
• Kawambwa is connected to Mansa through Mbereshi (Nchelenge road), an approximate distance of 200 km on a good asphalt road and a shorter distance of 80 km straight from Mansa on a gravel road in very poor condition.
• Mansa - Nchelenge road continues until it reaches Nchelenge on the lake bordering with the Congo.
• The Kawambwa Tea Company is approximately 40 km from the project site on a dirt road that is in very poor condition.

10.2 Public infrastructure

The public infrastructure needed to support the cane estate and factory does not differ from what might be needed for other industrial undertakings in the region. The four main categories are roads, electricity, telecommunications, and public service facilities. The infrastructure investments needed are described below, with cost estimates based on information from Zambian Ministry of Works and Supply and ZESCO.

10.2.1 Roads

A reliable road system is required in order to insure the smooth functioning of industrial operations, timely delivery of raw materials to the site, establishing profitable trading routes in the region, and moving people to and from the site.

• The first 23 km from Kawambwa of the Kawambwa - Mushota Road D74 (65 km to the factory site) is bituminous standard. The remaining 20 km would require upgrading (tarring) to bituminous I level, at a cost of 8.4 million USD.
• The Mushota - Kayese Road D74 (53 km from factory site) requires upgrading to class II gravel standard to facilitate movement of sugar products from the estate to the nearest railway station in Kasama for transportation to local and regional markets, particularly Northern Tanzania. The estimated cost of upgrading to class II gravel standard is 1.59 million USD.
• The Kayese - Kasama Road (160 km), which links to Kasama, requires upgrading to class II gravel road. The estimated cost of upgrading to class II gravel standards is 4.8 million USD.
• The Kawambwa - Mansa Road (80 km) requires upgrading to class II gravel standard to shorten the distance to Mansa (instead of
passing through the valley road, a distance of approximately 200 km). The estimated cost of upgrading to class II gravel standard is 2.4 million USD.

- The Mansa - Mufulira (190 km) road is the shortest connection to markets in the Copperbelt and Congo Democratic Republic. The first 90km to Luapula River at Chembe is of reasonable bituminous standard. Crossing the Luapula River requires the construction of two new 60 tonne capacity pontoons, at a cost of 2.5 million USD. The remaining 20 km to Mufulira is of reasonable bituminous standard. The total cost of this segment would be 4.9 million USD.

<table>
<thead>
<tr>
<th>Stretch of Road</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kawambwa - Mushota Road</td>
<td>8,400,000</td>
</tr>
<tr>
<td>Mushota - Kayense Road</td>
<td>1,590,000</td>
</tr>
<tr>
<td>Kayense - Kasama Road</td>
<td>4,800,000</td>
</tr>
<tr>
<td>Kawambwa - Mansa Road</td>
<td>2,400,000</td>
</tr>
<tr>
<td>Mansa - Mufulira including two new pontoons</td>
<td>4,900,000</td>
</tr>
<tr>
<td>Design Cost</td>
<td>1,700,000</td>
</tr>
<tr>
<td>Total</td>
<td>23,790,000</td>
</tr>
</tbody>
</table>

Table 30: Road infrastructure cost estimates

10.2.2 Electricity
The Kawambwa-Mporokoso 132kV power line provides the closest connection to the national grid, through Kasama. This line can be used to supply electricity to the project site and surrounding areas and to export surplus electricity. Teeing off from the Kawambwa-Mporokoso line (based on a 10MW demand estimate and an export potential of 30MW) would require constructing a 132kV overhead line from the tee off to the factory site substation. This power line would later be used for transmitting power from the plant to the grid, in the scenarios where electricity production exceeds Estate demand. There are four options for the power line route:

- The 1992 Evaluation report (Booker Tate Ltd., 1992) recommends a power line from Kawambwa Tea Estate (KTE) via Mushota. The route would be 36 km long. 30% of the distance would be over marshland.
- A direct route from KTE to Luena factory with a total distance of 25 km.
- A route from KTE via Chitondo, with a total distance of 29 km.

- A route from Fumba, about 11 km east of Kawambwa, via Chitondo with a total distance of 20 km.

ZESCO, Zambia’s national electric utility, would be responsible for the construction of transmission lines. Distribution would require constructing a 2 x 20 MVA, 132/33 kV, substation at the factory site and installing metering equipment. The cost of the power lines, substation and metering equipment, assuming the route via Mushota, has been estimated by ZESCO as 2.971 million USD.

10.2.3 Telecommunications
Various solutions for telecommunications are possible in Luena. One such solution is to connect through the Kawambwa, Mansa and Lusaka exchanges. The other is to use a direct satellite between Luena and Lusaka. Of the two possibilities, the latter is recommended because it is more efficient. The estimated cost for surveying, design, construction and installation of the necessary telecommunications equipment is 500,000 USD (Kumar, 1999).

10.2.4 Public service facilities
A modern industrial facility with skilled and trained workers requires public services to maintain the health, safety and welfare of the workers and their families. Cost estimates for public service facilities, including the cost of design/planning, are given in Table 31 (GRZ, 1997).

<table>
<thead>
<tr>
<th>Facility</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical center with staff accommodation</td>
<td>736,000</td>
</tr>
<tr>
<td>Primary school with staff accommodation</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Police post with staff accommodation</td>
<td>355,000</td>
</tr>
<tr>
<td>Design</td>
<td>230,000</td>
</tr>
<tr>
<td>Total</td>
<td>2,521,000</td>
</tr>
</tbody>
</table>

Table 31: Public service facility costs

10.2.5 Summary of public infrastructure costs
A summary of the public infrastructure costs is given in Table 32. Roads constitute the largest category of investment requirements for public infrastructure by far, accounting for 80% of the total cost.

<table>
<thead>
<tr>
<th>Cost category</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads</td>
<td>23,790,000</td>
</tr>
<tr>
<td>Electricity</td>
<td>2,971,000</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>500,000</td>
</tr>
<tr>
<td>Public service facilities</td>
<td>2,521,000</td>
</tr>
<tr>
<td>Total</td>
<td>29,782,000</td>
</tr>
</tbody>
</table>

Table 32: Summary of public infrastructure costs
10.2.6 Government financing of infrastructural development

Infrastructure development is one of the key issues for the implementation of the Luena Project. The total estimated cost of road, electricity, telecommunication and social amenities is nearly 30 million USD. It is commonly assumed that responsibility for providing all public infrastructure lies with the GRZ. However, in the absence of sufficient capital from the public sector, the investor could provide some of these funds. The development of infrastructure by investors would require a clear government policy and good investment incentive package for undertaking the project. One possibility would be to establish a Build, Own, Operate and Transfer (BOOT) scheme similar to that which has recently been undertaken for developing a railway linking Zambia, Malawi and Mozambique. This approach could be applied to a Luena Project.

Commitment to at least partial public-sector support for infrastructure development is desirable, for the following reasons:

- To indicate the government’s commitment to the project to potential investors.
- Public infrastructure investments will encourage development in the area by providing a more attractive environment for businesses considering moving to or investing in the area.

In discussions with stakeholders, the general consensus is that in order to attract investment in the area, the GRZ should consider improving the rural road, and extending power from Kawamba to Luena using the Rural Electrification fund. Through the Ministry of Works and Supply, GRZ has already indicated commitment to improving the following roads: Mansa-Luwingu, Kayese-Kamasa, Mushota-Kaseye, and Mansa-Chembe. In addition to improving the above-mentioned roads, the GRZ intends to build schools, clinics and a police station in Luena. Budget estimates for these projects will be included in future national budgets.

The Zambia Telecommunication Company (ZAMTEL) and the Zambia Electricity Supply Company (ZESCO) are prepared to extend telecommunication and electricity services, respectively, to the area. ZAMTEL is prepared to assist in the design, installation and maintenance of a telecommunication system in Luena that will provide a direct link via satellite to their hub in Lusaka. However, ZAMTEL expects the customer/investor to pay the cost of purchasing the equipment, installation and maintenance, estimated at 90,000 USD. ZESCO is prepared to extend its transmission line from Kawomba to the project area to provide 132kV electricity. Again, although ZESCO will perform the installation and maintenance, the investor is expected to pay for the extension of the transmission line. The estimated cost for their service to the project is estimated to be K200 million or about 80,000 USD. GRZ could also contribute to such an extension of this line — as it has done in other projects such as the electrification of the Mkushi Farm Block in Central Province — through the Rural Electrification Fund (REF) program.

10.3 Estate development

The operation of the estate and factory will require facilities for workers and their families as well as internal infrastructure to support movement of goods and people. Again in view of the remoteness of the area and the need to retain management and skilled/semi-skilled manpower, the project will need to provide housing, shopping and recreation facilities. The total estimated investment required for Estate development is about 62 million USD, of which 45.5 million USD is for housing and 16.5 million USD is for the Estate road network, commercial (mainly shopping) facilities, and social amenities. These costs are included in the total private investment cost for the project.

The Estate is expected to provide work for 1,500 permanent employees and 2,500 seasonal agricultural workers. Some of these employees are expected to come from the local villages. Four grades of housing would need to be constructed for those who would live on the Estate. Seasonal workers would typically live in dormitory-style housing. Table 33 shows the investment cost for housing construction.

<table>
<thead>
<tr>
<th>Type of Housing</th>
<th>No. of Units</th>
<th>Unit Cost USD</th>
<th>Total Cost USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Bedroom - 182 m²</td>
<td>50</td>
<td>57,111</td>
<td>2,855,550</td>
</tr>
<tr>
<td>Grade II:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 bedroom - 123 m²</td>
<td>200</td>
<td>38,597</td>
<td>7,719,400</td>
</tr>
<tr>
<td>Grade III:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Bedroom - 85m²</td>
<td>1,200</td>
<td>26,673</td>
<td>32,007,600</td>
</tr>
<tr>
<td>Dormitory: 306m²</td>
<td>30</td>
<td>95,709</td>
<td>2,871,270</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>45,453,820</td>
</tr>
</tbody>
</table>

Table 33: Investment costs for housing construction
### 10.4 Agricultural development

Establishing a large cane estate will require the preparation of 12,000 hectares of land earmarked for the project site. There are three main investment categories for agricultural development: land clearing, irrigation and drainage infrastructure, and agricultural equipment. Descriptions of and investment cost assumptions for each of these categories are provided below.

#### 10.4.1 Land clearing

The cost estimate for land clearing is based on the following assumptions concerning the trees, soil, and topography of the project site:

- Density: 900 trees/hectare (270 trees, 31 to 60 cm diameter; 630 trees, 1 to 29 cm);
- All are hard woods;
- Trees do not require splitting or other individual treatment;
- Flat topography; and
- Soil is damp but not wet and there are no rocks.

Two alternatives for acquiring the equipment necessary for land clearing were considered: 1) purchasing equipment to be used for land clearing, thereafter using the same equipment for other operations such as land preparation, road repairs and dam construction; and 2) renting/leasing equipment for land clearing purposes only. The option of purchasing equipment was assumed for the final cost estimates as it was found to be more cost-effective.

The investment cost estimates for land clearing are given in Table 35. Clearing 12,000 hectares within three years would require a combination of four types of CAT equipment: D6R, D7R, D8R and D9R with a combined clearing rate of 3,880 hectares per annum. Ten operational experts would be required: four operators, one supervisor, four handmen and one storeman. Because land clearing is a one time rather than a recurrent event, the operation and maintenance costs associated with this activity are treated as an investment cost.

#### Table 35: Investment costs for land clearing

<table>
<thead>
<tr>
<th>Item</th>
<th>CAT Equipment Purchase Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Investment</td>
<td>1,550,000</td>
</tr>
<tr>
<td>Operation and Maintenance (O&amp;M)</td>
<td>3,650,000</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>5,200,510</td>
</tr>
<tr>
<td>+ 10% for Special Attachments &amp; 2 Chip Spreaders</td>
<td>520,051</td>
</tr>
<tr>
<td>Total</td>
<td>5,720,561</td>
</tr>
</tbody>
</table>

Note: Operation and maintenance costs based on combined fuel rate of 183 liters per hectare per day at 0.45 USD per liter; maintenance cost of 1,150 USD per day; and operational cost of 820 USD per day.

#### 10.4.2 Irrigation and drainage infrastructure

To meet the irrigation needs of the Luena block, it is necessary to erect a low height dam on the Pambashye River. The dam would have a volume of 100 million m$^3$. Part of the equipment purchased for land development would also be used for constructing the irrigation and drainage infrastructure.

A main pumping station would convey water to storage tanks situated at different points. Water would be conveyed to the cultivation area through cement-lined canals and water separated through furrows. Irrigation and drainage infrastructure in both the Luena and Lufubu blocks would consist of concrete-lined primary, secondary, tertiary-earth canals, main and secondary drainage canals, low

<table>
<thead>
<tr>
<th>Irrigation component</th>
<th>Extent/capacity</th>
<th>Cost (million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete-lined Primary Canals</td>
<td>12.0 km</td>
<td>1.70</td>
</tr>
<tr>
<td>Secondary Concrete Lined Canals</td>
<td>10.0 km</td>
<td>0.88</td>
</tr>
<tr>
<td>Tertiary Earth Canals</td>
<td>100 km</td>
<td>1.10</td>
</tr>
<tr>
<td>Main &amp; Secondary Drainage Canals</td>
<td>200 km</td>
<td>1.77</td>
</tr>
<tr>
<td>Low-Height dam &amp; Piping System</td>
<td>99.4 x 10$^6$ m$^3$</td>
<td>0.11</td>
</tr>
<tr>
<td>Storage Dam</td>
<td>10 Reinforced Concrete Storage Reservoirs (5m x 30m x 0.1 m)</td>
<td>0.01</td>
</tr>
<tr>
<td>Pumping Station</td>
<td>4 Units</td>
<td>0.13</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5.70</td>
</tr>
</tbody>
</table>

Table 36: Investment costs for irrigation and drainage infrastructure
height storage dams, and pumping stations. Investment costs for a topographic survey and drafting, excavation and canal lining are included in the estimates of the investment costs for irrigation and drainage infrastructure given in Table 36.

