CHAPTER 5

# TECHNICAL AND ECONOMIC VIABILITY OF BIOFUEL PRODUCTION CHAINS

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## 5. INTRODUCTION

Bioenergy development will depend on how far the existing agro-industry is able to transform biomass to biofuel production, and the roles that public and private investment may have on the development of the sector[1]. These factors are key determinants on the economics of the biofuel industry and are fundamental to determine the potential for the eventual commercialization of biomass-derived fuels, in particular in developing countries. In the case of Tanzania, industrialization for biofuel production will probably bring about the installation and acquisition of new and foreign technologies. A key priority is to fit these technologies more closely to the country's conditions paying particular attention to the availability of local capacity and skills for the maintenance and operation of bioenergy plants. Moreover, if local capacity is low, future perspectives for building capacity and the associated supplier market should be considered. The results of this work provide information on estimates for cost of biofuel production based on local conditions in the country, make recommendations on biomass to biofuel technology pathways that are more adaptable to the country and raise issues and needs to enable and make the sector more competitive.

A technology capacity assessment indicated that the technological capability of Tanzania is limited and as such investment is needed to build human capital to ensure that technical personnel capable of handling industrial equipments and having the ability to solve possible operational problems is available to support biofuel development. Moreover, availability of the necessary skill set will also support the introduction of more advanced technologies to lower production costs and optimize economical profitability which will generate larger taxes from these profits. Furthermore, establishment of co-products (biocompost, biofertilizers and electricity) markets produced from by-products from the biofuel production chain is important because its sales significantly raise the competitiveness of the overall process, making the industry more profitable and bringing additional revenues to the government. In the case of Tanzania, for example, estimated revenue from bagasse-electricity could generate approximately USD5.7 million in sales.

1 From *Biofuels, Agriculture and Poverty Reduction* published by the Overseas Development Institute in Natural Resources Perspective volume 107 on June 2007.

The detailed breakdown on biofuel production costs indicated that feedstock prices are a significant part of the production costs and as such an important component in the economic viability of biofuel production in Tanzania. If the biofuel promise to rural development is to be realized supportive measures in the agriculture sector to increase yields need to be led by the government and/or in cooperation with potential investors. In particular there is a need to reach out to outgrower producers. Outgrower skills need to be nurtured and technical assistance provided to help maximize yields. As such, greater accessibility to on-farm technology through use of better varieties, access to training, irrigation, could be the means to improve productivity of feedstock and reduce biofuel production costs.

Other challenges that could possibly hinder development of biofuel production chains include the limited rural infrastructure - transportation (roads, rail and); potable and industrial water provision (agroprocessing and biofuel plants) and rural electrification, to effectively support and service the emerging rural industrialization. The availability of efficient and reliable transportation networks to support the connection of the various production components along the supply chain are lacking and are probable key elements to affect the profitability and thus the viability of biofuel production[2].

## 5.1 METHODOLOGY OVERVIEW

The analysis seeks to establish production costs using technology features and specific crop information. The production cost is analysed according to crop type, fuel type, and based on feedstock production characteristics and industrial technology conversion schemes. Within the analysis, scenarios are identified to determine how much fuel is to be produced, what feedstock is to be used in the process and who is to supply the feedstock i.e. smallholder (outgrower), commercial (estate) or mix of both (outgrower scheme). These scenarios are built based on information collected in the country and to a large extent reflect potential biofuel investment ventures. The production cost is then estimated based on these production characteristics and its competitiveness in the domestic and international markets assessed[3].

## 5.2 THE TANZANIA CONTEXT

### 5.2.1 TECHNOLOGY ACCESS CONDITIONS

A three-tier assessment criterion was established to evaluate the technology capacity in the country. The first tier of criteria is based on the human skills that are necessary to support a biofuel processing operation; this includes both skilled and unskilled labour. Areas assessed were engineering capacity in both basic and more specific fields, including microbiology and biochemistry, and technicians (electrical and plumbing). The second tier

2 Biofuel production is defined from here on as the conversion of biomass to biofuel.

3 A techno-economic analysis was prepared by the National University of Colombia at Manizales under the guidance of the BEFS team. The consultant's report was used as a technical background document. The technical document is available upon request.

focuses on access to technologies from local suppliers and provision of services. This tier evaluated the existing capacity for manufacturing and technology development of biofuel processing equipment required. Finally, the third tier focused on access to processing inputs for operating biofuel plants, including chemical, solvents, additives, etc. The results are summarized in Table 5.1.

TABLE 5.1

**Assessment of biofuel technology access and human capacity for Tanzania**

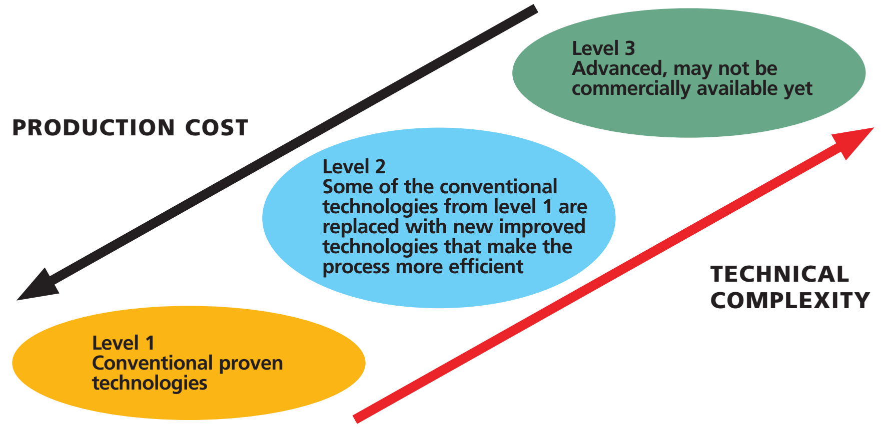
| Element of analysis | Qualitative valuation | Summarized description |
|---|---|---|
| Tier 1 | Insufficient | *Basic engineering:* There are departments of civil, chemical, biochemical and food engineering in six universities. There is one engineer per each 500 inhabitants. Practically, there are no research master's and Ph.D. programmes in the cited careers or areas related to biofuels. |
| | Deficient | *Microbiology, biochemistry and similar:* there are no evident developments in these areas that could support this type of project. |
| | Deficient | *Electric and electronic engineering, automatic control:* there is a limited existence of programmes in these areas in the universities. Automatic control is not under research in the country and does not reach the levels required by this type of project. |
| | Deficient | *Specific engineering:* design and construction of equipment. The country does not have its own developments in this area. |
| | Deficient | *Local capacity to supply maintenance services for equipment* and basis accessories (pipelines, electric installations, boilers, evaporators, etc.), high-tech equipment (fermentors, distillation and dehydration systems, waste treatment units, etc.) is almost nil. |
| Tier 2 | Deficient | There are no *companies with experience in manufacturing equipment* for fermentation, distillation and dehydration. There are no existing companies in metal-mechanical construction. There is no indication of research and development in the area of equipment construction. |
| Tier 3 | Deficient | Chemicals as solvents, additives, adsorbents, etc. needed for biofuel production are not produced in the country and need to be imported at a high cost. |

### 5.2.2 TECHNOLOGY OPTIONS FOR TANZANIA

Three production technology options suitable for Tanzania were defined (see Appendix 5A for more details). The options are differentiated based on the level of complexity of the technologies involved in each of the industrial processing steps (Figure 5.1).

Figure 5.1

**Description of Technology Options for Tanzania**




## 5.3 RESULTS

### 5.3.1 TECHNOLOGY

The recommended technology option for producing fuel-grade ethanol[4] (for both sugar cane and cassava) in Tanzania corresponds to the **second level** of technological development (see Table 5.2). This takes account of the fact that technology access and transfer conditions and the adaptation of technologies in Tanzania make it more difficult (and involves a higher initial investment) to set up and implement technological schemes based on technology level option 3, i.e. schemes that have high-performance technologies that are proven worldwide generally at the pilot plant level. On the other hand, level 1 technologies option represent the easiest level to be implemented in Tanzania requiring the lowest level of conditioning as it implies already mature conventional technologies proven worldwide, which are however less efficient and potentially less environmentally friendly.

For biodiesel regardless of technology level, the lack of a local network to supply chemical inputs necessary in the production process, such as methanol and sodium hydroxide, contributes to higher production costs. Biodiesel technology level 2 requires significant excess of methanol so access to this input poses a limitation for implementation in Tanzania. Moreover, technology level 3 is in the early commercial steps and their operation is not fully proven yet. Therefore, in the case of biodiesel, the recommended technology is the **first level** of technology development (i.e. conventional biodiesel production plants).

4 Fuel grade ethanol is denatured ethanol meeting the standards and specifications for blending with gasoline for use as fuel in spark-ignition engine. The standards and specifications are defined by legislation in the country.

