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BEFS

BIOENERGY AND FOOD SECURITY RAPID APPRAISAL (BEFS RA)

User Manual

Ethanol from molasses tool

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BEFS Rapid Appraisal

Energy End Use Options Module

Transport Sub-Module

Ethanol from molasses tool

User Manual

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[1] Unless otherwise specified, all authors were affiliated to FAO at the time of their contribution.

[2] The BEFS working Group in Malawi comprises the following members: Ministry of Energy, Ministry of Lands, Housing, and Urban Development, Ministry of Finance, Ministry of Agriculture and Food Security, Ministry of Environment and Climate Change and Department of Forestry, Ministry of Industry and Trade, Ministry of Economic Planning and Development, Ministry of Labour and Vocational Training, Ministry of Transport and Public Infrastructure, Ministry of Information and Civic Education, Ministry of Local Government and Rural Development.

[3] The National Biofuels Board is chaired by the Secretary of Department of Energy and includes the following members: Department of Trade and Industry, Department of Science and Technology, Department of Agriculture, Department of Finance, Department of Labor and Employment, Philippine Coconut Authority, Sugar Regulatory Administration.

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1 Overview of the *Transport Sub-Module*

Liquid biofuels are most commonly produced either as biodiesel or ethanol. Biodiesel can be produced from vegetable oil or animal fat and is used to replace fossil diesel. It can be used as a pure fuel or blended with petroleum diesel (commonly B5 or B20, which contains, respectively, 5 per cent or 20 per cent biodiesel mixed with fossil diesel). Ethanol is a clear alcohol that can be used as a fuel in a spark-ignition engine, either neat or blended with gasoline. Biodiesel has about 92% of the energy content of petroleum diesel. Ethanol has around two-thirds the energy content of gasoline (regardless of feedstock used), but it has a significantly higher octane rating.

The *Transport Sub-Module* assists the user in evaluating the potential to develop the production of liquid biofuels, namely ethanol and biodiesel in the country. The *Ethanol* section of the tool is used to assess the potential for developing the ethanol industry in the country. Likewise, the *Biodiesel* section assesses the potential for developing the biodiesel industry. The analysis builds on the results generated in the *Natural Resources* module in terms of feedstock availability and crop budget. The tool is designed to assess the competitiveness of liquid biofuel production chains, which vary depending on the origin of the feedstock (outgrowers scheme, own production scheme, and mixed outgrowers-own production scheme); and the pre-defined technology configurations and sizes of biofuel production plants (5, 25, 50 and 100 million litres per year). The tool provides preliminary estimates on the cost of production of the biofuel value chain and analyses the financial and socio-economic aspects of the production chains.

After completing the analysis, the user will be able to assess:

1. the economic profitability of the liquid biofuel value chain, particularly when including outgrowers as feedstock suppliers;
2. the most viable feedstock that can be used for producing ethanol and biodiesel;
3. the potential plant sizes that can be considered in the country;
4. the employment generation potential in rural areas associated with each value chain; and
5. the amount of biofuel that can be produced for domestic markets, export markets, or both.

More specifically, the results will provide an indication on:

1. the amount of biomass required to supply each of the pre-defined capacities;
2. the cost of production and the investment cost associated with each production option;
3. the financial indicators on Net Present Value (NPV) and Internal Rate of Return (IRR);
4. the feasibility to integrate outgrowers in the production chain; and
5. the quantity of jobs that can be created.

The flow of information within the *Transport Sub-Module*, which includes sections on biodiesel and ethanol, together with the links to other components in the BEFS Rapid Appraisal is depicted in Figure 1.