10.4.3 Agricultural equipment
A variety of equipment is needed for tillage and planting, cane harvesting, cane transportation, and service equipment. Cultivating (sub-soiling and moldboard plowing) 10,000 hectares within two months would require 15 tractors (taking account of repair and maintenance time). The capacity of the assumed crawler tractors is 90 Hp 4WD.

Manual harvesting is assumed, with grab loaders used for cane loading. The CAT equipment can be used for mechanical loading, but will require a special attachment (grab). Assuming that 6,250 tonnes of cane would be processed at a rate of 441 tonnes per day per grab loader, 14 grab loaders would be required.

Body trucks would be required to transport cane from the fields to the factory. Three-body, two-body and single-body trucks would be used to accommodate long, medium and short transportation distances at lower costs. The percentages of the total fleet assigned to each category of truck are 50, 30 and 20% respectively. Longer units would handle additional cane located further from the mill. For 160 days of effective work, crushing 6,250 tonnes of cane per day, a total of 22 trucks would be required (4 one-body, 7 two-body, and 11 three-body).

A total of 22 tractors would be needed for tillage and planting, comprised of the 15 tractors used for cultivation plus seven additional tractors. The tractors would also be used for mechanical weeding control. CAT equipment would be used for road and land servicing. Investment costs for agricultural equipment are given in Table 37.

10.5 Industrial development investment costs
Industrial development investments include the costs of all equipment and machinery needed for the sugar factory, cogeneration plant, and/or ethanol distillery. Table 38 lists the estimated investment costs for each sugar/ethanol strategy and each possible cogeneration option with which it could be paired. These costs have been estimated as CIF Lusaka and do not include excise duty or value added tax (VAT). It should be noted that under the Zambian Investment Act, excise duty and VAT would most likely be waived because the project deals with agricultural development and is situated in a rural area. The operating characteristics and production capacity for the scenarios are described further below.

The reference case for cogeneration consists of back-pressure turbines with sufficient generating capacity to cover the factory needs. The CEST and BIG-CC options were analyzed for two different design choices. The cost differences arise from the sucrose strategies only; there is no difference in cogeneration plant investment cost across two different choices of sucrose strategy.

The Sugar only investment includes one sugar factory with cane preparation (reception, juice extraction, juice treatment, steam and electricity...
production) and a milling capacity of 300 tonnes/hour. A machine shop, laboratories, and cane trash processing equipment are also included.

The Ethanol only investment includes an autonomous distillery with juice preparation (reception, extraction, juice treatment, steam and electricity production) and a capacity of 180,000 liters of ethanol per day. A machine shop, laboratories, pre-fermentation and fermentation sectors, distillation, and ethanol storage tanks are also included.

Sugar and Ethanol in fixed quantities includes juice preparation (reception, extraction, juice treatment, steam and electricity production); a sugar factory with milling capacity of 300 tonnes/hour; and one anhydrous distillery with capacity of 90,000 liters of ethanol/day including pre-fermentation and fermentation sectors, distillation and ethanol storage tanks.

Sugar and Ethanol with flexible production includes one sugar factory (reception, cane preparation, extraction, juice treatment, steam and electricity production), a maintenance workshop, laboratories and one anhydrous distillery of 180,000 liters of ethanol/day capacity including pre-fermentation and fermentation sectors, distillation and ethanol storage tanks). In this setup, ethanol can be produced either from ‘A’ molasses or ‘B’ molasses. The final molasses station (‘C’ molasses) is not needed, hence there are some small investment cost savings.
11 Operation and maintenance costs

The costs of running the cane estate, sugar factory and/or ethanol plant include operation and maintenance (O&M) costs. Some of these costs are the same across all strategies. In particular, the costs of producing cane and running the estate are essentially the same on a per unit basis. Labor costs differ very little across the strategies because most of the labor costs are incurred in the agricultural operations. The factory and plant O&M costs, however, differ by sucrose and bagasse utilization strategy. Therefore, agricultural and industrial O&M costs are addressed separately in the discussion below.

11.1 Agricultural O&M costs

There are three main categories of agricultural O&M costs: equipment costs, the cost of applying fertilizers, and harvesting (including labor) costs. The annual operation and maintenance costs for agriculture equipment are given in Table 39. In view of the nature of the soils in Luena, lime, urea and single super phosphate (SSP) or triple super phosphate (TSP) fertilization, in the proportions and with the costs listed in Table 40, would be required.

Manual harvesting of burned cane is assumed. It is the most widely used harvesting method for sugarcane in Zambia and the region and provides the highest levels of agricultural employment. The number of workers required is based on a work rate of five tonnes per day. The number of cane cutters equates to 6,250/5 which equals 1,250.

Once the cane is cut, it is loaded by grab loaders, which typically require two persons per grab loader to operate. The average annual harvesting cost in this study, including labor and O&M, was estimated at approximately 4.5 USD/tonne cane.

<table>
<thead>
<tr>
<th>Type of Fertilizer</th>
<th>Application</th>
<th>Average Quantity Required (Tonnes)</th>
<th>Cost per tonne (USD)</th>
<th>Total Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>2 tonnes/hectare every 2 years</td>
<td>7,000</td>
<td>13</td>
<td>91,000</td>
</tr>
<tr>
<td>Urea</td>
<td>130 kg N/hr</td>
<td>1,300</td>
<td>200</td>
<td>260,000</td>
</tr>
<tr>
<td>SSP or TSP</td>
<td>100 kg P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;/hr</td>
<td>1,000</td>
<td>200</td>
<td>200,000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>551,000</td>
</tr>
</tbody>
</table>

Table 39: Annual operating and maintenance costs for agriculture equipment

11.2 Industrial O&M Costs

Unit operation and maintenance costs for the sugar factory and distillery are given in Table 41. O&M costs for the medium pressure boiler and CEST configurations are estimated at three percent of the initial investment cost, while O&M costs for BIG-CC are estimated as 8 USD per MWh of electricity produced (Braunbeck et al. 1998).

<table>
<thead>
<tr>
<th>Technology</th>
<th>O &amp; M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Factory</td>
<td>0.047 USD/kg of sugar</td>
</tr>
<tr>
<td>Distillery</td>
<td>0.05 USD/liter</td>
</tr>
<tr>
<td>Medium Pressure Boiler</td>
<td>3% of initial investment cost</td>
</tr>
<tr>
<td>CEST</td>
<td>3% of initial investment cost</td>
</tr>
<tr>
<td>BIG-CC</td>
<td>8 USD/MWh</td>
</tr>
</tbody>
</table>

Table 41: Factory and distillery operating and maintenance costs
12 Economic/Financial analysis

The economic/financial analysis is intended to provide an indication of the relative financial viability of the specific investment options considered in this study. The results of the economic/financial analysis are not intended to emulate the financial perspective of particular investors who might be considering the viability of the options. There are several reasons to distinguish between the financial perspective provided by these results and the financial perspective of particular investors. First, the assumptions are general and do not reflect the actual market conditions that would be faced by a particular investor. Second, the assessment is relative across the scenarios, with special attention to the differences among the options, rather than to the absolute levels of costs. Finally, the overall economic situation in Zambia, which will certainly affect the environment for investment, has not been addressed in detail.

The economic/financial analysis and calculations are based on the scenarios listed in Table 19. The results of the market analysis provided in section 5.5 and the technical analysis given in chapter 8 were used as input to the economic/financial analysis. The relationship between supply and demand is viewed in terms of the market clearing values for sugar, ethanol, and/or electricity. Using the market-clearing production levels as input, a number of assumptions were made concerning financial parameters in order to conduct a financial analysis for each scenario. The COMFAR 2.1 (UNIDO, 1998) model, which is widely used in feasibility studies and industrial projects, was used to perform the calculations. In this section, the market-clearing production levels are discussed, the assumptions and input data are described, and the results of the financial analysis are given.

12.1 Market clearing production levels

Markets clear when supply equals demand. Most economic analyses assume that this is the case, i.e. that there is no excess supply and no unsatisfied demand. Where entire national economies are studied, General Equilibrium Models can be used to determine the prices and quantities at which markets clear. Such modeling is far beyond the scope of this analysis, as the economy as a whole is not analyzed. Nor have alternative international suppliers competing for sugar, ethanol, and electricity markets been explicitly considered in the analysis. Consequently, it is not appropriate to interpret the prices and quantities used in the analysis as representing market conditions under equilibrium. However, assumptions regarding domestic competition (from Nakambala) for sugar markets have been included, and some general aspects of expected future competition from alternative sources were included in the market discussion of section 5.5.

It is also important to note that the enabling environment provided by government and business can impact the market-clearing values for all three products. Legislation, taxation, regulatory bodies, and even the general business environment could discourage or encourage both the supply and demand side of the equation. It is beyond the scope of this analysis to offer specific conjectures on the potential quantitative impacts of government policies on supply and demand. Nevertheless, a reasonable picture of the expected market has been obtained using the historical and projected consumption data provided in section 5.5 along with the engineering-economic data provided in chapter 8. How the levels of supply and demand relate for the three products studied — sugar, ethanol, and electricity — is discussed in this section. The production level assumptions used in the financial analysis are based on these relationships. These production levels are used as proxies for market clearing production levels, i.e. those that will satisfy the expected demand.

12.1.1 Sugar

There are four possible maximum design capacity production levels for sugar and ethanol, depending on whether ethanol is produced from cane juice, or A, B, or C molasses. Table 42 gives these levels along with the realizable maximum based on an assumed capacity factor of 90%. The levels of sugar production in relation to the expected demand given in section 5.5 are considered first. Demand was given as 150 thousand tonnes in 2010, which is in excess of that which would be supplied from Nakambala sugar factory. It is assumed that the two Zambian factories would not compete, but would face complementary markets based on geographical location. From this perspective, it appears that the market could absorb even the highest potential production level of nearly 120 thousand tonnes in the sugar only strategy. However, given that more than half of the demand...
is export in 2010, the margin of error of 30 thousand tonnes would be valued, since exports generally pose greater risk. Conversely, the ethanol only strategy could potentially leave a considerable untapped export market for sugar.

12.1.2 Ethanol
The maximum production potentials for ethanol given in Table 42 can be compared with the expected domestic market for anhydrous ethanol in the year 2010 of 23.6 million liters (see Table 14). The production potentials from annexed distilleries using A, B, or C molasses are less than or equal to this demand level. Therefore, markets are assumed to clear at the realizable maxima listed in Table 42 in the financial analysis for these three cases.

An autonomous distillery large enough to utilize all of the sugarcane grown on the estate studied here would produce almost 79 million liters per year, which is more than three times the size of the expected market. Unless an extremely aggressive export program was developed and was successful or 100% ethanol cars were introduced, an autonomous distillery this large does not appear to be economically feasible.

As this case illustrates, the feasibility of an autonomous distillery appears to hinge on both the size of the market and the size of the sugarcane estate. If ethanol production were prioritized with the intention to satisfy the domestic market for blending, one might consider sizing an autonomous distillery to just meet the estimated demand of 23.6 million liters in 2010, and reducing the size of the sugarcane estate accordingly. This would save the investment in the additional sugarcane processing capacity. However, the costs of sugarcane production do not scale with production capacity, due to high fixed costs. Similarly the investment cost of the distillery itself is not sensitive to scale. Therefore, such an option is highly unlikely to be cost-effective. An autonomous distillery would need to be operated at a reasonable scale and would require a stable market at this higher level. This is not likely in the near-term, given that no ethanol market currently exists in the region. Nevertheless, autonomous distillery (ethanol-only) scenarios have been maintained in the analysis for reference purposes. Strong policy decisions in favor of exports, the introduction of 100% ethanol engines, or greater regional interest in neighboring countries are examples of developments that could move the market closer to feasibility in the future.

12.1.3 Electricity
The scenarios that result in surplus electricity production for export employ advanced cogeneration plants that combust bagasse from the sugar factory. When a CEST system is chosen, the electricity produced is estimated to range from 193 to 237 GWh, depending on the specific configuration. When a BIG-CC system is chosen, electricity produced is estimated to range from 464 to 552 GWh. An expanding demand base could easily absorb this source of supply. The total (domestic plus export) projected available market for electricity from Luena in 2010 is estimated at 14 thousand GWh (see section 5.5.3). The CEST system could provide one to 2% of this level of demand, while the BIG-CC system could provide three to four. Although these potential supply contributions are small compared to supply from large hydro plants, they do represent a significant contribution to national supply. They would also provide added value by offering some supply diversity in a system that is almost exclusively hydro-based.

### Table 42: Maximum sugar and ethanol production under alternative strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Sugar Production (tonnes)</th>
<th>Ethanol Production (1000 liters)</th>
<th>Ethanol Feedstock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design capacity</td>
<td>Realizable capacity (90%)</td>
<td>Design capacity</td>
</tr>
<tr>
<td>Sugar only</td>
<td>133,096</td>
<td>119,786</td>
<td>none</td>
</tr>
<tr>
<td>Ethanol only</td>
<td>87,360</td>
<td>78,624</td>
<td>Cane juice</td>
</tr>
<tr>
<td>Sugar and ethanol in fixed quantities</td>
<td>133,096</td>
<td>119,786</td>
<td>10,168</td>
</tr>
<tr>
<td>Sugar and ethanol in flexible quantities</td>
<td>125,360</td>
<td>112,824</td>
<td>14,661</td>
</tr>
<tr>
<td>Sugar and ethanol in flexible quantities</td>
<td>105,160</td>
<td>94,644</td>
<td>26,378</td>
</tr>
</tbody>
</table>

In this section, the inputs and assumptions for the financial analysis are described, and the basic indicators used to measure financial performance are defined. The required input data are outlined, and additional detail on key assumptions regarding prices, sales programs, and depreciation charges are provided.
12.2.1 Required input data
The financial analysis required the following input data:

- Investment costs;
- Factory/Agriculture costs (raw materials, labor, operations, maintenance, utilities);
- Administrative overhead costs;
- Sales and distribution costs;
- Production capacity and Sales program;
- Prices; and
- Depreciation charges.