TABLE 5.2

**Recommended technology options**

| Fuel | Feedstock | Recommended Technology Level |
|---|---|---|
| Ethanol | Sugar cane | Level 2 |
| | Cassava | Level 2 |
| Biodiesel | Jatropha & Palm Oil | Level 1 |

### 5.3.1.1 NECESSARY CONDITIONS FOR IMPLEMENTING THE TECHNOLOGY OPTIONS

As far as the skill set required for the implementation of a biofuel programme, this includes personnel with technical training capable of handling industrial equipment and having the ability to solve possible operational problems. In particular, there is the need to have graduate engineers and semi-skilled trade-trained personnel such as plumbers, electricians, mechanics, etc. As such, a pre-requisite for Tanzania to implement a long-term sustainable successful biofuel programme requires a well-designed technology transfer that comprises the involvement of universities in the production of biofuels using different technologies and raw materials and technical teaching centres[5] to support the industry. An initial joint venture is suggested with universities to use and prepare texts which, in conjunction with simulation tools, will enable various university groups to investigate technological and scientific issues relating to biofuel production. Note that while this does not require high levels of investment, it is fundamental for solving one of the main technological access barriers facing Tanzania.

### 5.3.1.2 ISSUES SURROUNDING COST

The economic viability for biofuel production was examined by analysing the production costs associated with the three technology options for each production scenario[6]. The industrial processing of biomass to biofuel generates materials other than the principal product (i.e. ethanol or biodiesel) referred to as by-products. The analysis took into consideration the effect of having these by-products used as a raw material in other processes to generate new products. These newly generated products from the use of by-products are referred to as co-products. For example, a by-product of sugar-cane processing is bagasse; if the bagasse is used in co-generation system then the electricity that is generated by burning the bagasse is a co-product[7]. The co-products markets included exploring energy generation through combined heat and power (co-generation) potential from the use of fibrous waste generated in the biofuel process as well as the production of biofertilizers and biocompost.

5 These include vocational centres offering training on typical trades such as plumber, machinist, electrician among others

6 Production scenarios were adapted to Tanzanian conditions. The scenarios were then simulated using Aspen Icarus Process Evaluator package. In the analysis, the prices for feedstock, service fluids, labour and maintenance, operating, general plant and general administrative costs were taken from secondary sources of information. More detailed assumptions are provided in appendix 5b.

7 By-products are considered waste streams from a process. Co-products are produced from by-products through a further processing to add-value. Co-products in this analysis include biofertilizers (vinasses), biocompost, and co-generated electricity.

## 5.3.2 ETHANOL PRODUCTION COSTS BY CROP

### 5.3.2.1 SUGAR-CANE JUICE ETHANOL PRODUCTION COSTS

The sugar-cane ethanol production scenarios below were developed based on country specific data and reflect potential production option in the country (Table 5.3).

TABLE 5.3

**Characteristics of sugar-cane ethanol scenarios**

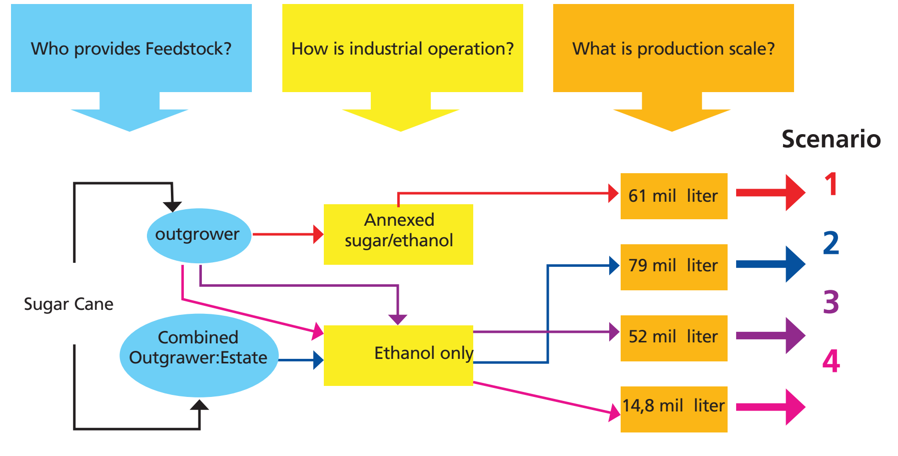
| Scenario | Description |
|---|---|
| Scenario 1 * | ■ 61 million litre capacity combined facility with sugar mill production.<br>■ Ethanol to be produced from molasses and sugar-cane juice.<br>■ Estimates additional need for 10 000 ha grown by outgrowers. |
| Scenario 3 | ■ 79 million litre stand alone facility producing ethanol.<br>■ Sugar cane comes from estate (12 000 ha) and outgrowers (3 000ha) |
| Scenario 3 | ■ 52 million litre stand alone facility producing ethanol.<br>■ Sugar cane supplied by existing outgrower producers assuming an increased in yield to generate the necessary surplus for ethanol. |
| Scenario 4 | ■ 14.8 million litre stand alone facility producing ethanol.<br>■ Small-scale production refinery located close to outgrower cluster. |

** This scenario is representative of the Brazilian ethanol production model whereby ethanol production is largely integrated with sugar mill operations*

The scenarios are schematically represented in Figure 5.2 indicating where the feedstock comes from, how the biomass to biofuel conversion operates and what scale of operation is needed.

Figure 5.2

**Sugar-cane ethanol production scenarios**



The estimated sugar-cane ethanol production cost for each scenario and each technology option is presented in Table 5.4. The level of technology directly affects the ethanol yield and as such the production cost. Technology level 3 represents the lowest cost of production for all scenarios. Although technology level 3 has the greatest investment expense, the cost of investing in a state-of-the-art technology is offset by a significant increase in the performance of the process which directly affects input materials requirements, in particular feedstock requirements. However, Tanzania's technology access and transfer conditions at present make it more difficult for the adaptation of technology level 3. Therefore over time, as the ethanol industry is built up and matures local conditions to meet the needs for deploying high-performance technologies will be in place to make the industry more efficient.

TABLE 5.4

**Sugar-cane juice ethanol baseline production costs (USD/L) at plant gate per scenario for each technology option level ***

| Scenario | Technology level | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Scenario 1 * | 0.6257 | 0.6055 | 0.5309 |
| Scenario 3 | 0.5129 | 0.4931 | 0.4338 |
| Scenario 3 | 0.6245 | 0.5857 | 0.5392 |
| Scenario 4 | 0.7369 | 0.6778 | 0.5940 |

** The baseline production costs is technology level 2 for ethanol and do not include any potential credits from co-product and co-generation sales.*

Using technology level 2 as opposed to level 1 reduces the cost of production from 3 percent to as much as 8 percent. The most significant difference comes from the cost in the maintenance category; for technology level 1 this cost is nearly three times higher than the cost of technology level 2. For example, the reduction cost between technology options levels 1 to 2 for Scenario 4 has a reduction of about 8 percent. This highlights that technology level option 2 is an economically valuable starting point for Tanzania. Moreover, it is consider that Tanzania's technology access and transfer conditions at present can uptake technology level 2 [8].

The production costs estimated for technology level 2 ranges from USD0.493 to as much as USD0.677 per litre[9]. As such the baseline production costs of production estimated for Tanzania for technology level 2 are higher compared to the cost reported in Brazil and Colombia, where production cost estimates range between USD0.27 to USD0.30 per litre

8 From here on the document discusses technology level 2 for ethanol production as the baseline for Tanzania.

9 The simulated sugar cane to ethanol yield ranges from 68 to 80 litres per ton of sugar cane and is contingent up on the technology level option and production scale.

of ethanol produced using sugar-cane juice as raw material. These costs are however closer to those estimated for India (US$0.48-US$0.55 per litre) and lower than the sugar-based ethanol production costs in the EU (USD0.76-USD0.78 per litre)[10].

*Discussion on findings and key issues for sugar-cane ethanol production*

- One of the reasons for higher ethanol production costs in Tanzania relates to the high production cost associated with the sugar-cane crop which is twice as costly as in Brazil and Colombia[11]. In the case of Tanzania, the factory gate price of sugar cane (i.e. including transport costs) was estimated to be USD0.027 per kg compared to, for example, the cost of USD0.012 per kg in Colombia. Although the lower cost of sugar-cane crop production could be explained in part by the quality of soils and climate conditions found in Brazil and in the case of Colombia to a full year harvest, the lower production costs are also the result of improvements in agricultural yields. For example, both Brazil and Colombia have supported programmes to produce and introduce new and improved cultivar varieties that are more resistant to drought and pests, along with higher yields and higher sugar contents. Moreover, Brazil's success as the world's most efficient ethanol producer comes from the support on R&D and innovation programme that have helped improve efficiencies in both the agricultural and industrial phases. This programme was first instituted by the government and later on taken up by the private sector[12].