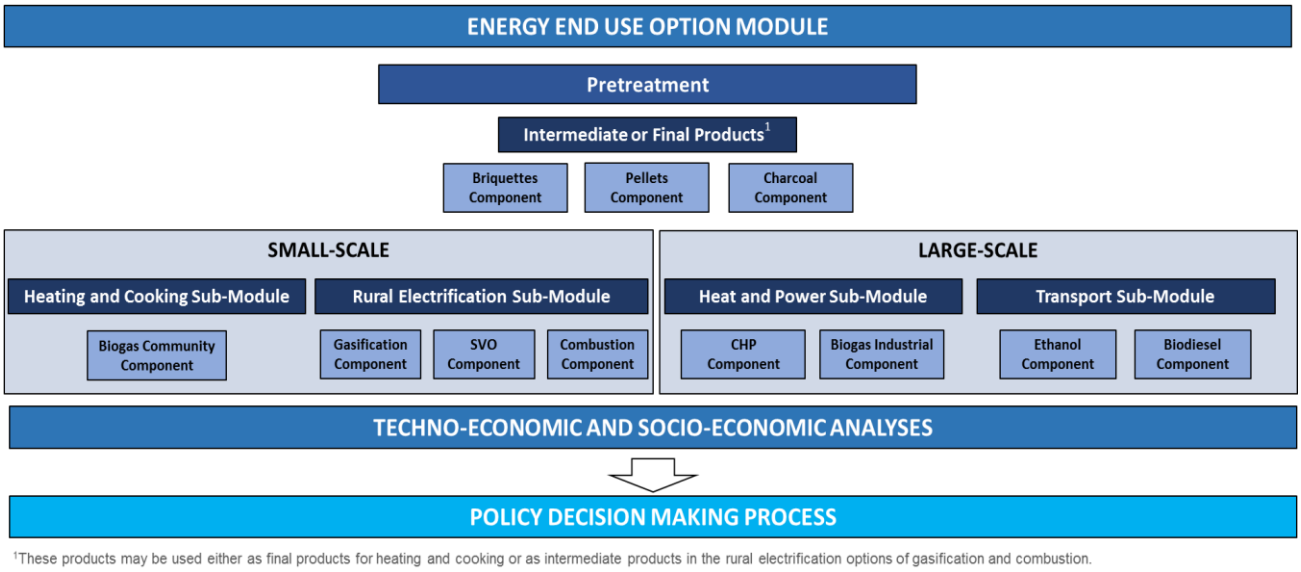

Figure 1: Overview of the BEFS Rapid Appraisal

2 The Ethanol from Molasses tool

The *Ethanol from Molasses tool* is designed to assist the user in evaluating the potential to produce ethanol from molasses at the industrial level. The boundary of the analysis for the processing of ethanol from molasses is shown in Figure 2. The tool is based on extensive literature reviews. The detailed assumptions and calculations used to develop the tool are provided in the Annex.

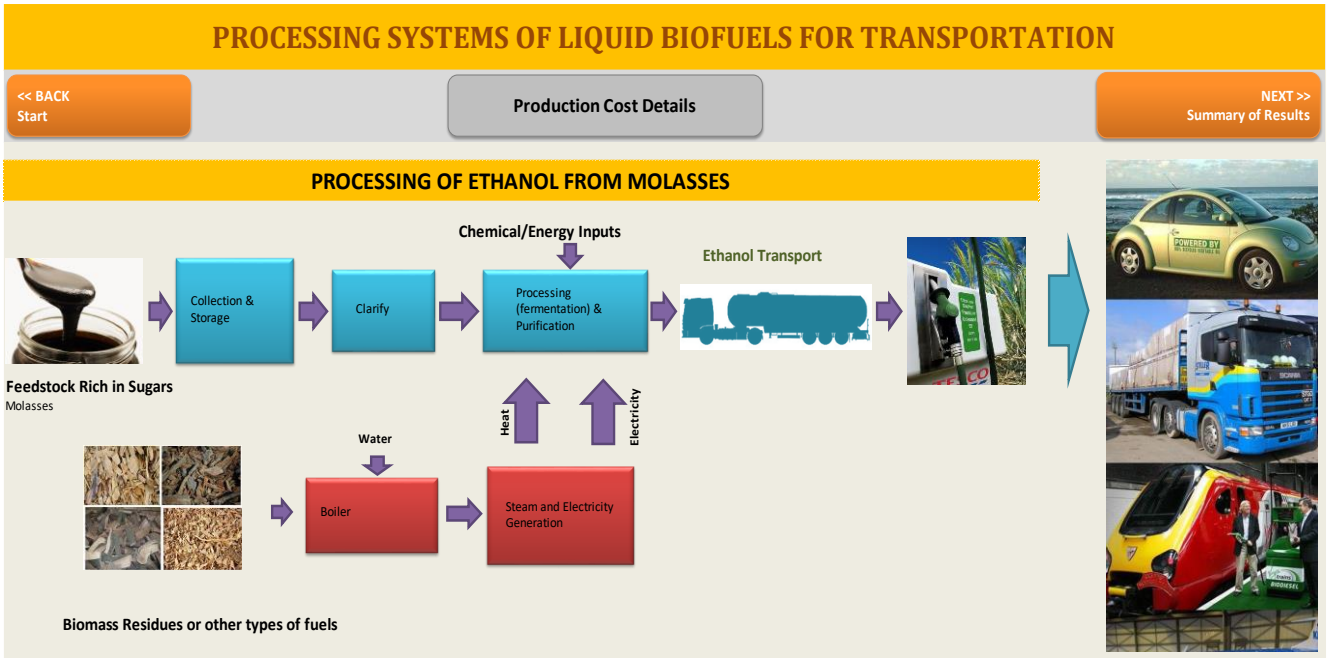

Figure 2: Processing of ethanol from molasses

After completing the analysis, the user will have an indication on: 1) ethanol production costs and investment required to set up plants of various scales; 2) feedstock demand according to plant scale; 3) Percentage of obtainable ethanol demand blend; 4) the number of jobs that could be potentially created; and 5) financial

viability associated to each plant scale, as shown in Figure 3. The user will also be able to include in the analysis a cogeneration system (as seen in Figure 4) and to perform a sensibility analysis of the production of sugar vs. ethanol (as seen in Figure 5).