The four cost categories have already been discussed in chapters 10 and 11. The production/sales programs, prices, and depreciation assumptions require further discussion, as provided below.

12.2.2 Sales programs
The design capacity of the sugar factory and ethanol distillery cannot be fully utilized, especially during the first few years when equipment is being tested and processing difficulties must be addressed. Annual sales calculations were made assuming a maximum production capacity of 90% and that maximum production capacity is unlikely to be achieved in the first two years. Achieved capacity for sugar was estimated at 80% of design capacity for the first year, 85% for the second, and 90% from the third year on. For ethanol, 80% of capacity would be achieved in year one. 90% is assumed from year two on. It is assumed that electricity could be co-generated at 95% of design capacity from the first year onwards. However, some additional feedstock might need to be procured, at marginal cost, in the initial years of operation when full bagasse recovery may be difficult. Table 43 gives the realizable maximum production levels for sugar, ethanol, and electricity for each of the scenarios based on the above capacity assumptions.

12.2.3 Prices
As discussed above, the prices used in this analysis are assumed, as opposed to being the results of calculations based on market equilibrium. These prices are conjectures as to what the market is expected to bear. Some analyses of the sensitivity of results to sales price have been included as part of the financial results. The sugar price was assumed to be 370 USD/tonne, the ethanol price was 45 US¢ per liter, and the electricity price was 3.5 US¢ per kWh. The sugar and ethanol prices could be subject to changes based on fluctuations in international sugar and oil prices. The electricity price is a function of own cost and the cost of alternative supply, which has been estimated at 3.5 US¢ per kWh for hydropower.

12.2.4 Depreciation rates
Depreciation refers to the reduction in value over time as equipment wears out physically and/or becomes outdated as newer and more efficient technologies become available. In terms of cost accounting, depreciation allows for the systematic recovery over time of the capital invested in the production facilities. Simple assumptions for depreciation have been adopted in the financial analysis, based on so-called straight-line depreciation, in which the book value of the asset is assumed to decline linearly over time. Separate depreciation rates were assumed for three investment categories, as follows:

- Buildings 2.5 % per annum
- Plant machinery 10 % per annum
- Transportation equipment 20 % per annum

The assumption for plant equipment is based on recovery over a period of ten years. In fact, the plant equipment, especially in the case of the sugar factory, generally has a longer lifetime, so that the resulting cost accounting can be viewed as conservative.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sales at Realizable Maximum Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sugar (Tonnes)</td>
</tr>
<tr>
<td>REF1</td>
<td>119,786</td>
</tr>
<tr>
<td>REF2</td>
<td>0</td>
</tr>
<tr>
<td>REF3</td>
<td>119,786</td>
</tr>
<tr>
<td>REF4A</td>
<td>94,644</td>
</tr>
<tr>
<td>REF4B</td>
<td>112,824</td>
</tr>
<tr>
<td>CEST1P</td>
<td>119,786</td>
</tr>
<tr>
<td>CEST1F</td>
<td>119,786</td>
</tr>
<tr>
<td>CEST2P</td>
<td>119,786</td>
</tr>
<tr>
<td>CEST2F</td>
<td>119,786</td>
</tr>
<tr>
<td>CEST3P</td>
<td>119,786</td>
</tr>
<tr>
<td>CEST3F</td>
<td>119,786</td>
</tr>
<tr>
<td>CEST4AP</td>
<td>112,824</td>
</tr>
<tr>
<td>CEST4AF</td>
<td>94,644</td>
</tr>
<tr>
<td>CEST4BP</td>
<td>112,824</td>
</tr>
<tr>
<td>CEST4BF</td>
<td>94,644</td>
</tr>
<tr>
<td>BIG1A</td>
<td>119,786</td>
</tr>
<tr>
<td>BIG1G</td>
<td>119,786</td>
</tr>
<tr>
<td>BIG2A</td>
<td>0</td>
</tr>
<tr>
<td>BIG2G</td>
<td>0</td>
</tr>
<tr>
<td>BIG3A</td>
<td>119,786</td>
</tr>
<tr>
<td>BIG3G</td>
<td>119,786</td>
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<tr>
<td>BIG4AA</td>
<td>94,644</td>
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<td>BIG4AG</td>
<td>112,824</td>
</tr>
<tr>
<td>BIG4BA</td>
<td>94,644</td>
</tr>
<tr>
<td>BIG4BG</td>
<td>112,824</td>
</tr>
</tbody>
</table>

Table 43: Production assumptions for the financial analysis
Note: Under the reference scenarios there is an estimated external import of 1920 MWh per year, since there is no local electricity generation during the off-season. Under the remaining (CEST and BIG) scenarios, surplus electricity is generated throughout the whole year.
12.2.5 Indicators of financial performance

The following financial parameters or indicators were evaluated for each scenario:

- Source of finance: either through borrowing (debt) or stock (equity);
- Cash flow: a measure of the balance between revenues and costs, with appropriate accounting for depreciation and liabilities;
- Net present value (NPV): the sum of revenues and costs over time, based on an assumed discount rate, referenced to the present (the first year). The discount rate assumed here was 10%;
- Internal rate of return (IRR): The IRR is defined as the rate of discount at which the net present value becomes zero; and
- Payback period: the amount of time required for net operational revenues to pay for the investment.

The criterion of NPV, IRR and payback period are commonly used for comparing financial options, and provide different information regarding which options might be preferred. The NPV results in a ranking according to net profits, which is generally reasonable unless the products or services involved have strategic or qualitative differences that prevent easy comparisons of costs and revenues. The IRR results in a ranking of investments according to their yields, thus avoiding the use of an externally established rate of discount, as is the case with NPV. The payback period results in a ranking based on the near-term benefits and costs, while ignoring benefits and costs that accrue beyond the payback period.

The IRR is generally viewed as the most comprehensive indicator of the three measures, and has been adopted here as the primary indicator for comparison. The NPV and payback period can then be applied as secondary criteria, applying the principle of strict dominance. For example, an option that has higher NPV and IRR and lower initial investment than another is always preferred. When preferences are not as clear, i.e. different options are preferred for different financial criteria, then preferences differ depending on the investor’s attitude toward risk.

Scenarios with IRRs below 10% were not considered viable, as this was the assumed discount rate. The results can be considered from the perspective of two basic strategic choices: the choice of producing sugar vs. ethanol and the choice of cogeneration strategy.

The ethanol-only strategies (REF2, CEST2, BIG2) are far from being viable, as can be seen from the fact that their IRRs are negative. These results are driven by the high price of sugar (370 USD/tonne) in relation to the price of ethanol, i.e. it is generally not profitable to divert sugar production to ethanol production at these prices. In the “fixed” production strategies, no economically salvageable sugar is lost because C molasses is used as the feedstock and ethanol production becomes profitable. In reality, of course, prices fluctuate over time, and should there be significant swings in prices from year to year, the relative

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Initial Investment (1000 USD)</th>
<th>Net Present Value (1000 USD)</th>
<th>Internal Rate Of Return (%)</th>
<th>Payback (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF1</td>
<td>132,100</td>
<td>32.7</td>
<td>13.9</td>
<td>6</td>
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<tr>
<td>REF2</td>
<td>120,100</td>
<td>-25.2</td>
<td>-24.5</td>
<td>n/a</td>
</tr>
<tr>
<td>REF3</td>
<td>133,300</td>
<td>26.9</td>
<td>13.2</td>
<td>6</td>
</tr>
<tr>
<td>REF4A</td>
<td>130,200</td>
<td>-21.5</td>
<td>7.3</td>
<td>9</td>
</tr>
<tr>
<td>REF4B</td>
<td>130,300</td>
<td>-15.4</td>
<td>-11.9</td>
<td>7</td>
</tr>
<tr>
<td>CEST1F</td>
<td>159,100</td>
<td>51.6</td>
<td>15.3</td>
<td>5</td>
</tr>
<tr>
<td>CEST1P</td>
<td>166,400</td>
<td>38.1</td>
<td>13.7</td>
<td>6</td>
</tr>
<tr>
<td>CEST2F</td>
<td>148,500</td>
<td>-22.2</td>
<td>-17.1</td>
<td>n/a</td>
</tr>
<tr>
<td>CEST2P</td>
<td>155,800</td>
<td>-24.0</td>
<td>-18.6</td>
<td>n/a</td>
</tr>
<tr>
<td>CEST3F</td>
<td>161,700</td>
<td>48.2</td>
<td>14.8</td>
<td>5</td>
</tr>
<tr>
<td>CEST3P</td>
<td>169,000</td>
<td>34.2</td>
<td>13.3</td>
<td>6</td>
</tr>
<tr>
<td>CEST4AF</td>
<td>155,700</td>
<td>-19.2</td>
<td>9.8</td>
<td>7</td>
</tr>
<tr>
<td>CEST4AP</td>
<td>165,900</td>
<td>26.6</td>
<td>11.9</td>
<td>6</td>
</tr>
<tr>
<td>CEST4BF</td>
<td>155,700</td>
<td>-19.2</td>
<td>9.8</td>
<td>7</td>
</tr>
<tr>
<td>CEST4BP</td>
<td>165,900</td>
<td>23.1</td>
<td>12.3</td>
<td>6</td>
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<tr>
<td>BIG1A</td>
<td>235,900</td>
<td>26.6</td>
<td>11.9</td>
<td>6</td>
</tr>
<tr>
<td>BIG1G</td>
<td>277,900</td>
<td>3.7</td>
<td>10.2</td>
<td>7</td>
</tr>
<tr>
<td>BIG2A</td>
<td>225,500</td>
<td>-25.9</td>
<td>-13.1</td>
<td>n/a</td>
</tr>
<tr>
<td>BIG2G</td>
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<td>-28.6</td>
<td>-12.1</td>
<td>n/a</td>
</tr>
<tr>
<td>BIG3A</td>
<td>238,200</td>
<td>21.0</td>
<td>11.5</td>
<td>6</td>
</tr>
<tr>
<td>BIG3G</td>
<td>280,100</td>
<td>-18.3</td>
<td>9.9</td>
<td>7</td>
</tr>
<tr>
<td>BIG4AA</td>
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<td>-40.2</td>
<td>7.1</td>
<td>9</td>
</tr>
<tr>
<td>BIG4AG</td>
<td>277,200</td>
<td>-62.5</td>
<td>6.0</td>
<td>9</td>
</tr>
<tr>
<td>BIG4BA</td>
<td>235,400</td>
<td>23.9</td>
<td>11.7</td>
<td>6</td>
</tr>
<tr>
<td>BIG4BG</td>
<td>277,200</td>
<td>-15.8</td>
<td>9.0</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 44: Investment profitability analysis

12.3 Results

The results of the financial analysis are provided in Table 44. The total initial investment requirement and the key financial indicators — NPV, IRR, and payback period — are given here for each scenario.
attractiveness of producing sugar and ethanol will also fluctuate. An analysis of the full dynamics of such fluctuations is beyond the scope of this study. However, we have attempted some sensitivity analysis discussed in section 12.3.8.

Several of the flexible production strategies are not viable, since they have IRRs below 10%, which is the assumed discount rate. These results arise for the same reason that ethanol-only strategies are not viable: it is not economically attractive to divert sugar production into ethanol production at the assumed prices. Of the ten flexible production scenarios, there are three scenarios that are financially viable: CEST4AF, CEST4BF, and BIG4BA. This is an interesting result. Because the same scenarios in the reference case are not financially viable, it suggests that the diversion from sugar into ethanol through flexible production can be in effect “cross-subsidized” through advanced cogeneration systems. Internal electricity demand is lower when sugar production is lower, since sugar production is energy-intensive in comparison to ethanol production. Hence, more electricity can be sold when less sugar is produced. But the effect is not sufficient to outweigh the disadvantages of the sugar-ethanol price differentials under the assumptions used.

The sugar-only strategies and those with fixed quantities of sugar and ethanol production are financially viable. These strategies can be compared across the cogeneration options to evaluate the effect of adding advanced cogeneration systems on financial viability. A comparison of REFI with CEST1F, which is an analogous option using CEST system, reveals that adding advanced cogeneration improves financial viability, since the IRR increases from 13.89 to 15.25. A similar comparison for BIG-CC systems shows the opposite result: BIG1A and BIG1G have lower IRRs than REFI. A similar result is found for the fixed production strategies: CEST3F has a higher IRR than REF3 while BIG3A and BIG3G have lower IRRs than REF3. The conclusion from these results is that CEST systems improve overall financial viability while BIG-CC systems do not. The higher efficiencies in biomass utilization and electricity production of the BIG-CC systems are not sufficient to compensate for their high up-front capital costs.

### 12.3.2 Selection of Promising Options

The scenarios with the highest IRR and NPV, and relatively lower payback periods were considered the most promising, and were selected for further consideration. These are given in Table 45. Out of the three most promising options, CEST1F — which maximizes sugar and surplus electricity production — is the most profitable, with an NPV of 51.6 million USD and an IRR of 15.26%. This is followed by CEST3F (NPV=USD48.2m and IRR=14.85), in which sugar and ethanol are produced in fixed quantities with full electrification. Because of its lower investment cost, the sugar only scenario with no ethanol or surplus electricity production (REF1) also ranks high, coming in third with an NPV of 32.7 million USD and an IRR of 13.89%.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Initial Investment (Million USD)</th>
<th>NPV (Million USD)</th>
<th>IRR (%)</th>
<th>Payback (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEST1F</td>
<td>159.1</td>
<td>51.6</td>
<td>15.26</td>
<td>5</td>
</tr>
<tr>
<td>CEST3F</td>
<td>161.7</td>
<td>48.2</td>
<td>14.85</td>
<td>5</td>
</tr>
<tr>
<td>REFI</td>
<td>132.1</td>
<td>32.7</td>
<td>13.89</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 45: Financial analysis results for the three most promising scenarios

The financial performance of scenarios using BIG-CC for cogeneration were poor due to heavy up-front investment costs. However, it should be noted that the capital cost for this technology is high because it is not yet commercially available. Once commercialization of the BIG technology has been completed, capital and operating costs are expected to decline (Gabra and Kjellström, 1995).