- The economic impact from the sale of co-products reduces the production costs. Assuming a viable existing local outlet market for co-products in Tanzania, a reduction of biofuel production costs can be realized from potential income generation from the sale of co-products and in particular from sales on co-generated electricity. For example, in Figure 5.3, the reduction from co-product credits ranges from as low as USD0.039 to as much as USD0.059 per litre of sugar-cane ethanol. For Scenario 2, the net effect of co-products including co-generation credits shows a reduction of 12 percent over the baseline production cost[13].

- The significance from co-generation credits on sugar-cane ethanol production costs is significant because besides generating additional income from the sale of surplus electricity, it also avoids high energy costs at the plant from purchasing electricity, it also (Figure 5.3). For example, in Scenario 2 the reduction on services, which include the purchase of electricity, is decreased by almost 71 per cent.

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10 Brazil, India and EU production costs are from the 2007 LMC International Starch and Fermentation Raw Materials Monitor Report. Note that since sugar cane is not produced in EU, the sugar-based ethanol production from EU may include sugar from beets and imported sugar from cane.

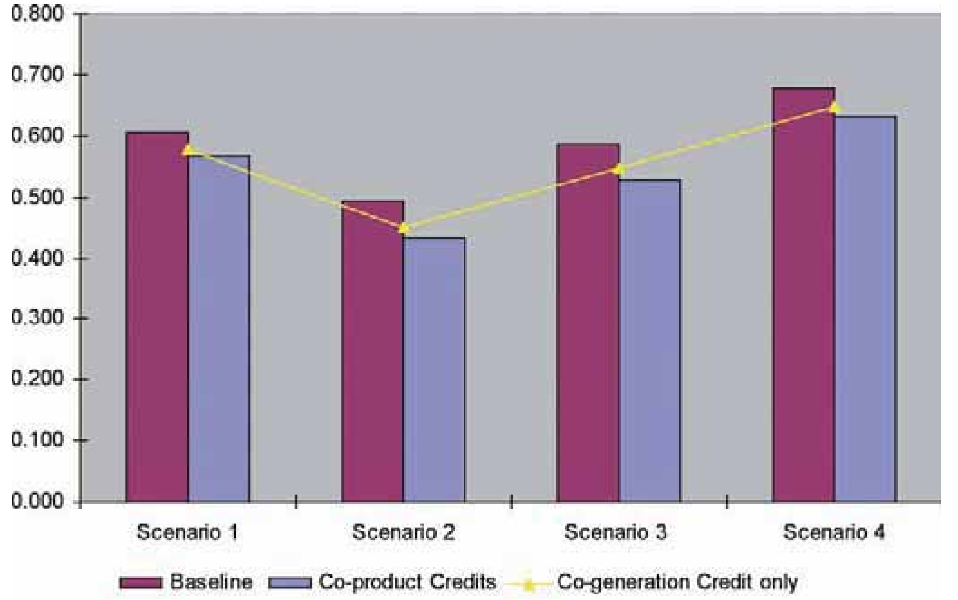
11 The cost of sugar cane production in Colombia comes from Fuel ethanol production from sugar cane and corn: Comparative analysis for a Colombian case publication by Cardona *et al.* The article is published on Energy, volume 33, issue 3 March 2008, Pages 385-399.

12 This information comes from the report on Bioenergy for Sustainable Development and Global Competitiveness: The case of Sugar Cane in Southern Africa published by Cane Resources Network for Southern Africa (CARENSA) in 2008.

13 The baseline scenario comprises ethanol technology level 2 without accounting for co-product credits.

Figure 5.3

**Molasses ethanol production scenarios**




*Why co-products matter?*

In countries with advanced biofuel production such as Brazil, Colombia and the USA, the co-products markets are well-developed and generate revenues to the industry. In Colombia the processed vinasse that contains high volumes of potassium, phosphorus, and magnesium, is sold as fertilizer (biofertilizer). The annual vinasse sales return is estimated at approximately USD40 million to the industry. In Brazil the surplus power capacity from bagasse is estimated at 509 MW. At current electricity tariffs ranging from USD66.1 to USD71.1 per MWh, the revenues from co-generation account for approximately 15 percent of the total revenue accrued from sugar and ethanol sales[14]. In Mauritius the bagasse-based electricity exports to the national electric grid were estimated at 53 MW and sale returns estimated at 23 million dollars[15]. To show the economic implications of a co-product market in Tanzania, the potential from Scenario 2 is analysed. Under this scenario there is a surplus electricity of 10 337 kW that can be sold to the grid. The analysis estimated that the cost to co-generate electricity from bagasse range from USD0.040 to USD0.062 per kWh which is lower than the estimated price of USD0.066/kWh that Tanzania currently pays to Independent Power Provider (IPP). Using the above price paid to IPP, the estimated revenue from bagasse-electricity based on Scenario 2 could generate about USD5.7

14 The information comes from the report on Cogeneration Opportunities in the World Sugar Industries, prepared in April 2009 by the International Sugar Organization.

15 Information was taken from Cogeneration Opportunities in the World Sugar Industries published by the International Sugar Organization in April 2009. Note that the data in the report is given in GWh units which were converted to MW by multiplying 1 000 and dividing by 8 760. The recommended sale price per KWh is assumed to be Rs.1.59 which is estimated to be USD0.05.

million in sales[16]. Moreover, cogeneration may also bring additional revenues from Certified Emission Reduction (CER) credits within the terms of the Clean Development Mechanism (CDM) which can help improve market conditions and facilitate recovery of capital investment costs.

### 5.3.2.2 MOLASSES-ETHANOL PRODUCTION COSTS AT FACTORY GATE

Molasses is a low value by-product of the sugar industry that can be used as raw material for several processes including ethanol production. The molasses-ethanol scenarios developed for Tanzania explore the opportunity for using the molasses generated as by-product from the sugar mill operations in the country for ethanol production (Table 5.5 and Figure 5.4).

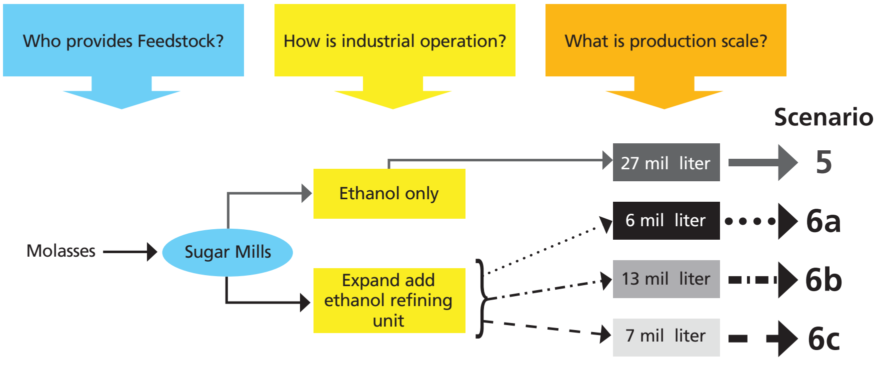
TABLE 5.5

**Characteristics of molasses ethanol scenarios**

| Scenario | Features |
|---|---|
| Scenario 5 | •Centralized facility.<br>•Molasses are purchased from all sugar mills and transported to facility. |
| Scenario 6a | •Facility co-located to sugar mill A in the country.<br>•Production capacity based on amount molasses from sugar mill A. |
| Scenario 6b | •Facility co-located to sugar mill B in the country.<br>•Production capacity based on amount molasses from sugar mill B. |
| Scenario 6c | •Facility co-located to sugar mill C in the country.<br>•Production capacity based on amount molasses from sugar mill C. |

Figure 5.4

**Molasses ethanol production scenarios**




16 The Standardised Small Power Purchase Tariff in 2009 in Tanzania is 85.66 TZS/kWh (or USD0.06/kWh). This tariff is used to calculate the revenue from bagasse-electricity for Scenario 2. The 10 337 kW are estimated to be around 90 552 120 kWh for Scenario 2.

Overall, the lowest production cost per litre of ethanol is for technology level 3 (Table 5.6). Under technology level 3 for Scenario 6c the production price is reduced by 17 percent with reference to technology level 1. This is because in the case of the least developed technology (level 1), the indirect plant expenses could be twice as high as those of technology levels 2 and 3. Technology level 1 is less efficient and needs more supervision to operate within a minimum safety margin while the higher-level technologies involve capital-intensive automated systems that are much more efficient operationally and lessen production cost. Comparing the production costs between level 2, which is the recommended technology for implementation in Tanzania, and technology level 1 it shows that as much as 10 percent reduction takes place when technology level 2 is used.