Figure 3: Layout of the ethanol from molasses Results Sheets

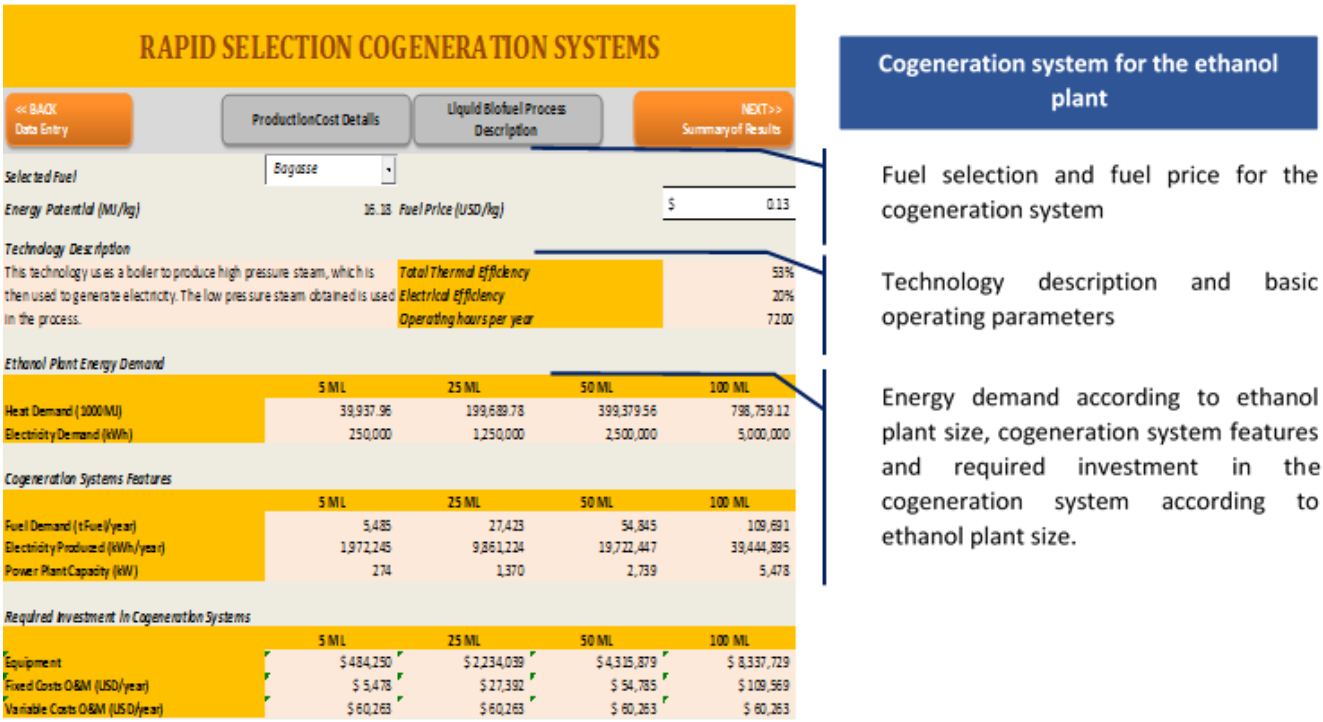

Figure 4: Data input and results for the inclusion of a cogeneration system in the analysis