#### 12.3.3 Liquidity analysis

For all three of the most promising scenarios (CEST1F, CEST3F and REFI) the equity capital plus long-term loans would be sufficient to cover the investment outlay during the construction period. For CEST1F, for example, the cumulative cash balance is negative for a period of five years. In the sixth year and later, the cash balance is positive, meaning that the project would be able to meet all the cash outflows and would produce a cash surplus throughout its operating period.

#### 12.3.4 Debt/Equity ratio

During the construction period, the equity proportion for all three options is lower than the debt, reflecting 33% equity financing of the investment cost. In the third year, when loan repayments commence, the debt proportion diminishes until the project is fully debt free in year 12 and, simultaneously, reserves begin to increase due to positive income results.

#### 12.3.5 Sensitivity analysis for IRR

The sensitivity of the IRR was assessed with respect to changes in operating costs, sales prices (for all products), and initial investment. The CEST1F scenario is least sensitive to changes in operating...
costs, with an increase of 10% in operating costs reducing the IRR to 13.2%, leaving the project still financially viable. However, CEST1F is moderately sensitive to changes in sales price. A 10% reduction in sales prices reduces the IRR to 11%, making the project marginally viable. Variations in the initial investment cost have a slight impact on the IRR for CEST1F. For REF1, increasing operating costs by 10% reduces the IRR to 12%. Reducing sales prices in REF1 by 10% reduces the IRR below 10% making the project not viable. CEST3F is most sensitive of all three scenarios to changes in sales price, with a 10% drop in sales prices causing the IRR to drop to 10.8%. Similar to CEST1F, CEST3F is only slightly sensitive to changes in operating and initial investment costs.

12.3.6 Sensitivity analysis for capacity utilization
The operational levels at which the three most promising scenarios break even (costs equal sales) are listed below. CEST1F has a lower risk of making cost overruns than the other two scenarios (CEST3F and REF1), as can be seen by the fact that it has the lowest break-even capacity.

- CEST1F: 65% of plant capacity
- CEST3F: 69% of plant capacity
- REF1: 73% of plant capacity

12.3.7 Risk analysis
The various scenarios involve uncertainties that should be considered before making an investment. Some variables are common sources of uncertainty. These include the size of the investment, the operating costs, and sales revenues. Often, the investment requirements for both fixed and working capital may be underestimated and the construction and running periods become longer than anticipated. This can affect the size of operating costs, investment costs and sales revenue. There is minimum risk caused by inflation in that it is common that prices of most inputs and outputs increase with time causing changes in prices.

12.3.8 Sugar and ethanol price sensitivity
The above results make it clear that the scenarios are highly sensitive to assumptions regarding the achievable sales prices for sugar and ethanol. Assuming that sugar can be sold at 370 USD/tonne but ethanol can only be sold at 45 cents/liter, as was done here, results in sugar production always being preferred to ethanol production. For the scenarios employing annexed distilleries, the breakeven price (the price at which the scenarios reach positive NPVs) for ethanol sales was explored. This breakeven price was approximately 50 cents per liter. Thus, assuming the market price assumption of 45 cents per liter is correct, a minimum subsidy of five cents per liter would be required for ethanol production to be considered valuable at the margin by a rational producer.
13 Environmental implications

13.1 The baseline scenario
The current environmental trends will continue and probably accelerate due to population growth that is estimated at 2.2 percent per annum without the proposed Luena Sugar Project.

It has been shown in section 5.24 that forest cover in the Luena area has declined by about 45 percent while grassland has increased by 75 percent due to forest clearing. Land devoid of natural vegetation cover, especially around villages, has also increased. This trend is projected to continue as village settlements expand in the area under the no-project alternative.

Soil degradation due to cultivation is unlikely to increase because of the better land management in the more intensively cultivated village gardens in which mounds are sequentially made and broken up for the cultivation of cassava, groundnuts and beans. This intensive, almost permanent, cultivation system has virtually replaced the traditional chitemene shifting cultivation system that was widespread in the past due to forest depletion. The low land relief also minimizes the incidence of soil erosion.

13.2 Establishing the Estate
Implementing any of the development scenarios would result in the following physical changes in the project area:

- Land clearing to develop a 10,000 ha sugarcane estate and additional land on which to construct houses for staff, factory, offices and social facilities.
- Construction of a dam wall across Pambashye River and swamp to create a 400 ha reservoir to store water for irrigation.
- Construction of roads in the project area totaling about 865 km.
- Construction of a power line through the area to the factory.
- Increased vehicle traffic to bring in materials and machinery.
- Construction of social infrastructure such as schools and a health clinic.

13.2.1 Clearing and preparing agricultural land
The total Estate area is estimated at 10,000 ha with possibility of an additional 1,300 ha for outgrowers. The Estate will be located on the upland that is primarily covered with Miombo woodland and bush. Land clearing would result in the deforestation and the removal of infrastructure (residences, roads, etc.) on 10,000 ha. Trees would be felled and piled into windrows by machines (such as bulldozers) and the biomass would be burned. This activity would affect the soil, water, air (atmosphere), ecosystems, flora and fauna. Felling and piling of debris into windrows would remove and redistribute the topsoil. However, because land preparation would follow immediately, the impact on runoff and seepage is likely to be insignificant.

The major ecosystem to be affected by land clearing is Miombo woodland. This ecosystem covers about 166,500 ha in the Luena area and clearing of 6,600 ha for the cane fields represents about four percent of the Miombo ecosystem. The impact is considered insignificant due to the extensive area of Miombo in the Luena area and its degraded state. However, Estate development would affect about 4,000 ha of the Pambashye forest reserve that would be submerged under the Pambashye dam. The total size of the reserve is 38,300 ha extending over three ecosystems: wetland, riverine/swamp forest and Miombo woodland. The reserve consists of three separate compartments and is already under considerable threat from local population pressure. Discussions with the District Forest Officer indicated that the encroachment on the forest reserve is unlikely to have significant effects on ecosystems in the area, assuming that those ecosystems in the forest reserves are not rare or unique.

There are approximately 1,530 species of flora and fauna in the Luena area (Chidumayo and Aongola, 1998; Astle, 1968-69) (Table 46). Among these species, only the checkered elephant shrew, Rhynchocyon cirnei, is vulnerable, according to the classification of The World Conservation Monitoring Center (1992). This shrew inhabits swamp/riparian forests in the northern parts of Luapula province, thus land clearing in the Luena area would not directly affect its habitat.
Land preparation during Estate development would involve sub-soiling, plowing, leveling and harrowing in the area where bush has been cleared. This activity would be done mechanically and would lead to soil and air impacts. The effects on soil relate to sub-soiling, plowing and leveling the land. These operations would loosen the soil, thereby increasing the risk of soil erosion by wind and water, especially during the period prior to planting. However, given the very low slopes of 1.0 to 1.5 percent on the upland where the Estate would be located, erosion by water is not likely to be significant. Wind erosion can be reduced by leaving strips of natural vegetation to act as windbreaks. The effects of land preparation on air are closely related to wind erosion that pollutes the atmosphere with dust. Wind speeds in the area are generally low (see Table 3). Providing vegetation windbreaks would adequately reduce this form of air pollution.

### 13.2.2 Power line construction

The selection of the power line route to be used would require a separate impact assessment study. The construction of the power line involves clearing a ten-meter wide swath. The size of the area that would be affected depends on the route the power line would take. Restriction of settlements within 30 meters of the line effectively excludes settlements in a 70m wide strip along the power line. The swath is made by clearing trees, bushes and grass and maintained annually by cutting back re-growth and burning. Generally, whatever route the line takes, the areas to be affected are small, representing less than 0.01 percent of Miombo ecosystem and 0.05 percent of wetland ecosystem in the Luena area and far less at the scale of Kawambwa district. The construction of the power line is likely to fragment the ecosystems in the affected area, but given the narrow width of the line, the negative effects on flora and fauna would be negligible. Empirical observations in Zambia suggest that 66kV power lines do not constitute significant barriers to gene flow and fauna movements. Except in grassland, the visual effect on the landscape would be insignificant because bordering vegetation would obscure the line.

### 13.2.3 Road construction

The major impact of road construction on soil would be the quarrying of gravel and stone for road building. Assuming a pre-compaction gravel thickness of 30cm, the access roads would require at least 1.5 million m$^2$ of gravel. Measures should be taken to ensure that the quarries created from mining gravel are properly rehabilitated. This is not common practice in Zambia.

Runoff from paved road surfaces can result in water pollution and serious soil erosion. If runoff causes erosion, the mud in the runoff would increase water turbidity. The most effective way of reducing water pollution and erosion caused by runoff from roads is to site and design roads and roadside drains carefully so that the discharge water is channeled safely into natural courses. Experience in Zambia suggests that oil and fuel in runoff from road construction has not been a significant problem.

Dust generation during road construction would be a temporary nuisance and should not be a major concern. Dust and noise generation from motor vehicles using the roads would pose a more permanent nuisance to inhabitants of roadside settlements. This would not be a problem for tarred roads. For gravel access roads within the Estate, watering and application of stillage coupled with proper vehicle maintenance are recommended, to reduce dust and noise pollution. Where possible, housing should be located away from cane transportation roads. Air pollution from motor vehicle exhaust gases occurs along roads but traffic intensity is likely to be low on the roads serving the project area.

Ecosystems in the project area are not rare or unique. In addition, road construction would involve upgrading of existing roads, except where the construction of temporary diversions would be necessary. Road construction therefore would have no significant effect on ecosystems. Road construction is not expected to have significant effects on flora and fauna.

### 13.2.4 Creating water storage capacity

The Pambashye dam and reservoir would impact water, air, ecosystems, flora and fauna. The dam would result in the artificial regulation of river flow. This is likely to significantly alter the characteristics of downstream river flow and the water balance in the Pambashye wetland. However, some of the water in the reservoir would be lost through seepage into the ground, reducing the downstream impacts. The magnitude of these changes cannot be easily determined without in-depth hydrological studies of

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<table>
<thead>
<tr>
<th>Group</th>
<th>Number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>362</td>
</tr>
<tr>
<td>Invertebrates</td>
<td>648</td>
</tr>
<tr>
<td>Amphibians</td>
<td>12</td>
</tr>
<tr>
<td>Reptiles</td>
<td>50</td>
</tr>
<tr>
<td>Birds</td>
<td>380</td>
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<tr>
<td>Mammals</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>1,494</td>
</tr>
</tbody>
</table>

Table 46: Diverse species in the Luena area.
the area. It would be necessary to monitor river flow in the Lufubu and Pambashye river systems to generate data for future analysis of the effects of the reservoir and determine what mitigation measures, if any, should be taken. There are no similar irrigation systems in Zambia that can be used to provide data for predicting the effects at Luena.

A considerable amount of water in the reservoir would be lost to the atmosphere through evaporation. This is likely to enhance water circulation between land and the atmosphere. A new microclimate in the dam area would be created that is likely to be more humid and cooler than the surrounding area. However, most of the area to be affected by the Pambashye reservoir is already wetland. The wetland ecosystem in the Luena area covers about 29,500 ha. The reservoir would affect 4,000 ha or 14 percent of the existing ecosystem. Most of the wetlands in the area dry out during the dry season. Creating the reservoir would form a permanent lake that would add to the diversity of the wetlands in the area. Furthermore, there are no wetlands of national or international significance in the Luena area. The impact of the reservoir from an ecosystem perspective would therefore not affect wetlands of national significance.

No significant negative effects on flora and fauna are expected from the creation of Pambashye dam. On the contrary, the dam could result in an increase in fish and/or fauna production. The construction of similar man-made dams in the country has resulted in increased fish production (after introducing fish), which has become an important social and economic activity, e.g., at Lusiwashi in Serenje district.

13.3 Operating the Estate

13.3.1 Urbanization

The Luena sugar project would result in a new semi-urban settlement (on and around the Estate) in a basically rural environment. The size of the settlement would probably be of the same order of magnitude as Kawambwa boma, which had a population of 11,262 living in approximately 2,250 households in 1990 (Central Statistics Office, 1990). The new urban settlement at Luena would create a concentrated demand for food and energy as well as generate domestic and industrial wastes.

A large part of the settlement at Luena would be paved and roofed. This would increase surface runoff from rainstorms. Unless such runoff is safely discharged into natural courses, it would cause soil erosion. The plan and development of the housing at Luena should consider minimizing soil erosion caused by runoff from paved and roofed areas. Some households are likely to engage in small-scale cultivation, either within or outside the Estate. These cultivated plots could also become sources of water pollution from soil erosion. However, given the low slopes of 1.0 to 1.5 percent that dominate the area, such a problem is not likely to be significant.

A domestic sewer system directed to stabilization ponds located adjacent to river areas would be required to avoid polluting watercourses with sanitary waste from the settlement. The design and capacity of the sewage ponds should take into account future population growth. Many urban sewage treatment ponds in Zambia do not operate effectively because they were designed for much smaller populations than they currently service (Muhwanga, 1994; Simuunza, 1992). The effluent from the treatment ponds should meet the current public health standards as set out in Statutory Instrument 161 of 1985 under the Local Government Act of 1980.