TABLE 5.6

**Molasses ethanol production cost (US$/L) at plant gate per scenario per technology level**

| Scenario | Technology level | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Scenario 5 | 0.7636 | 0.7352 | 0.6711 |
| Scenario 6a | 0.8225 | 0.7356 | 0.6796 |
| Scenario 6b | 0.6630 | 0.6217 | 0.5686 |
| Scenario 6c | 0.7955 | 0.7104 | 0.6541 |

The baseline production cost for the technology level 2 ranges from USD0.621 to USD0.735 per litre of ethanol. These production costs are higher than those reported for other countries such as Brazil, India, South Africa and Thailand (less than USD0.60 per litre) but closer to values estimated for the USA and the EU[17] (between USD0.60 to USD0.70 per litre)[18].

*Discussion of findings and key Issues for molasses ethanol production*

- The lowest production costs were obtained from Scenario 6b because this sugar mill produces the largest volume of molasses per year in Tanzania and can exploit economies of scale. The production cost for Scenario 6b is close to the molasses-ethanol cost reported by the USA and the EU.
- Scenario 5 is not a viable option at present because the amount of molasses produced in the country is not sufficient to effectively meet economies of scale. Moreover, molasses is a bulky material and for production in a centralized ethanol facility like in Scenario 5 requires transportation. The transport costs, which according to literature in Tanzania can be significant, contribute also to the higher production costs for Scenario 5. Therefore, in the case of Tanzania drawing feedstock supplies

17 Note that molasses used in EU for ethanol production may come from sugar beet.

18 Production prices from Brazil, India, South Africa, Thailand, EU and US are taken from the LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

from multiple sugars mills to a centralize ethanol refinery operations at one place is impracticable.

- The integration of ethanol distilleries in existing sugar mills is an attractive model because it can help ensure a profitability for the sugar industry by shifting production between ethanol and sugar in response to world market sugar prices. Moreover, in the molasses-ethanol scenarios the lower production costs were obtained for integrated facilities in Scenarios 6a, 6b and 6c when compared to the centralized ethanol facility in Scenario 5. Integrated or combined sugar/ethanol facilities are more advantageous because no transportation of molasses is required.
- The largest share of the production cost for molasses-ethanol is attributed to the price of molasses. The price of molasses for ethanol production is taken to be the opportunity cost from selling molasses for other uses; in the case of Tanzania the market price was used[19]. The prices of molasses are characterized by instability because the sugar producers can sell these at different prices responding to the market. In this case it was advisable to use a value for molasses that cost between USD0.36 to USD0.50 per litre of ethanol. This value is significantly higher than the USD0.25 per litre price of molasses used in the Mozambique study. As such, to fully understand the dynamics of molasses market in the country, it is recommended that policy-makers engage the sugar sector in the country to assess conditions and determine if molasses-ethanol is a viable alternative.
- It is worth noting that sugar producers in the country expressed concerns on the hardships on managing the molasses by-products. The main concerns were related to high transportation costs associated with molasses and their desire to find optional markets for this product. The focus of this analysis only assessed if molasses could be a competitive feedstock for ethanol production. As such, it did not evaluate which alternative market offers the highest economic benefit for handling the molasses. Therefore, ethanol, if at all or under what conditions, is a more economically attractive market for this commodity is still to be determined.

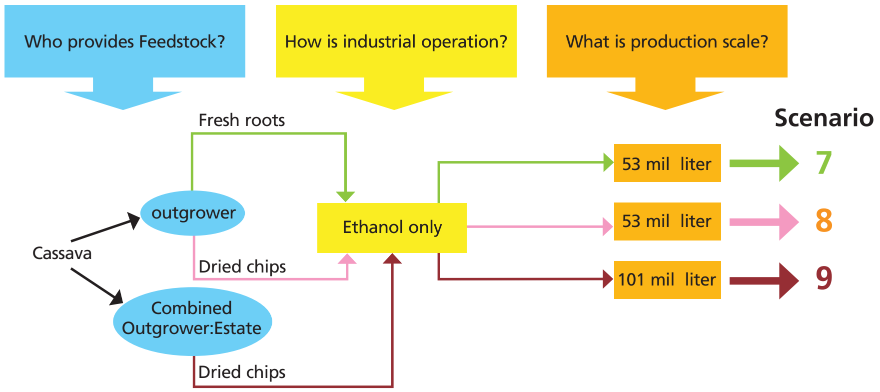
#### 5.3.2.3 CASSAVA-ETHANOL PRODUCTION COST AT FACTORY GATE

Considering cassava's rapid post-harvest deterioration and taking account of infrastructure conditions in Tanzania, it was opted to assess cassava-ethanol production from both fresh and dried cassava feedstock. Moreover, two scenarios assuming feedstock supply by outgrowers and having the same ethanol production capacity were developed but one was set to use dried and one to use wet cassava to evaluate production costs. An additional scenario was run to simulate a higher ethanol production capacity and to assess combined supply of cassava from both outgrower and estate in a 40:60 ratio respectively. The cassava ethanol production scenarios are summarized in Figure 5.5.

19 Country information indicated that at present sugar cane molasses is being sold to neighbouring countries and European markets. Therefore, the price for cane molasses feedstock was taken to be the world market priced minus cost of transportation of molasses to foreign markets.

Figure 5.5

**Cassava ethanol production scenario**




The production costs of cassava-ethanol for technology level 1 are lower than the cost estimated for sugar cane and molasses ethanol in Tanzania (Table 5.7). The more significant cost reduction factor is the scale of operation. This is illustrated by comparing production costs for Scenarios 8 and 9 for level 3 technologies. Having a larger scale of operation in Scenario 9 results in a 25 percent less production cost when compare to Scenario 8. On the other hand, shifting from technology level 2 to level 3 has relatively smaller difference in production costs when compared to scale i.e. reduction cost between level 2 to technology level 3 for Scenarios 8 and 9 is about 11 and 15 percent, respectively.

It is considered that Tanzania's technology access and transfer conditions at present can uptake technology level 2. The production costs for technology level 2 are about 7 percent less as compare level 1. Therefore, in case of cassava-ethanol technology level 2 also offers a valuable entry point for Tanzania. Furthermore, over time as the ethanol industry matures and local conditions are in place high-performance technologies in level 3 can be implemented in Tanzania making the industry more efficient.

TABLE 5.7

**Cassava ethanol production cost per scenario at plant gate per technology level (US$/L)**

| Scenario | Technology level | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Scenario 7 Fresh | 0.4506 | 0.4203 | 0.3604 |
| Scenario 8 Dry | 0.5029 | 0.4695 | 0.4172 |
| Scenario 9 Dry (larger scale) | 0.3907 | 0.3687 | 0.3118 |

The ethanol-cassava production costs estimated for Scenarios 7, 8 and 9 in technology level 2 range from USD0.368 to USD0.469 per litre which is higher than the cost estimated for medium scale wet milling production in Thailand and Vietnam (USD0.34 to USD0.40

per litre), close to production prices in Brazil (USD0.45-USD0.47 per litre), and much lower than those in China and India (USD0.60-USD0.65 per litre)[20].

*Discussion of findings and key issues for cassava ethanol production*

- Overall results indicated that cassava-ethanol is an attractive option in the Tanzanian context. Results from the analysis also indicate that inclusion of outgrowers in the production of feedstock is a viable alternative and can provide income generation opportunities for smallholder farmers.
- It should be noted that the commercial use of cassava for ethanol production requires supporting the agricultural sector to increase yields beyond the current 2 tons per ha dry basis to make sure that a new demand will not threaten the availability of cassava for food consumption.
- The cassava-ethanol production costs from fresh cassava are slightly lower than for ethanol from dried chips. However, if outgrowers are to supply the feedstock the use of sun-dried cassava chips may be more viable as fresh cassava use may be precluded due to limited transportation infrastructure in rural areas. As such, logistics options for dry processing, storage and transport of feedstock to ethanol refineries will need to be carefully assessed. The BEFS Module 1 can be used as a tool to evaluate areas having high potential for cassava production. These results can indicate the potential for development of bioenergy value chains. Moreover, this can also identify potential logistical options to improve feasibility of the value chain.
- The use of dry rather than fresh cassava is recommended to benefit integration of farmers in isolated areas. As such, Scenarios 8 and 9 provide a more realistic production option whereby fresh cassava roots are first dried to extend the shelf life, collected in centralized sites near the area of production and then the less bulky material is transported to an ethanol processing plant. These scenarios are likely to offer opportunities for smallholders in isolated rural areas to participate in the supply chain.
- The formation of associations of small-scale cassava producers could lead to small-scale agribusinesses being set up to process fresh cassava roots in sun-dried slices. This would ensure an adequate supply of raw material for ethanol production. This point is crucial in the case of cassava, since ethanol production using the fresh roots of the tuber requires a constant supply of raw material, which is difficult because the roots deteriorate rapidly and access to transport infrastructure in rural areas restricts this option.
- Fresh cassava roots, however, could be a suitable raw material in the case of medium producers in the neighbourhood of an ethanol distillery that can associate with estate plantations.