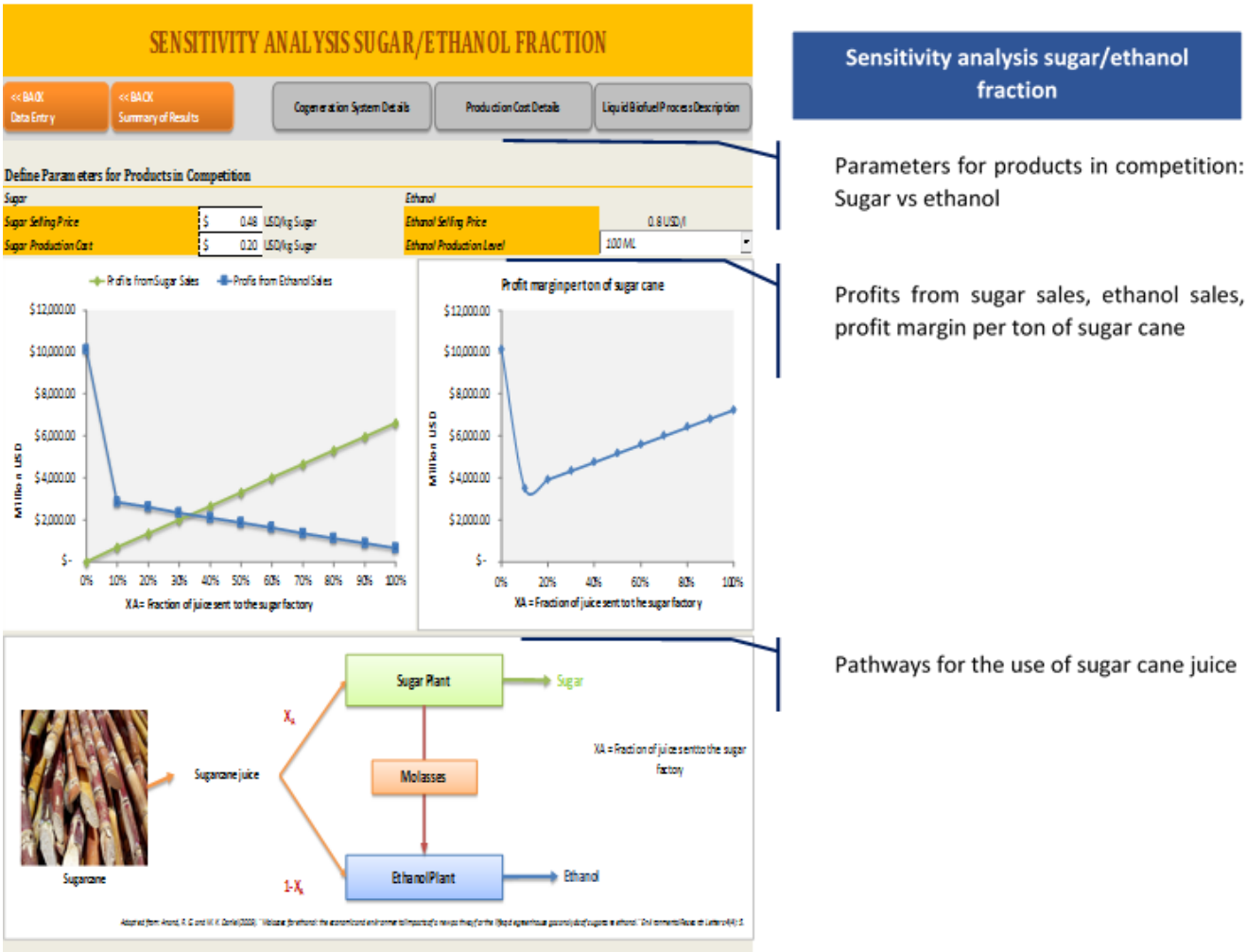

Figure 5: Results of a sensitivity analysis for the sugar/ethanol production fraction

3 Terms and Definitions Used in the *Ethanol from molasses Component*

This section includes definitions of specific terms used in the *Ethanol from molasses Component*. It is important to anticipate these definitions and consider them throughout the analysis, as to be able to interpret the results correctly.

3.1 Comparison between production cost of ethanol and fossil fuels/liquid biofuels

In the Data Entry sheet, users are asked to specify whether the country considered in the analysis is a net importer/exporter of ethanol; or a net importer/exporter interested in exporting ethanol. Depending on the answers to these questions, the users are confronted with different combinations of the scenarios described below, which entail different price comparisons and thus certain data requirements.

3.1.1 Comparison with fossil fuels

Scenario 1 – Net importing country

The sub-module compares the production cost of ethanol (in oil equivalent) with the Free on Board (FOB) price of gasoline.

If the main port used to import fossil fuels does not correspond with the main city (and thus consumption point) in the country, then the tool compares the production cost of ethanol (in oil equivalent) with the FOB price of gasoline to which the transport cost of these fuels from the port to the main city is added.

Scenario 2 – Net exporting country

The sub-module compares the production cost of ethanol (in oil equivalent) with the Refinery Gate Price (RGP) of gasoline.

3.1.2 Comparison with liquid biofuels

Scenario 1 – Net importing country

The sub-module compares the production cost of ethanol with the Free on Board (FOB) price of ethanol.

If the main port used to import fossil fuels does not correspond with the main city (and thus consumption point) in the country, then the tool compares the production cost of ethanol (in oil equivalent) with the FOB price of gasoline to which the transport cost of these fuels from the port to the main city is added.

Scenario 2 – Net exporting country

The sub-module compares the production cost of ethanol with the average factory gate price of ethanol in the country[4].

Scenario 3 – Interested in exporting

The sub-module compares the production cost of ethanol with the Free on Board (FOB) price of ethanol to which the transport cost of these fuels from the main city to the port has been subtracted.

If the FOB price of biofuels is not available, the sub-module uses the FOB price of the closest port where biofuels are traded.

- **Break-even point:** The break-even point represents the amount of sales that are required to cover total costs (both fixed and variable). Profit at break-even is zero, as costs and revenues are equal.

3.2 Ethanol production

The sub-module considers the following indicator based on the total amount required to meet the mandatory blending as indicated in the Biofuel Demand sheet (see section 5.1):

- **Percentage of obtainable mix with ethanol produced:** The maximum attainable ethanol production with available molasses indicates to which extent the ethanol obtained is enough to meet the amount proposed under different mandatory blending mandates. The demand created with blending mandates is calculated from the current demand of gasoline in the country (see section on Step 1: Fuel demand in the Country).

3.3 Financial analysis

[4] This is useful, for instance, when assessing the competitiveness of alternative feedstock for the biodiesel/ethanol already produced in the country.