Deforestation caused by harvesting cordwood for firewood and charcoal for domestic use at Luena would be the main impact on ecosystems. The deforestation rate would depend on the stocking in the woodlands. Above ground cordwood biomass in degraded woodland at Luena is estimated at 15 t/ha (Zimba, 1991) compared to 76 t/ha in well-stocked woodlands (Chidumayo, 1997). Assuming harvesting by clear felling and a wood-to-charcoal conversion efficiency of 0.23 (Chidumayo, 1997), producing 1,490 tonnes of charcoal would require 430 ha of degraded woodland or 85 ha of well-stocked woodland. The Forest Department regulates commercial harvesting of cordwood for firewood or conversion to charcoal through a licensing and enforcement system. However, there is inadequate capacity in the Department to effectively regulate this activity. If firewood demand were met by clearing woodland, an additional 115 ha of degraded forest or 25 ha of well-stocked woodland would be cleared annually. This rate of deforestation could be reduced during the development of the Estate if wood from land clearing (see section 13.2) could be used for domestic energy consumption.

No direct impacts on flora and fauna are expected from urban development at Luena. However, the demand for fish and game meat may increase the rate of fishing in existing fisheries and game hunting in the province in order to supply the new demand at Luena. This could result in over
fishing and/or over hunting of game. The introduction of suitable fish in the proposed Pambashye reservoir would reduce the risk of the Estate increasing pressure on existing fisheries in the province.

13.3.2 Producing sugarcane

Five activities undertaken while producing sugarcane are potential sources of environmental impacts:

- Fertilizer application;
- Cane irrigation;
- Crop protection;
- Cane harvesting; and
- Cane transportation.

13.3.2.1 Fertilizer application

Fertilizer application would be necessary to sustain the desired levels of cane production. All of the three main elements (i.e., nitrogen (N), phosphorus (P) and potassium (K)) would be required (see section 6.3.3). Fertilizer application affects soil, water, flora and fauna.

The continuous application of nitrogenous fertilizer in northern Zambia causes a progressive increase in soil acidity. If lime is applied at the recommended rate, this should prevent the acidification of soil as a result of continuous fertilizer use at Luena while sustaining soil productivity and even raising soil pH.

The main environmental risks of fertilizer use are associated with runoff from cane fields and seepage into ground water. The Luena soils have a low nutrient holding capacity. Consequently, they have a low capacity to retain added nutrients against the leaching effect of heavy rainfall and irrigation. Water pollution caused by eutrophic runoff from fertilized croplands has been observed in some parts of Zambia. In the Kafue Flats of central Zambia, where the Nakambala sugar estate is located, drainage waters from the estate contained 72 percent more nitrate-N and 229 percent more orthophosphates than the pre-irrigation water pumped from the Kafue River upstream (Salter, 1978-79). The Ngwerere stream, that drains the peri-urban commercial farmland northeast of Lusaka city, receives farmland runoff that has levels of orthophosphates and sulfates that are 32 percent higher than runoff from rural subsistence farmland (Obrdlik, 1984). Eutrophication often results in excessive growth of algae and aquatic macrophytes, especially in man-made reservoirs. Such weeds alter the quality of the aquatic ecosystem and reduce fauna diversity. The current water hyacinth (Eichhornia crassipes) weed problem in the Kafue Gorge Reservoir has been partly caused by nutrient loading in the Kafue River due to eutrophic runoff from commercial farmlands and industrial and urban domestic effluents.

In Luena it would be necessary to monitor the quality of drainage waters and in recipient natural watercourses in order to take appropriate measures to reduce eutrophication. Re-using runoff from the cane fields should be considered while avoiding excessive application of fertilizers. Other measures should be explored to ensure that leached nutrients do not accumulate to hazardous levels in ground water. Under normal conditions, phosphates have low solubility and long residence time in soils, but with continuous irrigation this situation can change, with negative effects on ground water quality. Unfortunately, no data could be found on changes in ground water quality due to fertilizer application under irrigation.

13.3.2.2 Irrigation

Although the soils in the Luena area have good drainage characteristics, it would be essential to provide adequate surface drainage for runoff from rainfall and irrigation. These drains would finally discharge water into natural courses. Thus the Estate would have to meet water quality standards set and enforced by the ECZ and the Public Health Department of Local Government to safeguard human health.

Furrow irrigation can cause soil erosion. This risk can be minimized by careful design of the lengths and gradients of the irrigation furrows. Soil erosion can also be minimized by establishing vetiver grass breaks in the spoon drains that would discharge the water into secondary drains for discharge into natural courses. With these measures properly implemented and maintained, soil erosion should not be a significant problem. Water quality regulations set and enforced by the ECZ determine the permissible concentration of total and dissolved solids in waste/effluent waters (The Water Pollution Control (Effluent and Waste Water) Regulations, 1993). The ECZ would therefore have to monitor the loading of solids in wastewater from the Estate and enforce water quality standards.

Irrigation also increases the solubility of phosphates in soil and this increases the risk of ground water eutrophication through seepage (Salter 1978-79). With careful design of the irrigation system and limiting fertilizer application levels, it is possible to minimize water pollution. These practices are used at Triangle in Zimbabwe, and Nakambala is now applying fertilizer parsimoniously to control water pollution in the Kafue River. The operation of the Estate would
have to meet water quality standards set and enforced by the ECZ and the Public Health Department of Local Government to safeguard human health.

Irrigation canals and runoff drains are potential habitats for invasive weeds and pests that may increase the diversity of the local flora and fauna. Unfortunately, weed and pest species may interfere with the proper operations of irrigation systems either directly in the case of weeds or indirectly in the case of pests. Again, the proper design and maintenance of irrigation systems should prevent such environmental problems. Such designs are in operation at Triangle in Zimbabwe.

13.3.2.3 Weed, pest and disease control
Weed, pest and disease control would be necessary for protecting a sugarcane crop in Luena. The specific crop protection practices that would be required at Luena cannot be determined without the knowledge of the type of weeds, pests and diseases that would significantly affect the sugarcane crop. At Nakambala weeds are not a serious problem. Therefore, the need for specific weed control recommendations has not arisen. Pests are also not of economic importance at Nakambala, although these have been controlled largely through agricultural practices. Sugarcane is susceptible to many diseases (see section 6.3.5), but the most important disease in southern Africa is smut. The cane variety that has been recommended for the project site (NCO 376) is susceptible to this disease. Smut can be controlled by hot-water treatment, fungicides, uprooting diseased plants, or by growing only plant cane. Ultimately, the most economic and satisfactory method of dealing with this disease is replacing susceptible varieties with resistant ones. Crop protection is unlikely to have significant impacts on the environment at Luena.

13.3.2.4 Cane harvesting
All of the scenarios assume that the sugarcane would be burnt and then harvested manually. Burnt cane harvesting would return nutrients in the resulting ash to the soil. It would also result in emissions of ash, particulate matter and gases into the atmosphere. However, the latter is a temporary problem that, although it is a nuisance to the local population, does not negatively impact the biophysical environment. Burning cane residues (tops and leaves) before harvesting would not result in net emissions of greenhouse gases. Burning the fields would affect the animals present, especially invertebrates, amphibians, reptiles and small mammals. However this effect is likely to be temporary, as these animals recover fairly quickly after fire (Gilon, 1971; Gillon, 1971).

The option of harvesting green cane does exist. Green cane harvesting might deprive the soil of nutrients, but would have no effect on the air or the surrounding flora and fauna.

13.3.2.5 Cane transportation
Previous studies on the Luena project have recommended machine cane loading and transportation by grab loading rather than cane billeting (Tate and Lyle, 1978). The use of heavy machines in cane loading and transportation can cause soil compaction, especially on moist soil. However, the impact of this activity would be of limited nature both in space and time and can be reversed by reworking the soil. No other significant environmental effects are expected from cane transportation.

13.3.3 Factory processes
Three main factory processes were identified as having potential impacts on the environment:

- Cane handling and milling,
- Juice processing, and
- Alcohol production.

13.3.3.1 Cane handling and milling
Cane handling involves the inventorying of cane at the factory gate and conveyance to the mill. In the mill, the cane is crushed and processed to extract cane juice. The main waste products from cane handling and milling are dust and bagasse. Dust is generated through cane handling and conveyance to the mill and causes limited soil and air pollution around the cane reception area.

The amount of excess bagasse to be disposed of at the factory depends on the bagasse strategy adopted (Table 47). The Reference scenarios would result in excess bagasse ranging from 72,497 to 87,073 tonnes per year, with REF2 (Reference case bagasse utilization, Ethanol only sucrose strategy) resulting in the highest amounts of un-utilized bagasse of all the scenarios. The second largest bagasse surplus occurs in the BIG-CC process systems (Table 47). The BIG-CC scenarios result in excess bagasse due to the high efficiency of production. The CEST scenarios would use up all the bagasse and therefore would not be associated with bagasse disposal problems.

Fine bagasse, or bagacillo, can be used to make animal feed, but the market for this product is limited in Zambia. As a result, bagasse stocks have accumulated at Nakambala Sugar Estate. Surplus bagasse could be compressed into biomass...
briquettes and used as a household energy source by employees at the Estate. This would reduce the use of wood-based energy sources. This option is relevant for all but the CEST scenarios.

13.3.3.2 Cane juice processing
Processing cane juice results in two significant by-products: filter cake and molasses. Filter cake is applied on cane fields as a fertilizer and, because of the small amounts produced, does not present disposal problems. Molasses would only present potential disposal problems under the scenarios employing the Sugar only sucrose strategy, which would produce about 39,200 tonnes of disposable molasses per year (Table 47). In the other scenarios, molasses would be used as feedstock for producing ethanol. Furthermore, since molasses is an internationally traded commodity, there may be opportunities to sell excess molasses not needed for ethanol production.

13.3.3.3 Ethanol production
Ethanol production involves two sequential processes: fermentation and distillation. The main by-products are carbon dioxide during fermentation and stillage during distillation. The carbon dioxide produced during fermentation can be sold as industrial gas and is often sold for use in applications in the beverage industries. As the carbon released originates from the sugarcane plant, it does not represent a net greenhouse-gas emission.

Vinasse or stillage is a high-strength wastewater stream resulting from the bottom fraction of the distillation process. It is often conveyed to settlement ponds where it cools before disposal. Stillage production would be associated with all of the scenarios producing ethanol. The quantity produced is directly related to the quality of yeast used in ethanol production. A high-quality yeast allows a maximum alcohol concentration of eight percent by volume, so that the minimum stillage to ethanol ratio is 12:1 (Lettinga and Van Haandel, 1993). The amounts of stillage produced are thus estimated as ranging from 104 million liters per year for fixed production of sugar and ethanol to 891 million liters per year for the autonomous distillery using cane juice (Table 47).

At most sugar estates, the stillage is spread on cane fields as a substitute for phosphorus (P) and potassium (K) fertilizer. This would be the most appropriate disposal method at the project site, where the soils lack adequate amounts of these nutrients. It is necessary to dilute the stillage before application onto the fields to avoid burning the cane crop. Dilution levels with irrigation water range from 30 to 400 fold (Scurlock, et al., 1991). Although highly diluted, it would still be necessary to monitor soil quality in the fields and ground and surface water in streams receiving runoff from the cane fields by the Estate and to take appropriate measures to avoid pollution. Stillage has a P/K imbalance and these elements should be monitored in cane fields to avoid negative effects on crop yields. Some stillage can also be spread on gravel roads within the Estate area as a binding agent. This controls erosion and dust on gravel roads but also corrodes vehicles.

Anaerobic digestion by bacteria in stillage ponds emits methane, a greenhouse gas. The amount is likely to be small, but was not estimated in this study. Accidental spillage from pipes and over-flow from stillage ponds can cause soil and water pollution. It is important, therefore, to have adequate procedures for dealing with such accidents. A number of technologies exist for disposing of stillage and/or utilizing methane, including electricity production in high-efficiency gas turbines. We have not considered such options in this study. This is an area that could be explored further in future analyses.

13.3.4 Greenhouse-gas emissions
Anticipated greenhouse-gas emissions on site were found to be negligible. Net CO₂ emissions from the sugarcane itself and from energy use for sugar and/or ethanol production are close to nil, as the cane crop would be grown on a renewable basis and the

<table>
<thead>
<tr>
<th>Sucrose strategy</th>
<th>Excess Bagasse (tonnes)</th>
<th>Molasses (tonnes)</th>
<th>Stillage (1000 of liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REF CEST BIG-CC case</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Atmospheric Pressure</td>
<td>Pressurized Gasification</td>
<td></td>
</tr>
<tr>
<td>Sugar only</td>
<td>72,497</td>
<td>0</td>
<td>66,586</td>
</tr>
<tr>
<td>Ethanol only</td>
<td>87,073</td>
<td>0</td>
<td>66,586</td>
</tr>
<tr>
<td>Sugar plus ethanol in fixed quantities</td>
<td>72,497</td>
<td>0</td>
<td>66,586</td>
</tr>
<tr>
<td>Sugar and ethanol with flexible production</td>
<td>72,497</td>
<td>0</td>
<td>66,586</td>
</tr>
</tbody>
</table>

Table 47: Estimates of annual waste flows. Stillage based on a 12:1 ratio to ethanol production.
factory processes in all of the scenarios rely exclusively on bagasse as an energy carrier. Those emissions that would occur would arise from land clearing during the establishment of the Estate, from farming machinery and trucks used at the Estate, and from transporting products to markets.

If ethanol were produced and used as a substitute for gasoline, a net reduction in CO$_2$ emissions would occur. Of the three most economically viable scenarios, only CEST3F, in which fixed quantities of sugar and ethanol are produced, involves ethanol production. The maximum realizable production capacity of this scenario is 9.2 million liters (see Table 42). Assuming that this ethanol was blended with gasoline, it would avoid 20,132 tonnes of CO$_2$ annually.

If policy measures were enacted to compensate for the 5 US¢/liter revenue deficit from ethanol production in the other annexed distillery scenarios, 13.2 to 23.7 million liters of ethanol (depending on whether A or B molasses were used) could be produced to substitute for gasoline (see Table 42), thus avoiding 29,029 to 52,228 tonnes of CO$_2$ emissions annually. Assuming that this was achieved through a 5 US¢/liter subsidy, the cost of avoiding these emissions would be 5 US¢/liter or 23USD/tonne of CO$_2$. Adopting the use of gasohol would also allow for the replacement of lead while avoiding the necessity of employing other octane enhancers, such as MTBE.