20 The production cost for ethanol from tapioca for Thailand, Vietnam, Brazil, China and India are taken from the LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

### 5.3.3 BIODIESEL PRODUCTION COSTS BY CROP

Biodiesel production was assessed from two feedstock palm oil and jatropha. Palm oil was limited to one scenario since there was already concern on the use of palm oil for fuel when Tanzania is already a net importer of palm oil for food. In the case of jatropha, three scenarios representing potential investments were simulated (Table 5.8 and Figure 5.6).

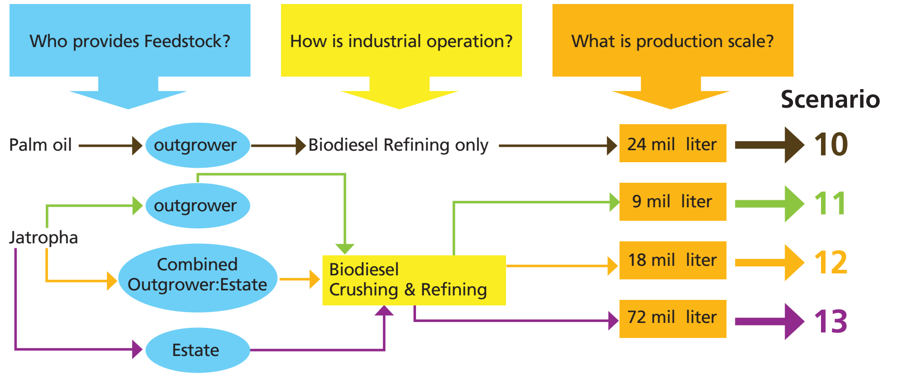
TABLE 5.8

**Characteristics of biodiesel scenarios**

| Scenario | Features |
|---|---|
| Scenario 10 | •Stand alone refinery facility only (no oil extraction), small scale.<br>•Palm oil produced from outgrowers. |
| Scenario 11 | •Combined facility oil extraction and refinery, small scale.<br>•Jatropha from outgrowers (10 000 ha). |
| Scenario 12 | •Combined facility oil extraction and refinery.<br>•Jatropha from estate (10 000 ha) and outgrowers (10 000 ha). |
| Scenario 13 | •Combined facility oil extraction and refinery larger scale.<br>•Jatropha from estate (80 000 ha) |

Figure 5.6

**Biodiesel production scenarios**




Considering the production costs estimated for technology level 1 since this is the recommended technology for biodiesel production in the country, the lowest cost for production of biodiesel is obtained from jatropha ranging from as low as USD 0.66 per litre to as much as USD 0.95 per litre (Table 5.9). In the case of jatropha biodiesel, results indicate that the most significant factor is the origin of the feedstock. Scenario 11, which is based on feedstock from outgrowers, has the least cost of production, followed by Scenario 12, whereby feedstock comes from combination estate: outgrowers production and the highest production cost is estimated for estate production in Scenario 13. Jatropha is a very labour-intensive crop and as such commercial plantations will spend substantially amount of money in hired labour. The difference between Scenarios 11 and 13 is remarkable; it costs 30 percent more to produce biodiesel from estate production than outgrowers. This indicates that integrating outgrowers in the jatropha biodiesel supply chain is a more economically attractive option.

These results indicate that changes in technology have savings on processing inputs and utility costs but these are relatively small compared to the effect of feedstock price. In the case of palm oil the import parity price of crude palm oil was taken to be USD626 per ton and the price of jatropha USD164 per ton for outgrowers and USD270 per ton for estate[21]. Therefore, for both palm oil and jatropha biodiesel feedstock rather than technology is most significant to the cost of production.

TABLE 5.9

**Biodiesel production costs at plant gate based on scenario and technology level USD/L**

| Scenario | Technology level | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Palm Oil | | | |
| Scenario 10 | 0.8302 | 0.8101 | 0.8011 |
| Jatropha | | | |
| Scenario 11 | 0.7439 | 0.6865 | 0.6687 |
| Scenario 12 | 0.8172 | 0.8171 | 0.7850 |
| Scenario 13 | 0.9551 | 0.9361 | 0.9274 |

21 Information for feedstock was collected in the country. The Palm Oil Partity Cost was provided by Mngeta, a potential biodiesel investor. The jatropha buying price from outgrowers was provided by Prokon, a biofuel investor in the country. The jatropha price in commercial (estate) production was assumed to be the production cost. The producton cost for jatropha at commercial (estate) scale was based on values provided by the World Bank in Tanzania.

Production costs of jatropha biodiesel technology level 1 in Tanzania are higher than those estimated for India (USD0.602 per litre)[22] but somewhat lower than the cost estimated for Zambia (USD0.95 per litre)[23] and closer to those estimated for Mozambique (USD0.780 per litre)[24]. In the case of palm oil biodiesel, the production costs are higher than the production costs reported in Malaysia which are estimated at USD0.69 per litre when the market price of crude palm oil is at USD670 per ton[25]. The European biodiesel market projects a lower production cost for biodiesel (USD0.58-USD0.62 per litre) but as the main feedstock is rapeseed oil this is closely linked to the vegetable oil market and could be even higher if the prices of vegetable oil commodities increase[26].

*Discussion of findings and key issues for biodiesel production*

- The feedstock price is a significant part of the production cost and as such an important component in the economic viability of biodiesel production.
  - In the case of jatropha biodiesel production, feedstock supplied by outgrowers represents a more attractive option than commercial (estate) production.
  - In the case of palm oil the price is very unstable and closely linked to vegetable oil global markets. This severely affects and puts too much risk on the development of the use of palm oil for biodiesel production.
- Limited market accessibility to chemical inputs necessary for the biodiesel production process (such as methanol and sodium hydroxide) contribute to higher production costs.
- It should be noted that the estimated production costs for jatropha biodiesel are very uncertain due to issues surrounding the feedstock availability, the need to better understand the agronomy and concerns with potential risks presented by jatropha to cassava mosaic disease. Therefore at the present time a significant potential of jatropha should be limited to small-scale production and in particular encourage energy uses for local or self consumption. One such option is the use of raw vegetable oil in power generation for domestic use in rural communities.
- It is important for Tanzanian to explore the possibility of developing other oilseed crops for biodiesel production such as moringa, castorbean, and cotton among others.
- If biodiesel production is desired the viability of this should be promoted first at the small-scale rather than at the large scale and for domestic uses rather than export markets.

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22 Production cost for India came from publication by D. Ramesh *et al.*, titled Production of biodiesel from *jatropha curcas* oil by using pilot biodiesel plant.

23 Presentation from Oval Biofuel Limited, September 2009.

24 The production costs for Mozambique are taken from the Mozambique Biofuel Assessment prepared by Ecoenergy International Corporation in May 1, 2008.

25 The production cost for Malaysia came from publication by Gregore Pio Lopez and Tara Laan entitled Biofuels - at What Cost? Government support for biodiesel in Malaysia. In the study the production cost is reported in energy equivalent. This value was adjusted to have cost on volume basis to be able to compare to production cost obtain in this analysis.

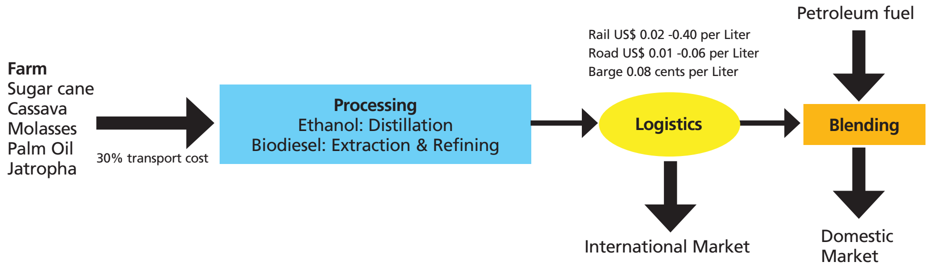
26 The production cost for biodiesel in the EU came from report on Techno-economic analysis of Biodiesel production in the EU: a short summary for decision-makers, Report EUR 20279 EN, May 2002. ftp://ftp.jrc.es/pub/EURdoc/eur20279en.pdf

## 5.4 MARKET COMPETITIVENESS ASSESSMENT

This section compares the competitiveness of biofuel production in Tanzania in domestic and international markets (Figure 5.7). The analysis focuses primarily on the production of ethanol from sugar cane and cassava. This is performed by looking at the production chain using the biofuel costs from Scenarios 2, 7, 8 and 9 and adding additional logistics costs.

Figure 5.7

**Structure of the biofuel value chain**




### 5.4.1 DOMESTIC MARKET

A simple analysis was performed for the purpose of showing how to assess the competitiveness of ethanol fuel in the Tanzania domestic market. This analysis considers transportation of feedstock and ethanol fuel considering truck and rail transport. A more comprehensive transport and distribution analysis should be carried out using detailed information on feedstock production areas generated in BEFS Module 1 and transportation networks in the country. This information can be used to help define the feedstock production areas and the most optimal site for the industrial processing and define the transportation needs, access to transportation networks and as such the transportation costs[27].