The financial analysis examines the profitability of investing in biofuel processing plants of different sizes. The sub-module computes the following indicators[5]:

- **Net Present Value (NPV)**: The difference between the present value of cash inflows and the present value of cash outflows. Cash flows are a sequence of values extending over several years. When using NPV, the selection criterion is to consider positively all investments with a NPV greater than zero, when discounted at a suitable discount rate, most often the opportunity cost of capital.

- **Internal Rate of Return (IRR)**: The discount rate that makes the NPV equal zero. If the IRR on the investment is greater than the minimum required rate of return – the cost of capital – then the investment is worth it. Conversely, if the IRR on the investment is lower than the cost of capital, then the best course of action may be to not proceed with the investment.

Other financial terms that the user should consider:

- **Discount rate:** The interest rate used to determine the present value of a future value through discounting.
- **Opportunity cost of capital:** The cost of using resources in the specific investment rather than in their next best alternative option. It is usually expressed in the interest rate form, i.e. the rate at which benefits and costs are discounted in calculating the Net Present Value.

4 Scope and Objective of the *Ethanol from molasses tool*

The aim of the *Ethanol from molasses tool* is to assess the feasibility to develop ethanol production systems that use molasses produced during the processing of sugarcane to obtain sugar.

The results of the analysis can be used to identify the viability of ethanol production from molasses in terms of feedstock availability, the financial viability of the different processing scales, maximum attainable ethanol production according to available feedstock, and the socio and economic benefits that can be attained. The information generated by the analysis can also be used as an initial basis to discuss potential strategies to promote the production of ethanol at the industrial level.

The *Ethanol from molasses Component* can also perform a sensitivity analysis of the production of sugar compared against the production of ethanol, since the production of these products is flexible and can be adjusted according to market conditions. Additionally, the component allows to analyse the inclusion of a cogeneration system for the generation of electricity and/or heat at the industrial level.

The following section describes the flow of the analysis and options within this component. The background methodology for the financial analysis, biomass collection and biomass storage is described in detail in the Annex.

[5] For further information on the indicators see De Benedictis, 1976; Gittinger 1982; Squire van der Take, 1975.