### Table 48: Potentially significant biophysical impacts and possible mitigation measures.

<table>
<thead>
<tr>
<th>Process</th>
<th>Activity</th>
<th>Impacts</th>
<th>Possible Mitigation measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Preparation</td>
<td>Land Clearing</td>
<td>Ecological changes</td>
<td>Avoid land containing key ecological components</td>
</tr>
<tr>
<td>Cane production</td>
<td>Fertilizer application</td>
<td>Soil acidification,</td>
<td>Control with lime and other agents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water eutrophication</td>
<td>(fertilizer, monitor water quality)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Creation of water reservoir</td>
<td>Possible increase in Bilharzia</td>
<td>Control with natural molluscide</td>
</tr>
<tr>
<td>Infrastructure development</td>
<td>Road paving and urban development</td>
<td>Deforestation and loss of forest resources</td>
<td>Promote more efficient fuelwood use</td>
</tr>
<tr>
<td>Sugar production</td>
<td>Cane milling</td>
<td>Production of bagasse</td>
<td>Use as fuel in efficient cogeneration units, use surplus bagasse to produce pellets</td>
</tr>
<tr>
<td>Ethanol production</td>
<td>By-products</td>
<td>Production of stillage</td>
<td>Use stillage as fertilizer and monitor water quality</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Apply stillage on gravel roads</td>
</tr>
</tbody>
</table>

13.4 Summary of implications of the development scenarios on the biophysical environment

From the analysis of the environmental implications of the scenario outputs, six activities have been identified as having potentially significant impacts on the biophysical environment (Table 48). The majority of the potential impacts are negative and appropriate mitigation measures would be required to avoid or reduce them. Mitigation measures for each are indicated in Table 48. The suggested measures require further cost-benefit analysis in order to assess their feasibility at the project site.

The main effluents coming from the processes include stillage, filter cake, and boiler ash. These do not pose any environmental impact if they are recycled as fertilizer and applied to the agricultural fields. There would be no toxic chemicals or sulfur in the boiler flue gases from bagasse combustion. Net emissions of greenhouse gases would not be significant.

A few activities depend on the scenario being evaluated. For example, the scenarios involving ethanol production would avoid the disposal problem of the molasses at the cane juice processing stage, but create a stillage disposal issue. The scenarios employing the Sugar only sucrose strategy, while avoiding the stillage disposal problem, would create a molasses disposal problem.

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4 Although ethanol has improved combustion properties compared to gasoline, giving it higher theoretical energy value, its use in modified Otto-cycle (gasoline spark-ignition) engines results in diminished engine power of approximately 80% (Goldemberg et al, 1993). With a blend of 15%, however, and allowing for improved compression and other characteristics, it is reasonable to assume minimal overall impact on fuel economy, so that blended gasoline is roughly equivalent in performance.

5 It is assumed that on average, one liter of ethanol substituted for gasoline saves 2.2 kg of CO$_2$ (Goldemberg et al, 1993).
The Reference and BIG-CC scenarios would result in surplus bagasse that would require disposal. REF1 is the only viable scenario that would result in surplus bagasse. It is possible that this could be used to produce pellets for household cooking. This option has not been explored in this study.
14 Socio-economic implications

14.1 The baseline scenario

The baseline scenario examines the consequences of not implementing a project. It excludes the external political consequences arising from outside, for example war or peace in the DRC. If a project were not implemented, the existing political, socio-economic infrastructure and lifestyles of the people in the project area and its environment would continue. By definition, this means that the baseline environment would be different than that found in Luena today, by virtue of continued activities over time, but there would be no relative impacts of the project.

In reality, there is one potentially significant negative social impact of not implementing a project. This is due to the fact that the Luena Sugar Project was introduced to the area as an idea in the late 1970s and series of subsequent feasibility studies on the project over the last 20 years or so have raised hopes and expectations among the local population about project implementation. Thus the baseline social environment includes a positive expectation regarding the implementation of the project. There would be a negative social impact if it were to be made clear that this expectation will not be met. The severity of this potential impact is not possible to quantify. However, it is interesting to note that it was one of the few issues of concern that was raised at all three stakeholder meetings (see Table 49, Implementation, “Project should be implemented as soon as possible” and “Local people have been waiting for the project for too long”).

<table>
<thead>
<tr>
<th>Issue</th>
<th>Specific aspects</th>
<th>Meeting at which the concern was expressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resettlement</td>
<td>Need for resettlement</td>
<td>Lusaka</td>
</tr>
<tr>
<td></td>
<td>Population to be resettled</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Target area for resettlement</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Type of compensation</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Retention of homesteads in Estate area</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Transportation to resettlement area</td>
<td></td>
</tr>
<tr>
<td>Land/cane growing</td>
<td>Location of cane fields</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Will local people sell cane to Estate</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Assistance to local people to grow cane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Will Estate buy local cane varieties in the area</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Competition between cane growing and food production</td>
<td></td>
</tr>
<tr>
<td>Local benefits</td>
<td>Benefits to local people</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Project’s direct benefits to Chiefs</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Provision of social services: schools, clinics etc.</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Project to bring electricity to area</td>
<td></td>
</tr>
<tr>
<td>Health</td>
<td>Project may increase malaria</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Food shortage due to cane growing</td>
<td>x</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Roads into area to be improved</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project to build schools and clinics</td>
<td></td>
</tr>
<tr>
<td>Sustainability</td>
<td>Will project be sustainable</td>
<td></td>
</tr>
<tr>
<td>Labor/employment</td>
<td>Size of labor force</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Where will labor force be recruited from</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Will Estate employ local people</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Competition for labor with tea Estate</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Competition for labor with Nakambala</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Will local people accept labor from outside area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assurance that wages will be reasonable</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Assurance of gender equity in labor recruitment</td>
<td></td>
</tr>
<tr>
<td>Implementation</td>
<td>How soon will project be implemented</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local people have been waiting for the project for too long</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project should be implemented as soon as possible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Who is the investor for the project</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Law requires that investor undertakes the EIA</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Production of animal feed from cane byproducts</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Project may increase CO2 emissions</td>
<td>x</td>
</tr>
<tr>
<td>Project location</td>
<td>Why Luena and not another area</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 49: Stakeholders’ concerns about the Luena Sugar resources project by meetings
14.2 The development scenarios

Were a sugarcane Estate to be established in Luena, the increased accessibility of the area, high concentration of the population within the Estate and its surroundings, influx of laborers from other regions, and shifts from subsistence farming to commercial agriculture and processing and from self employment to wage labor, would affect the livelihoods, lifestyles and the quality of life of the local people. At the local level, the different development scenarios would result in similar changes, and are therefore addressed collectively below. At the national level, however, there are potential social impacts that differ depending on the sucrose and bagasse strategies followed. These differences are indicated where relevant in the text on the specific impact issues below.

As discussed in section 4.2, the two methods used for identifying and evaluating potential impacts were stakeholder meetings and expert judgment analysis of expected activities associated with establishing and running the Estate. The concerns raised at the stakeholder meetings regarding the proposed project are summarized in Table 49. They are not ranked due to lack of objective criteria for doing so.

The issues of greatest concern at the stakeholder meetings were related to: resettlement; local employment opportunities; and the provision of local public services. These coincided well with the issues identified by the project team, and were included in the list of issues to be addressed in the expert analysis of the potential severity of anticipated impacts. To these, the project team added local issues related to: demographics and the tribal social structure; an overview of impacts on economic activity; human health; food security and nutrition; and infrastructure and access to natural resources. Three additional issues focused on impacts at the national level were added to the list: exports and foreign exchange earnings; electricity supply; and import substitution.

14.2.1 Resettlement

Before such a project could be implemented, the specific members of the affected population would have to be identified and a detailed resettlement and compensation plan would be required. It would be important to include the affected community in the process of developing this plan. Doing so would require a social survey of the areas proposed as resettlement locations, to assess the views of the populations living in these areas concerning the resettlement of the displaced populations prior to the implementation of the resettlement program. A monitoring program would also be needed.

Developing a resettlement and compensation plan was beyond the scope of this study. However, estimates have been made of the size and location of the affected population, specific resettlement issues have been raised, and general recommendations made.

The Estate area is in Mushota Chiefdom (Luena block) and Chama Chiefdom (Lufubu block). Based on the census data, the 1990 population in the Luena block is estimated to have been approximately 1,200 persons in 240 households. In Lufubu the population is estimated to have been approximately 2,300 persons in 460 households. The total estimated population that would be affected is 3,500 living in approximately 700 households. These people would lose their residences, land and crops. Many of the residents of the Estate area have lived there for more than five years and therefore have an intrinsic attachment to the area.

The size of the population to be relocated could be reduced if the project established small-scale plots on Estate land that can be designated for commercial sugarcane production by outgrowers. These plots could be offered to their current inhabitants or others among the population that is to be displaced. If 1,000 ha were reserved for outgrower sugarcane production on five-hectare holdings, a total of 200 households could benefit from such a scheme, thus reducing the number of households requiring distant resettlement from 700 to 500.

Based on the 1990 population census and survey respondent preferences, there are three potential areas for resettlement (see Figure 3):

- Estate extension area,
- Chama Southeast, and
- Mushota South

If expansion of the Estate is likely, then the Estate extension area in the Pambashye, Luwo and Luongo blocks should not be considered for resettlement. This would prevent having to resettle the displaced population twice. The remaining two potential areas for relocating the Estate population are Chama Southeast (700 km²) and Mushota South (275 km²). Both of these areas are within 30 km of the project site. In the 1998 survey, the views of members of the affected population about resettlement were recorded. About 84 % of those interviewed claimed to be willing to relocate. Of these, 78 % preferred relocation within the Chiefdom in which they are currently residing.
It is proposed that the population displaced from the Lufubu block be relocated within Chama Chiefdom in the southwest and that those in the Luena block be relocated within Mushota Chiefdom in Mushota South (see Figure 4). As a result of these resettlements, the population density in the resettlement areas would increase from 1.35 to 5.77 per km² in Chama Southwest and from 3.55 to 7.68 per km² in Mushota South. These new population densities are lower than the current densities in the displacement area. Unfortunately, no survey has been done in the proposed resettlement areas to determine the willingness of the existing populations in these areas to the expected newcomers.

Resettlement would change the current social composition of villages, church congregations and schools and require the abandonment of burial sites. The resettlement process would cause social disruptions, such as the disintegration of long standing social support networks in the displacement area. There would also be problems of adjustment in the resettlement area, especially for the elderly (about 9% of the displaced population) and households with school age children. Resettling the populations in village groups can minimize these disruptions.

Assistance should be provided to the displaced populations. Resettlement would particularly affect the food security of the displaced population, who would lose their cassava fields that cannot be immediately replaced in the resettlement areas because the crop takes three to four years to mature. Any compensation to the displaced population would have to take into account the following:

- Moving costs;
- Loss of houses and other structures; and
- Loss of food security (in the short, medium and long term)

Additional assistance would be required to establish new and/or increase the capacity of existing public service facilities and infrastructure, such as schools, health care facilities and access roads in the resettlement areas.

The development of a resettlement plan would be facilitated by the establishment of a clear government policy addressing the issue of relocation and compensation to the affected communities. Such a policy should provide investors with clear guidelines regarding compensation for houses, local structures in the homestead and transportation to the new area, and ensure that those relocated are able to maintain their system of livelihood.

A more detailed study and a survey in Kawambwa Tea Estate is recommended as it could guide the possible salary and management structure and could also provide other interesting socio-economic information.

**14.2.2 Demographics and tribal social structure**

Aside from resettlement, the most significant and long-term social implications of the project are likely to involve the influx of people from other regions into the local communities that will result as a consequence of the new employment opportunities generated on and around the Estate. The new members of the communities are likely to increase ethnic diversity and introduce new lifestyles to the area. This can weaken local cultural values and the traditional organization structure.

Similar experience on other sugarcane estates in the southern African region, such as Nakambala in Zambia, Dwangwa in Malawi and Triangle in Zimbabwe indicate that the labor force involved in short-term employment and the seasonal agricultural workers are likely to be dominated by single men. Married men involved in seasonal work are usually not allowed to bring their families. This can result in a high proportion of single men in the population, affecting the gender balance in the region. In other setting this has been seen to lead to behavior that is unacceptable in the local communities, such as drunkenness and promiscuity. The more serious potential consequences of such behavior include the emergence and prevalence of sexually transmitted diseases, such as gonorrhea, syphilis and HIV/AIDS. These diseases do not currently appear to be a major problem in the area.

The more serious potential consequences of such behavior include the emergence and prevalence of sexually transmitted diseases, such as gonorrhea, syphilis and HIV/AIDS. These diseases do not currently appear to be a major problem in the area. Men who are only temporarily or seasonally in the area may also enter into short-term relationships with local women. This can reduce the number of FHHDs, increase the number of illegitimate children, and destabilize family units.

At Nakambala the labor force engaged in short-term employment is not offered housing by the sugar estate. If this practice is adopted in Luena, it can result in the emergence of unauthorized settlements that persist long after the construction phase of the project because people may be unwilling to leave the area. Unemployment levels could therefore increase after the construction phase. An increase in the unemployed population in the project area would put additional pressure on local social services (especially health facilities) and on land for subsistence cultivation. These groups of people could also be settled in nearby villages and marry local women, thus increasing the cultural
diversity. Such mixing among different social groups could also lead to tensions between the local population and the newcomers, as they would be competing with each other in the social sphere.

The establishment of the Estate would create a small modern settlement inhabited by people who have little relation or allegiance to the traditional chiefs in the area. It is more likely that the modern laws and regulations would govern the new settlement and the traditional norms and customs are expected to have less impact among the new dwellers. The implementation of the project is likely to reduce the traditional chiefs’ area of influence. The modern structure of authority would increase in power.