For the analysis on the competitiveness of the ethanol fuel, the production costs of ethanol are presented next to the reference sale price of gasoline (Figure 5.8)[28]. The ethanol production costs do not include any profits along the production chain as the decision regarding allocation of profits needs to be considered by the government in their decision-making process. The results indicate that there is a price difference between the production cost of ethanol and price of gasoline which indicates the potential for price margin sufficient in ethanol to cover for investments, taxes and other fees.

A price build up for blended gasoline with 10 percent ethanol was projected to assess how it will fare with gasoline. Two scenarios were defined, one where the blended gasoline

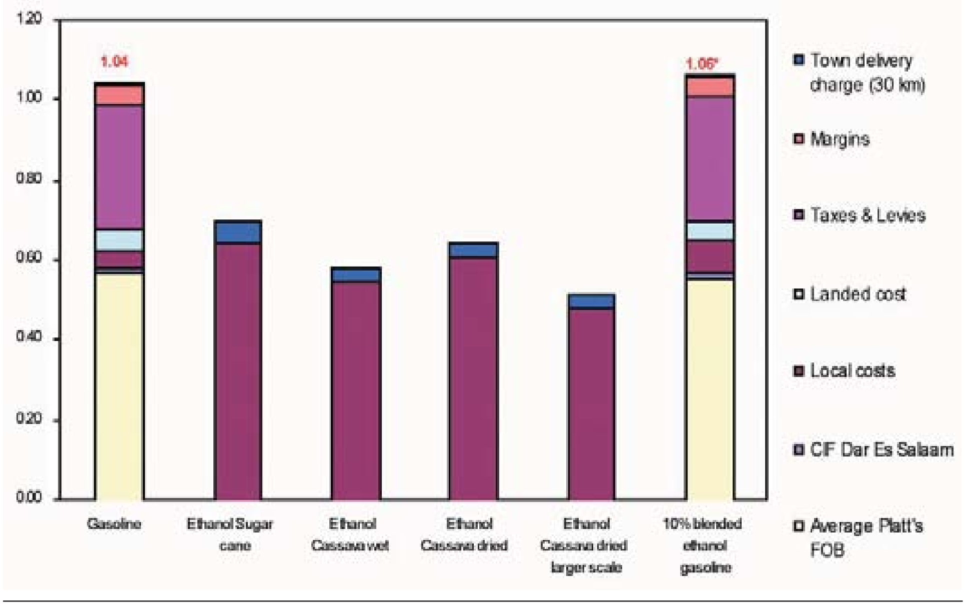
27 The assumption on the logistical cost estimated from factory to end market for sugar-cane ethanol Scenario 2 was USD0.06 per litre and for cassava ethanol Scenarios 7, 8, 9 USD0.04 per litre.

28 The referenced gasoline price was taken from values published by EWURA for October 2009. The ethanol production cost is adjusted to reflect the difference in energy content (30 percent less for ethanol). The blended gasoline with 10 percent ethanol is adjusted to the energy content i.e. 4 percent less energy in the blend as compared to 1 litre of pure gasoline

includes all levies and taxes and one where no levies and taxes were included in the 10 percent portion representing the ethanol. When taxes and levies are not included in the blended gasoline the estimated price is USD1.065 per litre. If full taxes and levies and a five percent margin profit costs are included the price is USD1.10 per litre (not shown in Figure 5.8). These values are indicative only and the main objective here is to show how biofuel production cost can be used to help policy decision in the country.

Figure 5.8

**Comparison of production cost of ethanol and imported gasoline in USD per Litre ***




* The production cost for ethanol production presented here is adjusted for energy difference between gasoline and ethanol (i.e. 30 percent less energy content in ethanol than gasoline).

### 5.4.2 INTERNATIONAL MARKET

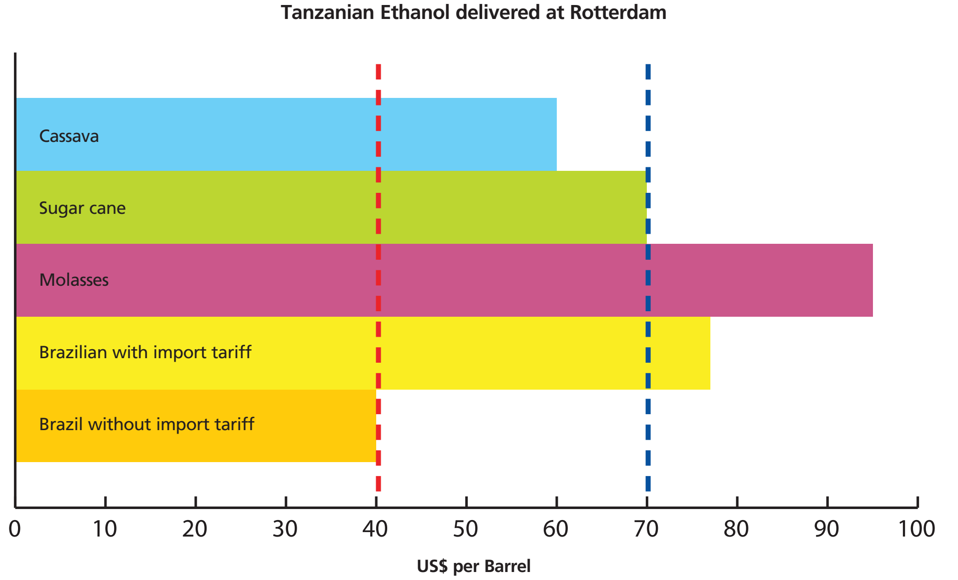
The assumption on the logistical cost estimated to transport ethanol from sugar cane and cassava was USD0.08 per litre. Based on the estimated production cost plus transportation and logistics without profit margin, the cost for delivering one barrel of ethanol to Rotterdam is estimated to be less than USD70 per barrel for ethanol from cassava and sugar-cane feedstock (Figure 5.9). The lowest cost of insurance freight (CIF) cost is obtained for cassava-based ethanol. According to literature the estimated cost of delivery of one barrel of Brazilian ethanol without profit margin to Rotterdam is around USD40 per barrel[29]. However, Brazilian ethanol has to pay an import tariff of about USD37 per barrel which Tanzania is exempt to pay under preferential treatment in the Everything-

29 The cost for Brazilian ethanol is taken by Olivier Henniges titled Competitiveness of Brazilian Bioethanol in the European Union, Department of Farm Management, University of Hohenheim Stuttgart

But-Arms (EBA) Initiative. Therefore, Tanzania's ethanol from both cassava and sugar cane are competitive and attractive options to the European export market.

Figure 5.9

**CIF values for Tanzanian ethanol in Rotterdam**




*Ethanol Cassava: dried scenario 9. Ethanol Sugar cane: Scenario2. Ethanol Molasses: Scenario 6b, Including co-product credit*

*Discussion of findings on market competitiveness*

- The price difference between the production costs of ethanol and the price of gasoline in the domestic market, even without including profits along the biofuel production chain, indicates that ethanol could be a competitive fuel option for the country.
- The potential for price margin in the ethanol production chain appears to be sufficient to cover for investments, taxes and other fees for ethanol.
- Overall, taking into account Tanzania's preferential duty and quota-free entry into European and US ethanol markets makes Tanzanian ethanol production very attractive. For example, in European markets under the EBA[30], Tanzania's biofuel production is competitive with ethanol producers with global ethanol producers who are obliged to pay the entry tariff.
- The question is whether Tanzania could also be competitive with other countries that have the same preferential tariff entry into these markets. For example, a biofuel study for Mozambique conditions estimated the ethanol production cost to be around USD0.30 to USD0.38/litre[31].

30 Under the Everything-But-Arms (EBA) Initiative ethanol produced in Tanzania is exempted from paying tariff. This tariff is estimated to be about US$0.25 per litre (€19.20 per hectorlitre) based on information in Annex A of the OECD-FAO Agricultural Outlook 2007-2017.

31 The cost of ethanol production for Mozambique came from Mozambique Biofuel Assessment prepared by Ecoenergy International Corporation in 2008.

- The CIF export cost for cassava and sugar-cane ethanol suggest that these are the most viable feedstock options. Molasses ethanol on the other hand is the least attractive option.
- Opportunities for improving competitiveness of the Tanzania ethanol production are promising, in particular due to prospects for improving crop yields which can contribute to cost reductions. Therefore, if conditions in the agricultural sector are conducive and improved productivity in feedstock is realized, this can lead to reduction of feedstock prices.