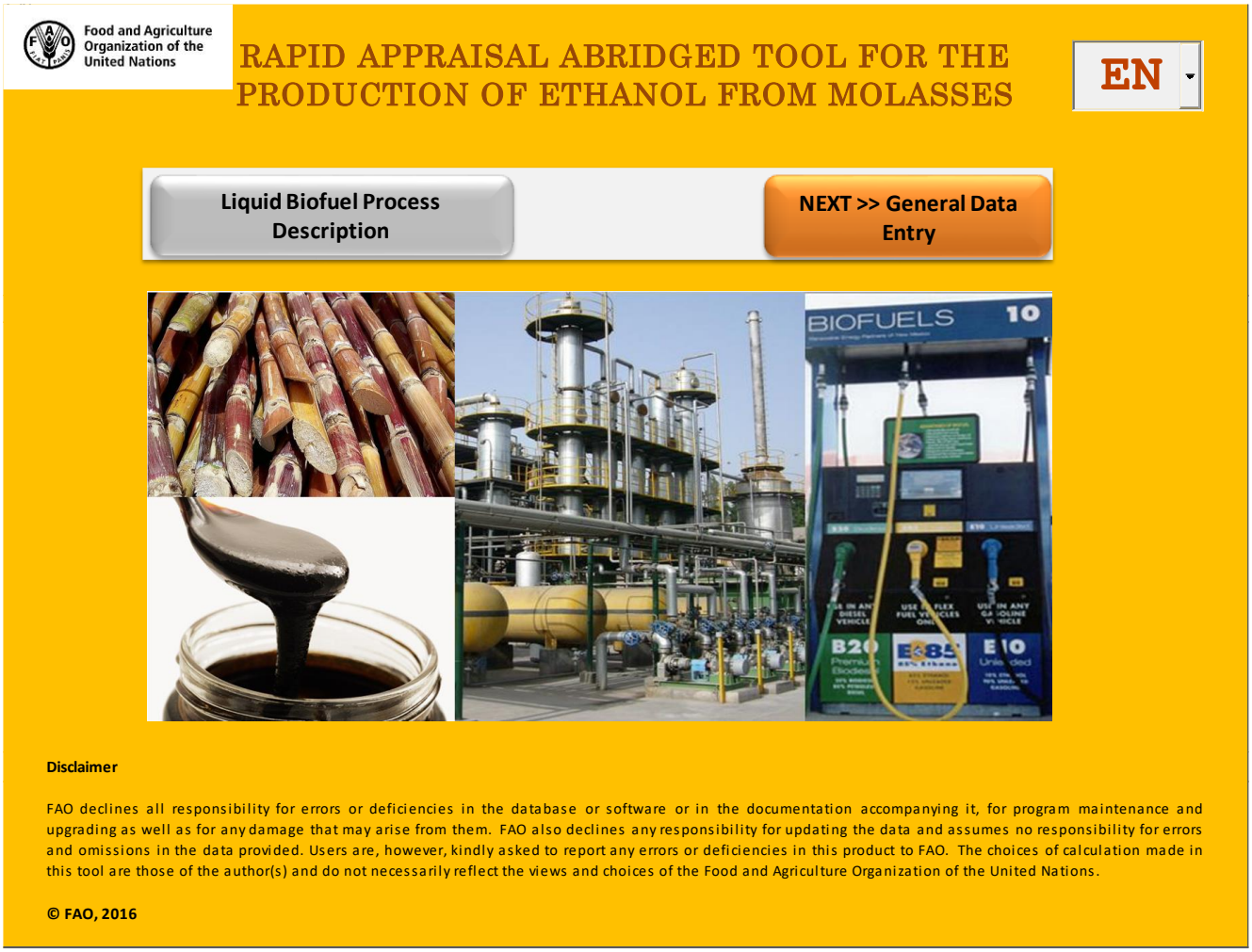

Figure 6: Rapid Appraisal Abridged Tool for the production of Ethanol from Molasses

5 Running the *Ethanol from Molasses tool*

The user navigates step by step through the options and is asked to input necessary data to obtain final results. The navigation buttons are placed on the top and bottom of each sheet, indicating the next step with the button "NEXT>>" and allowing the user to return to a previous section with the "<<BACK" button.

The following sub-chapters describe each step of the analysis, using an example for a country currently in a situation of being a net importer of fossil fuels and interested in the production of ethanol to cover its own demand and potentially export surplus production. All input parameters are based on a generic situation.

5.1 Step 1: Fuel Demand

This step provides an overview of gasoline consumption and the current situation of production and trade of ethanol in the country. From this information it will be possible to estimate the fraction of different given mandates for blending for gasoline that could potentially be achieved with the production of ethanol from molasses.

The user has to enter:

1. Data on gasoline domestic consumption in ML/year. Information provided in the *Country Status* module can be used here (Figure 7, label 1).
2. Data on ethanol production and trade in ML/year. Information provided in the *Country Status* module can be used here (Figure 7, label 2).
3. Status of fuels trade balance. Further explanation is given below:

The user is asked to specify whether the country considered in the analysis is: a net importer or exporter of fossil fuels (Figure 7, label 3); a net importer, net exporter, or interested in exporting ethanol (Figure 7, label 4). The user has also to indicate whether the main port is located next to the main city in the country (Figure 7, label 5). Depending on the selections made, the user is confronted with different scenarios, which entail different price comparisons and data requirements (see section 3.1.1).

For gasoline, the FOB price of gasoline will be used if the country is a net importer (see Step 4). Otherwise, if the country is a net exporter, the Factory Gate Price (FGP) of gasoline price will be considered. If the main entry port of fossil fuels does not correspond with the main city (and thus consumption point) in the country, the user is asked to consider the transport cost from the port to the main city (Figure 7, label 6).

As for ethanol, if the country is a net importer, the FOB price of ethanol will be considered. Otherwise, the average factory gate price of ethanol will be used. Furthermore, if the main entry port for liquid biofuels does not correspond with the main city (and thus consumption point) in the country, the user is asked to consider the transport cost from the port to the main city (Figure 7, label 6). Finally, in the case of a country interested in exporting, the FOB price of ethanol to which the transport cost from the main city to the exit port is subtracted, should be considered (see Step 4).