14.2.3 Economic activity
The greatest anticipated long-term implications of implementing a development project of the scale analyzed in the scenarios are associated with indirect employment and income created as the incomes of the labor force and profits from the endeavor are spent and invested on goods, services and activities within the project area and elsewhere in Zambia. The development of a road infrastructure would improve access to and from the project area and would also be expected to stimulate the development of income generating activities both within and outside the project area. Quantifying such indirect impacts is beyond the scope of this study.

With the new agricultural activities, anticipated direct economic impacts would include considerable increases in local incomes. If the Estate purchased sugarcane from independent outgrowers in the Mushota block, it would increase cash incomes from crop production in the area. The Pambashye dam could improve the income generating potential of the affected population by increasing local potential for fishing for local consumption and sale. For such benefits to be realized, managing the dam as a fishery by introducing suitable indigenous fish species, such as Tilapia spp should be considered. The Fisheries Unit of the Department of Agriculture has introduced these species in many parts of the country to promote income generation and provide animal protein in rural areas. The project is also expected to pay ground rents to the Kawambwa district Council that would increase revenues and expenditure of the Council. This in turn could improve the council’s ability to provide services to the area.

In the short term, the purchase of materials (such as cement, timber, steel for construction of buildings and food and clothing) may create temporary increases in manufacturing activity elsewhere in Zambia.

14.2.4 Short-term employment
It is difficult to estimate short-term local employment impacts, as they relate directly to the level of investment into the project area during the construction phase of the project and the extent to which local labor is used. However, the employment-generation potentials of the main activities required for establishing the Estate can be qualitatively described.

Land clearing and preparation would be carried out mechanically and would therefore have little impact on employment. Laborers would be mostly engaged in picking and heaping small branches left behind by bulldozers. Short-term employment opportunities would be generated for constructing power lines, roads, houses, the Estate plant, public facilities (such as schools and clinics), and the Pambashye dam.

14.2.5 Long-term employment
The sugarcane plantation and factory is estimated to require 1,514 permanent employees, of which 435 would be skilled and 1,060 would be unskilled laborers. A limited number of additional jobs would be generated for the maintenance of roads and power lines. Many of the Estate positions classified as Executive (which includes supervisors) would likely be filled from a national applicant pool. However local training efforts could be made to provide permanent employment opportunities in a large fraction of the skilled, and all of the unskilled, positions.

An opportunity exists to strive for gender balances when filling the almost 1,500 skilled and unskilled positions. Women could fill a wide range of the required positions in the industrial and managerial components. Women are also known to do weeding and other agricultural tasks on existing sugarcane plantations. In fact, women currently living on the site do all but the heavy agricultural labor. The one likely exception is the 45 cane loading positions, which are likely to be offered to men due to the physical demands of the task.

Sugarcane requires a weed-free environment for the first three months. In order to increase employment opportunities manual weed control is recommended. At the Nakambala sugar estate, fertilizer application is hand-applied (Salter, 1978-79). If this method were practiced at Luena it would be an additional source of employment.
In addition to the direct employment opportunities on the Estate, the project would create jobs in the local communities. These would include jobs in the teaching, health, protective services, and merchandizing professions.

14.2.6 Seasonal employment
The Luena Estate would provide employment to 2,500 seasonal agricultural workers, most of whom would be cane cutters (see Table 27). At Nakambala, the majority of cane cutters are recruited from Kaoma district in Western province. Due to the physical demands placed on cane-cutters, these positions are commonly offered exclusively to men.

14.2.7 Health impacts
The most significant short-term health impacts would involve effects of noise and dust that would directly affect workers involved in land preparation activities. The project developer should provide noise and dust protection equipment to the workers to reduce the health effects of this activity. Most of the potentially significant long-term health impacts relate to water and the creation of a reservoir. The primary risks are increased incidence of malaria and bilharzia (schistosomiasis) and nutrient loading of drinking water.

Malaria is pandemic in Zambia. The creation of the reservoir is likely to increase the prevalence of malaria-carrying mosquitoes (by increasing breeding ground). Irrigation water storage and canals can also offer suitable breeding conditions for malaria-carrying mosquitoes. The quarries created by gravel mining for road construction, if not properly rehabilitated, can become seasonal pools of water that promote the breeding of mosquitoes that transmit malaria to populations living along the roads. The developer should be required to rehabilitate quarries rather than abandoning them. At Nakambala sugar estate, spraying to control mosquitoes is regularly undertaken to reduce the risk of malaria infection in the local population. Such a program might reduce the malaria risk at Luena. However, consideration should be given to using biological control measures, such as introducing mosquito-feeding fish, to reduce the incidence of malaria.

Dams and irrigation water storage and canals can also offer suitable breeding conditions for bilharzia snails. Apparently, bilharzia is not a major problem at Nakambala sugar estate. However, dams in Zambia have been known to increase the diversity and populations of bilharzia snails that act as intermediate hosts of schistoma germs that cause bilharzia in man (Chidumayo et al., 1998; Mungomba et al., 1993). It would be necessary, therefore, to institute measures to control bilharzia snail populations in the reservoir. The application of a natural molluscide, Phytolaca dodecandra, has proved successful in the control of bilharzia snails elsewhere in Zambia (Chidumayo et al., 1998) and its use would avoid the risk of chemical pollution that is often associated with synthetic molluscsides.

The Estate would have to meet water quality standards set and enforced by the ECZ and the Public Health Department of Local Government to safeguard human health. There is a risk of water pollution through nutrient loading, which could increase nitrate levels. It is essential to maintain low levels of nitrate in surface and ground water, especially those that are sources of drinking water. The standard for nitrate (NO₃) levels in drinking water is 45 ppm. Nitrate levels higher than 100 ppm can be toxic to infants (Salter, 1978-79).

Another concern is increased incidence of motor vehicle accidents that can occur on roads newly constructed or improved to improve access to the Estate area. It is therefore important to create an awareness program regarding possible accidents. Police enforcement of motor vehicle speed limits to reduce the risk of accidents would also be needed.

Were ethanol to be produced and blended with gasoline, emissions of several air pollutants from vehicles would be reduced. As the extent to which these emission reductions would result in reduced human exposure to the pollutants could not be quantified within the scope of this study, no attempt has been made to quantify related potential health benefits.

14.2.8 Food security and nutrition
The Luapula province is not a food surplus area, the project area produces only a small surplus for sale. Literature has also shown that the growing of non-food cash crops such as tea at Kawambwa (which is 40 kilometers from the proposed project site) exacerbates food shortages resulting in widespread malnutrition (Higgins, 1981, p131). Sugarcane and tea share the same attributes of not being staple crops. Therefore, establishing a sugarcane estate could worsen food supply in the area, especially in the short term when the relocated population would not have mature cassava tubers for own consumption and sale. At least during this period, some food is likely to be imported from other regions to meet food demand. This could lead to temporary increases in food prices.

In addition, recruiting Estate employees from other regions could gradually affect the local
population’s dietary patterns. Shifts from rural to urban settlements in Zambia have been associated with dietary shifts from cassava and millet to maize (Moore and Vaughan *op. cit.* pp182-183), western vegetables such as cabbage, and meat. In the medium and long-term, small-scale commercial farming of new crops and livestock are likely to emerge and meet the demand by the Estate workers. However, maize is likely to continue to be imported, due to the poor soils of the area.

The Pambashye dam may improve the nutrition potential of the affected population by increasing local potential for fishing for local consumption and sale.

14.2.9 Infrastructure and access to natural resources
Constructing the Pambashye dam may reduce water supply to downstream users, especially during the late dry season when natural river flows are at their minimum. However, no data exists on the level of dependence on river flow by downstream populations. If an investment project were pursued the project developer should collect such data and develop and implement a water management plan that would reduce possible negative impacts on downstream users.

Initial land clearing would remove 654,480 tonnes of potential fuelwood. Consideration should be given to using some of this biomass as domestic fuelwood for the workers, instead of burning it in the field. This would also reduce the negative effect of this activity on the emission of greenhouse gases. The possible additional impacts of biomass burning from the influx of workers were in section 13.3.

14.2.10 Public services
The proposed Estate is in an area that currently includes two primary schools, one health center at Kanengo, and a number of churches. Villagers originally built some of these facilities on a self-help basis. Those facilities that would be removed during the construction phase would have to be replaced by building new ones or increasing the capacity of facilities in the resettlement areas. Establishing new public service facilities, such as schools and clinics, could provide additional benefits if access were made available to neighboring communities. However, the influx of people into Luena may have negative social and cultural effects on neighboring communities, resulting in a whole new set of complex social and economic relations.

The establishment of the Estate would result in loss of cultural heritage sites, such as historical and burial sites. A survey of cultural heritage sites should be undertaken to ascertain their existence, status and whether they need to be preserved or replaced.

14.2.11 Foreign exchange earnings
The potential to generate foreign exchange (FOREX) earnings (or savings, in the case of ethanol) as a result of establishing a sugarcane Estate in Luena depends on both the sucrose and bagasse strategy followed. These potentials from sugar, ethanol and electricity exports for the three economically viable scenarios, CEST1F, CEST3F and REF1 are summarized in Table 50. The maximum potential sugar market for Luena in 2010 was estimated at about 150,000 tonnes (section 5.5.1.2), essentially all of which would be exported. The realizable capacity of the sugar factory at Luena was estimated as 119,786 tonnes for the three viable scenarios (see Table 42), and this is therefore the actual potential quantity exported. Assuming that the export price is 370 USD/tonne and the export markets are realized, the annual increase in FOREX earnings would be approximately 44 million USD by 2010.

For ethanol, the calculation is based on a gasoline price of 84 cents per liter in 2010 (Table 13) and a price mark-up of 2.5, resulting in FOREX savings of approximately 3 million USD per year, assuming 9.151 million liters of ethanol (Table 42). For electricity, assuming that exports of electricity are in the same proportion to total electricity production as for Zambia as a whole, the exported electricity would vary from 45 to 49 GWh per year for CEST1F and CEST3F, respectively, with FOREX earnings as shown in Table 50.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sugar (1000 metric tonnes)</th>
<th>Ethanol (1000 metric tonnes)</th>
<th>Electricity (GWh)</th>
<th>Total FOREX (million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEST1F</td>
<td>44,321</td>
<td>7,665</td>
<td>51,986</td>
<td></td>
</tr>
<tr>
<td>CEST3F</td>
<td>44,321</td>
<td>3,075</td>
<td>55,674</td>
<td></td>
</tr>
<tr>
<td>REF1</td>
<td>44,321</td>
<td>—</td>
<td>44,321</td>
<td></td>
</tr>
</tbody>
</table>

Table 50: Estimated foreign exchange potential increase (in 1000 USD) by the year 2010 for the three economically viable scenarios.

14.2.12 Increased electricity supply
If a scenario involving surplus electricity supply were adopted the Estate would contribute towards the country’s need to increase national electricity supply capacity in a manner that is environmentally...
sustainable and does not involve the scale of investment that would be associated with current supply-expansion plans (see section 5.5.3). All of the scenarios involving electricity export from the Estate assume that the surplus would be sold and transmitted over the national grid.

While those living on the Estate would have access to electricity, exporting a surplus to the grid does nothing to ensure access to local communities. However, installing the distribution infrastructure necessary for the Estate (see section 10.2.2) would bring nearby communities closer to the grid, both physically and economically, thereby improving the options for connecting these communities to the national grid. Given the proximity of national grid infrastructure, the option of using surplus electricity from the Estate to supply these communities directly has not been explored in this study.

14.2.13 Import substitution

Import substitution is primarily an issue related to ethanol production (related to the choice of sucrose strategy), due to the potential to avoid oil imports. Table 50 gave the FOREX savings from oil import substitution in the case of the CEST3F scenario. Increasing ethanol production would make further contributions to import substitution and FOREX savings. A subsidy of five cents per liter is sufficient to make expanded production scenarios economically attractive (as shown in section 12.3.8). If the flexible production scenarios were supported through policy measures to provide this subsidy, 13.2 to 23.7 million liters of gasoline (depending on whether A or B molasses was used) could be displaced. Using the same assumptions from section 14.2.11, the annual FOREX savings would then range from 3.8 to 6.8 million dollars, which implies additional FOREX savings of approximately 1.2 to 4.2 million USD, in comparison to the CEST3F scenario.

14.3 Summary of potentially significant social implications of the development scenarios

Potentially significant negative social impacts that would require mitigation include are listed in Table 51. Many of the negative social impacts are likely to be disproportionately distributed in the population. For example, some impacts may affect vulnerable groups such as women and children more than others. A deliberate program to minimize the adverse impacts on vulnerable groups in the population should therefore be developed early in the project and adhered to.

<table>
<thead>
<tr>
<th>Social Impact</th>
<th>Possible Mitigation measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short term</strong></td>
<td></td>
</tr>
<tr>
<td>Loss of public and private village infrastructure</td>
<td>Direct compensation</td>
</tr>
<tr>
<td>Food insecurity</td>
<td>Fast replacement of public infrastructure</td>
</tr>
<tr>
<td></td>
<td>Short term food provision and economic support</td>
</tr>
<tr>
<td></td>
<td>Direct crop compensation and mixed cropping (maize, rice, millet</td>
</tr>
<tr>
<td></td>
<td>and sorghum)</td>
</tr>
<tr>
<td><strong>Long term</strong></td>
<td></td>
</tr>
<tr>
<td>Disruption of village settlement patterns</td>
<td>Resettlement areas should be similar to the existing settlements.</td>
</tr>
<tr>
<td></td>
<td>Villages should be relocated as one entity where possible.</td>
</tr>
<tr>
<td>Demographic changes and social disruptions</td>
<td>Public health campaigns</td>
</tr>
<tr>
<td></td>
<td>Family support programs</td>
</tr>
<tr>
<td>Changes in traditional authority</td>
<td>Public consultation on ground rent and land authority</td>
</tr>
</tbody>
</table>

Table 51: Potentially significant negative social impacts and possible mitigation measures

The following measures would contribute to minimizing these impacts.