## 5.5 CONCLUSIONS

Based on this analysis, the scenarios that best match Tanzanian conditions and are recommended for development are the following:

- Ethanol from sugar-cane juice: Scenario 2 at technology level 2 represents the most economical viable option for this feedstock. This set-up consists of feedstock being supplied from combined outgrower-estate (smallholder farmer-commercial) and considers sales for energy co-generation and co-product. The estimated production cost is estimated at USD0.4336 per ethanol litre.
- Ethanol from molasses: the price volatility of molasses may prove to be too risky as biofuel feedstock. However, Scenario 6b has the lowest production cost estimated at USD0.5938 per litre ethanol accounting for co-products sales. Nonetheless, it is recommended that prior to pursuing the use of molasses for biofuel, a trade-off analysis in the context of Tanzania with other uses is carried out to asses the most economically effective market for molasses.
- Ethanol from cassava: the production costs for cassava ethanol were the lowest biofuel production cost for Tanzania ranging from USD0.36 to USD0.46 per ethanol litre. Scenarios 8 and 9 based on the use of dry cassava are recommended for their potential to integrate smallholder (outgrower) in the production chain. This would require the formation of small-scale cassava producers associations necessary to set up small-scale agribusinesses for processing fresh cassava roots to sun-dried slices. Moreover, support to increase cassava yields beyond the current 2 tons per ha (dry basis) is needed to ensure that a new demand will not threaten the availability of cassava for food consumption.
- Biodiesel production from palm oil is not recommended as this is not economically viable and places too much risk on palm oil uses for food.
- Biodiesel from jatropha: the lowest cost for production of jatropha biodiesel is obtained in Scenario 11 estimated at USD0.687 per litre of biodiesel assuming feedstock supplied by outgrowers (small-scale farmers) which at present time seems to represent a more viable option than estate (commercial) production. However, production costs for jatropha biodiesel are based on uncertainty on jatropha production in particular on yields. It is important for Tanzania to explore the possibility of developing other oilseed crops for biodiesel production such as moringa, castorbean, and cotton among others.

*Key Issues*

If the biofuel promise to rural development is to be realized supportive measures in the agriculture sector to increase yields need to be led by the government and/or in cooperation with potential investors. In particular, there is a need to reach out to outgrower producers. Outgrower skills need to be nurtured and technical assistance provided to help maximize yields. Greater accessibility to on-farm technology through use of better varieties, access to training, irrigation, inputs among others could be the means to improve productivity of feedstock and reduce biofuel production costs.

The price of the feedstock plays a crucial role in ensuring that biofuels produced in Tanzania can be economical. Overall, a 25 to 50 percent reduction in the price of feedstock would allow ethanol produced in Tanzania to become more competitive in international markets[32]. Furthermore, in the case of sugar cane, a 70 percent reduction in the purchase price of sugar cane feedstock will bring the ethanol production costs closer to Brazil's. In the case of molasses, if the price of molasses were reduced by 50 percent or more, the production cost would be closer to the production cost reported in Thailand and India. A 50 percent or greater reduction in price of cassava feedstock will make ethanol production costs very competitive with global cassava-ethanol prices estimated at about USD0.40-0.50 per litre[33].

Increased agricultural yields will also imply a lesser amount of land requirement. For example, to meet 10 percent blending ethanol mandate in Tanzania requires either the expansion of sugar-cane production areas or an increased in yields[34]. Looking at existing sugar-cane yield from outgrowers an increase in their yields from 44 to 70 tons per ha will reduce the land requirement by one-third which consequently lessen competition for land resources. However, more in-depth analysis on yield increase potential vs. land expansion is analysed within the context of BEFS Module 1.

Even in the case whereby the potential for biomass and biofuel production may be significant, lack of transportation networks may become a barrier for its commercialization. In Tanzania the higher cost of production in the agricultural sector is in part attributed to high transportation costs which are on average 30 percent of the crop production costs[35]. A major factor that has been identified as key to the competitiveness and efficiency of ethanol production in Brazil is the level of investment that has been devoted to develop the infrastructure to reduce transportation costs from the mill to consumer centres and ports. Brazil's ethanol infrastructure model did not arise from free market competition but it required huge taxpayer subsidies over decades before it could become viable.

32 See Appendix 5C for more details.

33 Production costs are taken from LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

34 Existing molasses production will only provide for half of the demand of a 10 percent blending mandate, as such meeting the reminder demand will required either land expansion or increased productivity of existing sugar cane cultivars.

35 This estimated transportation cost comes from discussions with country experts.

APPENDIX 5 A

# MODULE 2 METHODOLOGY DESCRIPTION

The analysis used a process engineering methodology to evaluate the technical and economic aspects associated with a variety of biofuel industrial production systems. The technological options considered in the analysis were designed based on an assessment of the country's ability for technologies. The production systems included a mix of conventional and advanced technologies. It contextualized the technological options to real-life investments project and analysed the relationship between operating cost and technology efficiencies for processing biomass to biofuel. Overall, the results provided a basis on which to assess the most technical adaptable and cost efficient options under the country's economy conditions. The techno-economic analysis was prepared by the National University of Colombia Manizales under the guidance of the BEFS project. The consultant's report was used as a background document for formulating policy recommendations on bioenergy potentials from the viewpoint of conversion technologies for liquid biofuel production.

The application of the methodology starts with the ***information gathering process*** whereby both secondary and country specific data are used to contextualize and adapt the methodology to the country. The next step in the methodology is the selection of feedstock, which in the case of Tanzania was based on the crops in which the country had an expressed interest for bioenergy uses. Then the ***characteristics of the industrial feedstock materials***[36] for processing biofuels are evaluated to determine the chemical composition. First the crop varieties are evaluated to assess the sugar, starch and oil content. Then, the chemical composition of intermediate materials (such as juice, molasses and vegetable oil) is determined to define the theoretical biofuel yield. The chemical composition is also needed to derive thermo-chemical properties to run the simulations. ***Technology capacity assessment*** is carried out to evaluate the countries technology access conditions.

Based on the results from the technology assessment a range of globally ***available technologies for*** biofuels production are evaluated to identify technologies that are most appropriate to Tanzania's capacity. To carry out this exercise, the biofuel production process is broken down into four main processing steps, then the technologies are matched for each one of these steps[37]:

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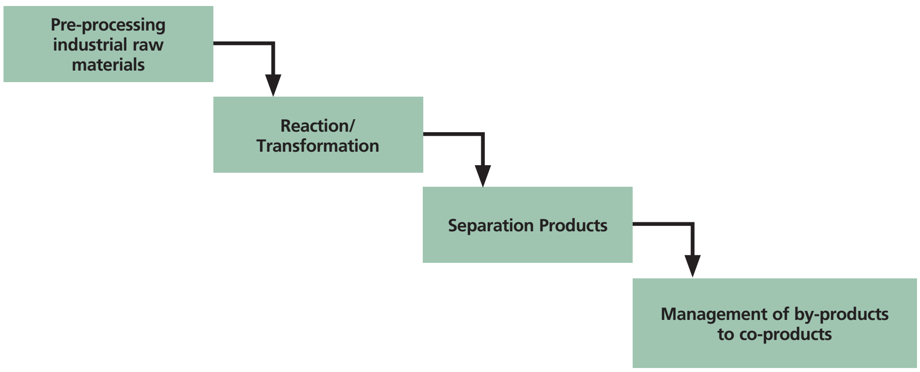
36 The cane juice, molasses and oil extracted from sugar cane and palm oil were considered as the industrial raw materials for ethanol and biodiesel production respectively.

37 Pre-processing may include mechanical i.e. crushing or chemical extraction. Transformations include fermentation in the case of ethanol and transesterification in case of biodiesel. Transesterification is the process of exchanging the alcohol group of an ester compound with another alcohol.

Figure 5A.1




A matrix of potential technologies for each of the processing steps (Figure 5A.1) that are country-specific is generated. These technologies are then matched for each of the processing steps and paired together to define the three technology level options. Prior to running the simulations, a set of production scenarios based on realistic investment projects are developed to define parameters such as the scale and conditions for biofuel production in the country. Simulations are then run using the desired technology configurations for each of the production scenarios. The simulations results are then evaluated based on a set of pre-established criteria. In this case, the criterion are operating cost, potential for management of by-products i.e. beneficial use within the production system or other potential markets, and production efficiency including energy surplus. The results generated from the evaluation are used to develop recommendations on the best alternative and the potential steps needed to develop the biofuel agro-industrial sector in the country.

APPENDIX 5 B

# DETAILED ASSUMPTIONS ON THE COSTS OF FEEDSTOCK, PROCESS, CHEMICAL INPUTS AND TRANSPORT.

A. The sugar cane and cassava prices were derived from literature, the jatropha prices were taken from biofuel producers in the country, the molasses and palm oil prices were taken from the market price in Tanzania.