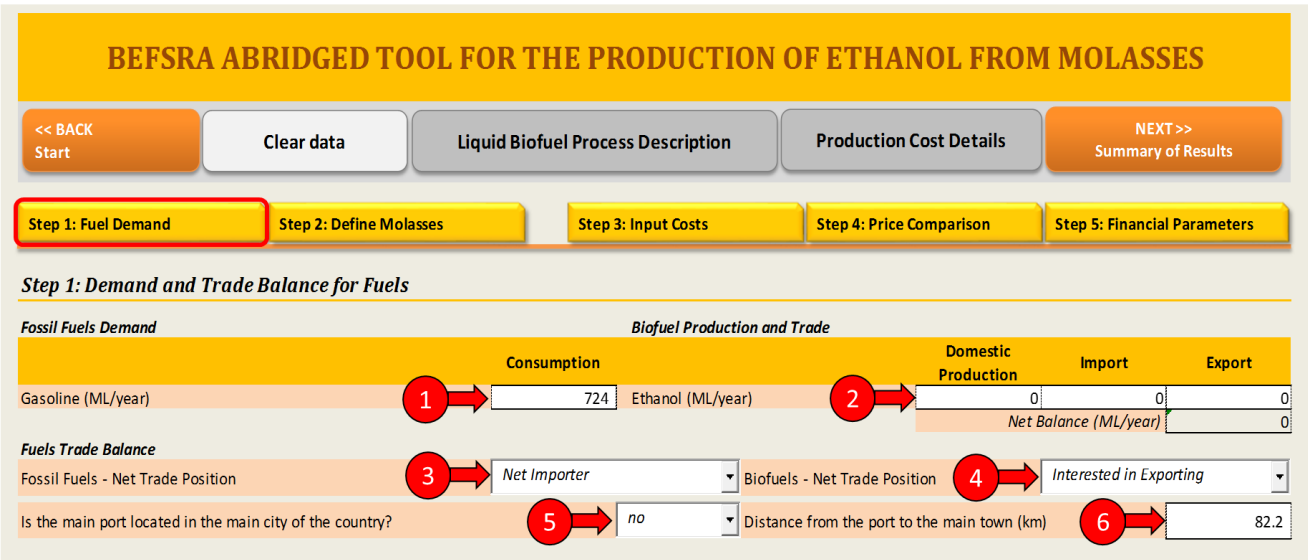

Figure 7: Demand and trade balance for fuels

5.2 Step 2: Define molasses

In this step the user is asked to define the availability and cost of molasses to be used as feedstock for ethanol production. The user has to enter:

Step 2.A Feedstock availability and cost

1. Feedstock available in t/year (Figure 8, label 1).
2. Percentage of fermentable sugars in molasses (Figure 8, label 2)

3. Feedstock cost in USD/t, where the current price in the country for molasses should be input (transport excluded) (Figure 8, label 3)
4. Define the characteristics of molasses supply using the storage calculator (Figure 8, label 4)

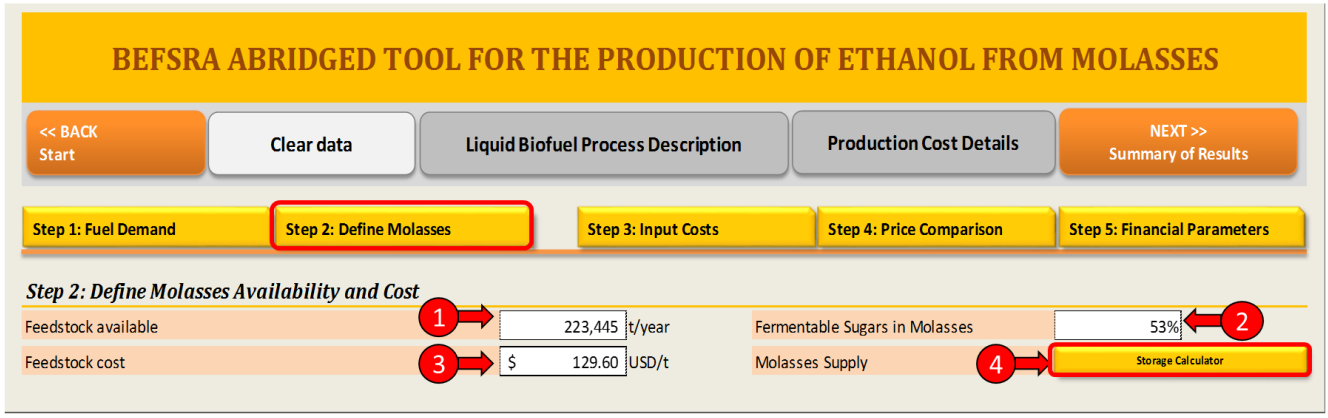

Figure 8: Availability and characteristics of Feedstock

Step 2.B Storage calculator for molasses supply

In order to calculate the storage capacity needs, the user needs to click on the "Storage Calculator" (Figure 8, label 4). This will take the user to the Biomass Storage Calculator (Figure 9). In this worksheet, the user will need to:

1. Selects the collection month(s) of molasses (Figure 9, label 1).
2. Enter the biomass safety stock rate (%) for each plant size. This is the percentage of molasses needed to secure continuous supply of feedstock to deal with uncertainty in production due to seasonal availability and other factors. This stock rate % is used to estimate the storage capacity (Figure 9, label 2).
3. Click on "Calculate" (Figure 9, label 3) to automatically compute the amount of maximum storage capacity required (tonnes) and the minimum safety storage (tonnes per month) for each of the pre-defined capacities (Figure 9, label 5).
4. If data is not available it is possible to obtain reference values by clicking on "Default values" (Figure 9, label 4)
5. Click "OK" to return to the Data Entry Needs sheet (Figure 9, label 6).