- Involving Chiefs, village headmen and the District Council in developing and implementing the resettlement plan. The plan should include explicit provisions for providing compensation where appropriate and for expediting the replacement of public and private infrastructure.
- Recruiting as much of the general labor force as is possible from the project area. The estimated available labor force in 1990 comprised 2,376 people. The majority of the respondents (91%) in the 1998 survey expressed an interest in working on the Estate. Efforts should also be made to train where necessary and hire local women in positions at the Estate.
- Carrying out public health campaigns to sensitize and educate the labor force and general public in the area about the prevention and dangers of sexually transmitted diseases, including HIV/AIDS. Triangle Estate in Zimbabwe has special health education campaigns, which are funded by the Estate.
• Encouraging seasonal agricultural workers to bring their wives, especially those that have served for more than one year. This is practiced at Triangle in Zimbabwe.

• Involving Chiefs and village headmen and the District Council in the control of unauthorized settlements in and around the Estate and casual integration of outsiders into local village communities.

The potentially significant positive social impacts that are inherent to the development scenarios are primarily economic, and include employment generation and the promotion of rural development as well as impacts on the national economy. There are significant potential foreign exchange savings from exports of sugar and electricity. Production and (domestic) sale of ethanol substitutes for gasoline, thereby providing foreign exchange savings and health and environmental benefits at a national level. The reduction in CO₂ emissions through use of ethanol could open up international and investor interest on the basis of climate mitigation efforts. Opportunities for additional economic and non-economic benefits could be harnessed if efforts were made beyond what would normally be expected from a private-sector investor in the Estate.
Summary and Conclusions

15.1 Objective, goal and scope
Possibilities for expanding sugar production in Zambia by establishing a new cane estate in Luena have been discussed for a quarter of a century. What is different about this study? This is the first study performed by a neutral project team that attempts to objectively evaluate the resource options for a new cane estate in Luena from a development perspective. The objective of this study was to provide an independent source of information for decision makers in the public and private sectors as to the feasibility of establishing a sugarcane estate in Luena and stimulating sustainable development under a range of scenarios.

The goal of the study was to determine not simply whether an investment would pay off from a business perspective, but whether or not it would be in the best interest of the people in the region, and of the country as a whole. This development perspective is critical, due to the magnitude of the investment required from the public sector and the likely need to attract bilateral and/or multilateral support for a project.

15.1.1 Scenarios
The sugarcane plant is a multi-commodity biomass resource from which many valuable products can be derived. Applying a development perspective to the analysis required evaluating the feasibility of a range of product-oriented scenarios for using the sugarcane resource and comparing the benefits they offer.

The scenarios were based on four sucrose utilization strategies. These were classified by product:

1. Sugar only (the traditional approach);
2. Ethanol only;
3. Fixed quantities of sugar and ethanol; or
4. Flexible quantities of sugar and ethanol.

Each of these primary scenarios were analyzed for three different options with respect to bagasse utilization for cogeneration:

a. No surplus electricity generated (reference case);
b. Surplus electricity with a Condensing Extraction Steam Turbine (CEST); and

The sucrose strategies and bagasse utilization options were combined to produce a total of twelve primary scenarios. The analysis encompassed technical, economic/financial, social and environmental aspects of the scenarios.

15.1.2 Limitations of the study
The scope of this study was limited in several important respects. Further analysis is required before an actual project proposal should be considered. Such investigations should begin with the implementation of cane trials, to provide detailed information regarding agronomic conditions on the site and the performance of different cane varieties. In parallel, two issues related to product costs and markets need to be analyzed in depth. A wider range of sensitivity analyses with respect to expected product markets and prices is needed. A detailed analysis of transport costs and their impact on competitiveness in domestic and regional markets would also be required. A full Social Impact Assessment should be carried out, including the development of a resettlement strategy. Finally, an investment analysis to identify and evaluate specific financing options is needed.

15.2 Main findings

- The baseline scenario (with no sugarcane estate) would mean continued degradation of the natural environment on and around the study site. This result suggests that action should be taken to address dwindling forest cover and related environmental degradation, even if a sugarcane investment is not made.
- Significant opportunities exist in Luena to use sugarcane resources as a vehicle for sustainable development.
- Given GRZ expectations for economic and population growth over the medium term, there appear to be significant market potentials (both domestic and export) for the sale of all three primary products addressed in this study (sugar, ethanol and electricity).
- More than one financially viable option appears to be available, although more variation in prices and demand must be analyzed.
Regardless of the scenario chosen, establishing a sugarcane estate would require investments in public infrastructure in the order of 30 million USD.

Measures are available for avoiding and/or mediating all of the potentially significant negative environmental and social impacts associated with the scenarios.

Local support exists, including tribal chiefs and villagers as well as businessmen and local politicians.

Government interest exists.

The potential risks and benefits of establishing a new sugarcane estate in Luena depend as much on how any given scenario is implemented as which scenario is implemented.

**15.3 Prospects and prerequisites for implementing a project**

**15.3.1 Financially promising options**

The financial viability of the scenarios was analyzed by evaluating their internal rates of return, net present value, and payback periods. The most profitable scenario (CEST1F) maximizes sugar and surplus electricity production. The second most profitable scenario is one in which sugar and ethanol are produced in fixed quantities with full electrification (CEST3F). The traditional sugar-only scenario with no surplus electricity production (REF1) also ranks high (third), because of its lower investment cost, which in turn drives up the rate of return. In general, the sugar-only strategies and those with fixed quantities of sugar and ethanol production are financially viable. Adding advanced cogeneration (using a CEST\(^8\) system) to produce surplus electricity significantly increases the initial capital cost but improves financial viability.

Assuming that sugar can be sold at 370 USD/tonne but ethanol can only be sold at 45 cents/liter, as was done in this study, results in sugar production always being preferred to ethanol production. Ethanol production that does not displace sugar production is profitable. However, the breakeven price for ethanol sales was estimated to be 50 cents/liter. Hence, a subsidy of five cents per liter would be sufficient to make ethanol competitive with sugar production, from a producer perspective, at the given prices.

**15.3.2 Financing**

A deeper discussion of financing options within and outside of Zambia and their respective pros and cons is needed. The initial analysis in this study identified five potential sources of financing and cost-reduction within Zambia: the Enterprise Development Fund; the Rural Investment Fund; the Rural Electrification Fund; the Venture Capital Fund; and Investment Act Incentives. The Investment Act incentives themselves (such as exemptions from the imposition duties, value added tax, etc.) could prove a major benefit to the investors, by significantly reducing costs. However, whether or not a sugarcane project would qualify for such incentives, and if so which, is unclear: projects are evaluated and qualifications are determined through case-by-case negotiations.

A number of potential international sources of support were also identified. These include bilateral aid, the Global Environmental Facility, and the Clean Development Mechanism. Collaboration between the Zambian private sector and GRZ would be required to capitalize on such sources of support.

**15.3.3 Policy requirements**

The scenarios explored in this study assume that any investment would have to be self-sustaining (i.e., profitable). However, policy measures would be required to create an enabling environment for any of the alternatives to the traditional approach of only producing sugar and using the bagasse resource inefficiently. Electricity and gasoline pricing policies, which are controlled by the Energy Regulation Board, are key in this regard, as are policies on the imposition of duties and taxes on energy carriers. The latter are a source of uncertainty, as they do not currently exempt renewable energy resources. Harnessing the bagasse resource would require a fully operational legislative environment for Independent Power Production (IPP). Legislation allowing for IPP exists, thus concrete steps toward implementing the long-term expectation amongst policymakers of private ownership of everything but the grid have been taken. However, the policy framework for operationalizing independent power production is not entirely in place. Similarly, acquiring the broader benefits of the ethanol scenarios — such as the potential health and economic benefits outside of Luena — would require policy

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\(^7\) The interest of potential private-sector investors was not assessed.

\(^8\) CEST refers to a Condensing Extraction Steam Turbine plant, which represents the state-of-the-art among those cogeneration plants that are widely commercially available.
intervention. For an investor to choose a product strategy involving ethanol production, a domestic market for ethanol would have to be guaranteed through some type of national policy, such as a mandated blending strategy. Such intervention could be tied to the current policy to shift away from the use of leaded gasoline. As mentioned above, a subsidy would be required as well to induce ethanol production on a larger scale.

15.3.4 Stakeholder participation
To ensure the success of a Luena Project the planners would need to take responsibility for addressing the social (including gender) impacts associated with project implementation. Stakeholder participation would be a key factor. To ensure the full participation of the people in Luena who would be directly affected by the project, the project planners would need a deeper understanding of the socio-economic aspects of the project (including land tenure systems) than this study provides. Building on this understanding, they would need to instill a sense of ownership in the project proposal amongst the local people. This would require involving them in the decision-making process and ensuring that local representatives can express their opinions openly. A number of key stakeholders in the private sector also need to be included in the planning process. For example, if gasohol production were to be included in the project, auto companies' concerns would have to be addressed. Similarly, independent power production would require collaboration with electric utility representatives. Issues related to competition arising in the sugar markets would also need to be addressed, as would the capacity of supporting business structures (e.g. suppliers of parts and services) to meet the needs of the new enterprise.

15.4 Anticipated development costs
15.4.1 Public sector investment
The most recent previous formal proposal for establishing a new sugar estate in Luena called for a public-sector contribution of 196 million USD (INDECO, 1991). The scenarios in this study suggest that a successful endeavor could be achieved with a public contribution of less than 30 million USD. The primary difference between these two figures lies not in differences between cost estimates, but in differences between the assumptions regarding where the line between public and private sector responsibilities is drawn. The results of this study indicate that financially viable private-sector investment options exist despite this reallocation of responsibility for specific investment costs.

15.4.2 Mitigating environmental risks
The project does present some environmental impacts that could pose risks if action is not taken to mitigate or avoid them. Ecological changes can be addressed by avoiding land clearing in sensitive areas. Soil acidification and water eutrophication can be controlled through careful fertilization and treatment with lime and other agents. A potential increase in bilharzia can be controlled with a natural molluscide. Deforestation and loss of forest resources could be countered by more efficient fuelwood use to offset the land cleared for the estate and factory. Installing advanced cogeneration equipment and selling surplus electricity can avoid bagasse accumulation. Stillage, the organic wastewater from ethanol production, can be used for fertilizer or methane production.

15.4.3 Mitigating social risks
The project also presents some social impacts that must be compensated through short-term food/price supports and multi-cropping strategies. Disruption or loss of villages can be mitigated through direct compensation and by rapid installation of new infrastructure. Demographic changes and social disruptions can be minimized through public health campaigns, family support programs, and by recruiting as much of the labor force as possible from the local population. Relocating villages as one group wherever possible can minimize loss of kinship ties. Loss of traditional authority and cultural practices can be addressed by including tribal chiefs and headmen in resettlement and dispute resolution related to relocation.

15.5 Anticipated development benefits
A successful sugarcane estate in Luena could include the following public benefits:

- Rural development in the Luena region;
- Rural electrification;
- Improved land-use management;
- Health improvements through reduction of air pollutants, including lead;
- Sustainable livelihoods for employees at the estate and factory;
- Stimulation of demand for new goods and services as a result of increased income of local residents;
• Stimulation of new businesses and jobs for transporting, distributing, marketing, etc. of final products;
• Stimulation of new businesses and jobs in supporting industries, in supplying goods and services to the estate and factory;
• Reduced petroleum imports leading to foreign exchange savings and improved balance of payments;
• Increased national self-sufficiency derived from utilization of a domestic resource;
• Contribution to providing a sustainable energy system based on renewables;
• Contribution to diversifying Zambia’s electricity supply; and
• The avoidance of carbon-dioxide emissions.

15.6 Partnerships for development
As mentioned above, the potential risks and benefits of establishing a new sugarcane estate in Luena depend as much on how any given scenario is implemented as which scenario is implemented. All of the scenarios explored involved the potential for both negative and positive local environmental and social impacts. The potential negative impacts did not differ significantly for the scenarios explored, and were all avoidable given attention in project implementation. However, whether or not the potential for broader development benefits is harnessed depends on both the scenario chosen and the actors responsible for implementing it.

Establishing a traditional sugar estate would be a financially viable strategy and could provide some of the direct economic benefits to local people in Luena. However, the alternative scenarios offer broader potential development benefits; locally, nationally, and globally. Following an alternative development path, with the aim of acquiring these benefits, would require that choices be steered in directions that might not be chosen if left entirely to an entrepreneur.9 Hence, the successful implementation of a sugarcane project in Luena, from a development perspective, would require collaboration and coordination across institutional sectors: government, civil society, and the private sector. Needless to say, private-sector initiative is prerequisite to bringing about investment in and implementation of a successful sugarcane project in Luena. Civil society would have an important role to play in calling attention to and mitigating conflicts that are bound to arise between public and private interests. Government oversight would be critical for ensuring that the potential benefits of any scenario were capitalized upon and the environmental and social risks outlined above are avoided.

Collaboration and coordination within government would also be required. This is not an energy project, or a water project, or an agricultural project, or an industrial project; it is a development project. Collaboration across ministries and their departments would be critical for integrating the complex sectoral issues that the scenarios entail. That said, for a project to move forward would require a Zambian driving force, a champion.

9 There is also a significant risk that some of the direct economic benefits of the project would leave the country if the project were handled following a strict laissez faire policy.
References


Chidumayo, E.N. 1997.


GRZ. 1997. Report by the Technical Committee to the Committee of Permanent Secretaries on the proposed Luena Sugar Project.


Kumar, Managing Director-Zamtel during policy interviews, Private Communication, July, 1999.
Tate and Lyle 1978. Luena integrated agricultural project. INDECO Ltd., Lusaka.