- The price of sugar cane produced by outgrowers was projected to be USD0.027 per kg based on yield 55 ton per ha production and includes transportation costs to the mill. For sugar cane produced in estates, the price was assumed to be USD0.0208 per kg based on 97 ton per ha. The sucrose content for sugar cane in Tanzania is based on varieties cultivated in the country and assumed to be around 13.80 percent.
- The molasses price was estimated to be around USD0.134 per kg for stand alone production facilities (Scenario 5) and USD0.0938 per kg for molasses-ethanol integrated facilities (Scenario 6). The main difference in the molasses price between the two scenarios comes from eliminating the transportation costs in the integrated facilities which are assumed to be annexed to the sugar mills.
- The cassava purchase price was assumed to be USD0.038 per kg for fresh cassava roots (Scenario 7) and for dried cassava chips (Scenarios 8 and 9) was USD0.133 per kg; these came from the One UN Cassava Value Chain Production Report. The price of palm oil feedstock is linked to world market prices for vegetable oil and as such was based on local estimated cost of USD440 per ton of palm oil plus an additional USD111 for transport.
- The price of jatropha was estimated for outgrower 164 USD/ton at 4 ton per hectare and for commercial USD270 per ton based on values provided by World Bank in Tanzania.

B. The biofuel processing cost includes capital and operating costs. The capital costs were estimated based on the scale as set by the level of production and adjusted for each of the production scenarios as necessary. Capital costs were based on global average equipment prices incorporated in the commercial simulator Aspen Plus. The operating costs were obtained from national statistics data and used in the simulation. Operating prices are the same for all scenarios and modified according to consumption as required by each of the production scenarios.

- The local prices reported for processing chemicals needed for biodiesel production were USD811 per ton for methanol and USD1 250 per ton for sodium hydroxide.
- Labour costs were based on the 2006 Tanzania Labor Survey and were estimated to be USD0.29 per hour for unskilled and USD0.44 per hour for skilled labour.

- The price of electricity was estimated to be USD0.03796 kilowatt hour and water price was estimated to be USD0.00038/cubic metre. Both water and electricity prices came from the prices stipulated by the Energy and Water Regulatory Commission.
- The tax rate was assumed to be 30 percent per period. The depreciation period was ten years.
- Construction costs were estimated based on assumed firm clay soil conditions.
- Maintenance and plant overheads were assumed to be 3 percent and 50 percent, respectively.

C. This analysis assumed a 30 percent of the crop production cost for feedstock transport costs from farm to plant gate and was included in the feedstock price.

D. As there is no current biofuel production in Tanzania, the distribution of biofuel to end markets was estimated based on transportation costs for the sugar-cane industry and estimated from the sugar sector study carried out by the Federal Agricultural Research Centre Institute of Farm Economics. The base cost for rail was estimated based on average cost of USD0.017 per litre and the transport costs from Dar es Salaam to Rotterdam Port CIF were estimated to be USD0.08 per litre. The cost for road transport was estimated based on petrol distribution and provided by the Energy and Water Regulatory Authority. Road transport per litre of biofuel was based on a 10 Tanzanian Shillings per 30 km per litre.

E. The following transporting options were considered for each of the scenarios:
   - Scenarios: 1, 3, 5, and 6 look at moving ethanol from ethanol-producing sugar mills via rail to Dar es Salaam for either domestic or international markets
   - Scenarios 2, 4, 7, 8, 9 and 10 moving ethanol from plants by road to Dar es Salaam for distribution to domestic or international markets.

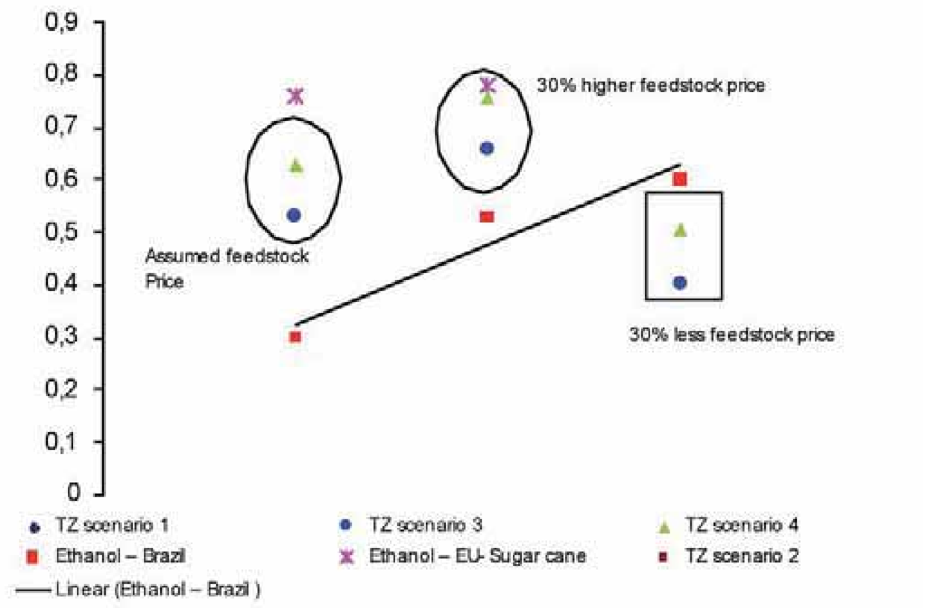
APPENDIX 5 C

# SENSITIVITY ANALYSIS ON FEEDSTOCK PRICE

The impacts of a reduction on the feedstock price on ethanol production costs for sugar cane, molasses and cassava for Scenario 3 for sugar-cane juice, Scenario 5 for molasses and Scenario 7 are presented in Figure 5C.1.

Figure 5C.1

**Estimated cost of ethanol production and sensitiveness to feedstock price assumptions in USD/L**




Results for Scenario 3 indicate that the sugar-cane feedstock prices as simulated in this analysis result in ethanol production costs that are lower than those reported in India and the EU but much higher than those estimated for Brazil and Colombia (about USD0.30 per litre)[38]. A 25 or 50 percent reduction in the price of feedstock indicates that ethanol production costs in Tanzania become more competitive in international markets. A 70 percent reduction in the purchase price of sugar-cane feedstock will bring the ethanol production costs closer to Brazil's.

38 Literature indicates estimated production cost in the range as low as 30 cents per litre in these countries. The cost of sugar-cane production in Colombia comes from fuel ethanol production from sugar cane and corn: Comparative analysis for a Colombian case publication by Cardona et al. The article is published on Energy, volume 33, issue 3 March 2008, Pages 385-399. The production cost for Brazilian comes from LMC International Starch and Fermentation Raw Materials Monitor 2007 Report.

In the case of molasses-ethanol, results on production as simulated in Scenario 5 indicated that the production costs far exceed those reported in other countries. Here reduction in the price of molasses by 50 percent or more will bring production costs closer to production costs reported in India and Thailand. However, it is probable that a greater than 50 percent price reduction is necessary to provide an economic incentive to invest in stand-alone facilities for molasses-ethanol production in the country. For cassava-ethanol the production price estimated was closer to international levels. If the cost of feedstock was overestimated by 25 percent, this implies that the cost for Tanzania cassava-ethanol production is already along the line of estimated ranges for Thailand and Vietnam. A 50 percent or greater reduction in feedstock prices will also make ethanol production costs very competitive with global prices (estimated about USD0.40-0.50 per litre)[39]. These highlight the importance of reducing the costs of feedstock material to make the production costs of fuel-grade alcohol economically viable in global markets.

The reference for global ethanol production cost use throughout the study to compare against the Tanzania simulated production cost are summarized in Table 5C.1.

TABLE 5C.1

**Reference Ethanol production cost**

| Country | **Referenced value** (US$/Litre) | Source |
|---|---|---|
| Brazil | 0.53 | Estimated OECD-FAO, Ex-distillery Sao Paolo |
| Brazil | 0.30 | LMC average of 2005-2007 100% bagasse energy |
| Brazil- sugar cane | 0.60 | 2006 values LMC |
| EU- sugar cane | 0.76-0.78 | 2006 values LMC |
| Brazil- molasses only | 0.52-0.54 | 2006 values LMC |
| Brazil co-product (molasses/sugar cane) | 0.33-0.39 | 2006 values LMC |
| EU- molasses only | 0.61-0.65 | 2006 values LMC |
| US- molasses only | 0.65-0.70 | 2006 values LMC |
| India Molasses | 0.42-0.45 | 2006 values LMC |
| India co-product (molasses/sugar cane) | 0.48-0.55 | 2006 values LMC |
| Thailand Cassava | 0.38-0.40 | 2006 values LMC |
| Vietnam Cassava | 0.34-0.36 | 2006 values LMC |
| Brazil cassava | 0.45-0.47 | 2006 values LMC |
| China cassava | 0.60-0.63 | 2006 values LMC |
| India cassava | 0.61-0.65 | 2006 values LMC |

39 LMC International Starch and Fermentation Raw Materials Monitor 2007 Report