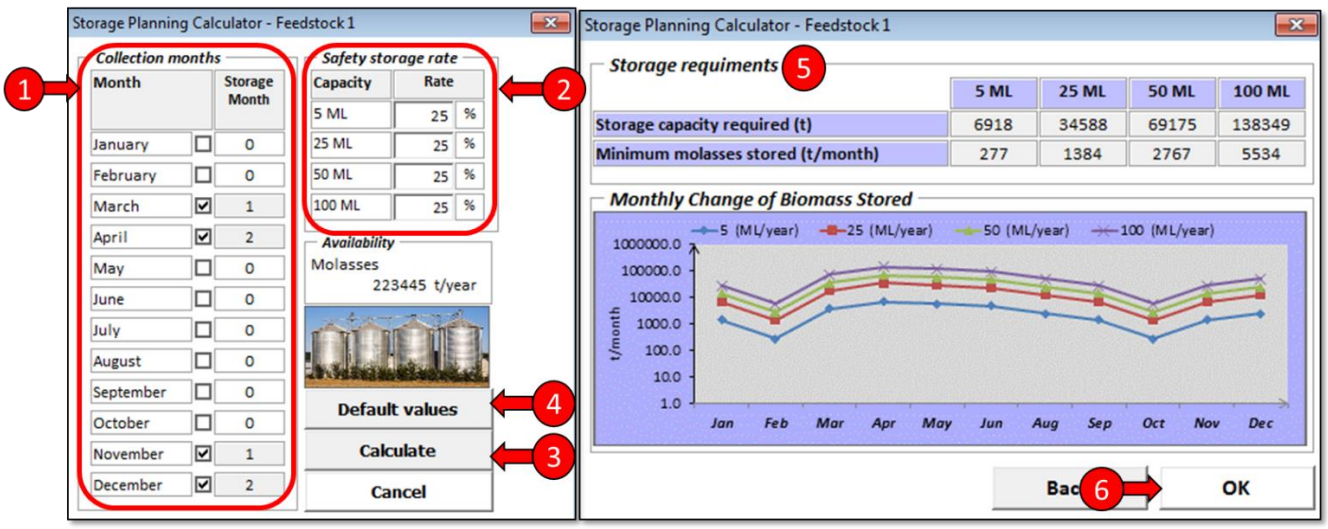

Figure 9: Storage Calculator of Feedstock

For this example, molasses are collected in 4 months: March, April, November, and December. As a result, the storage capacity required is 6918 tonnes for the 5 ML plant size. The minimum safety feedstock to store is 277 tonnes per month (Figure 9, label 5)

5.3 Step 3: Input costs

In this section, the user is asked to enter data related to inputs, services and wages used in feedstock processing, specifically: ethanol inputs, services, labour, other costs, update of the investment cost and storage costs.

1. Ethanol inputs and Services

Chemical inputs used in molasses processing for ethanol production are: ammonia, yeast, sulfuric acid and hydrated lime (Figure 10, label 1). The user has to enter input prices in USD/t and can research online for current prices. The user also has to insert the prices of services such as steam (USD/t), water (USD/m3) and electricity (USD/kWh) employed in the transformation process (Figure 10, label 2).

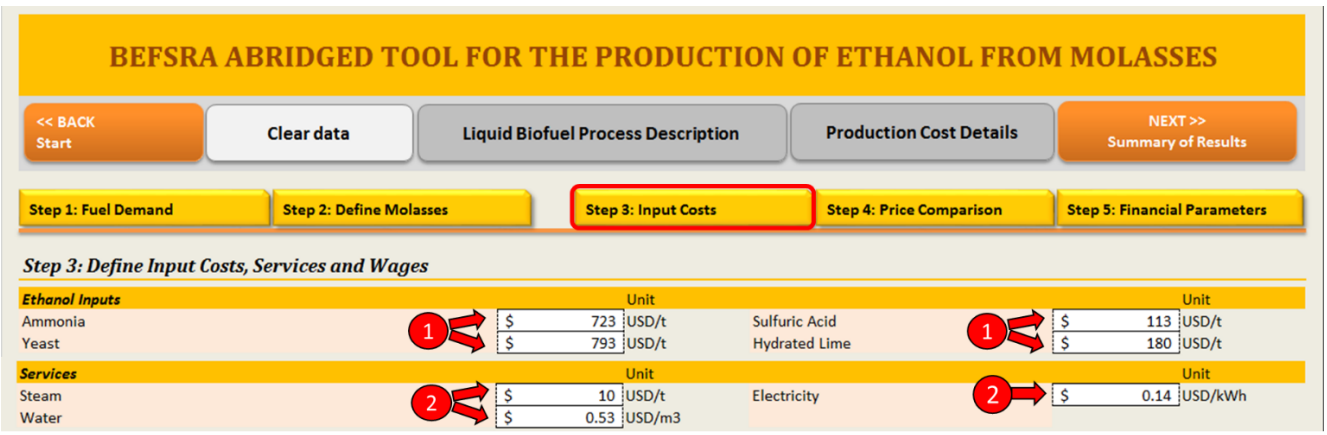

Figure 10: Input cost for ethanol production from molasses (ethanol inputs and services)

2. Labour and Other costs

The user should enter (unskilled and skilled) labour cost rates, in accordance with the national average wages (expressed in USD per person per hour) (Figure 11, label 3). The number working days per year and the number of harvesting (zafra) days for sugarcane (Figure 11, label 4). However, given the significant differences among countries regarding this parameter, the user may insert the number of working days per year which better reflects the country's reality.

Additional costs, which cannot be easily calculated, are estimated. These include:

- Maintenance costs (maintenance of equipment and devices), calculated as a percentage of the total cost of depreciation (Figure 11, label 5);
- Plant overhead (general expenditures), expressed as a percentage of the sum of labour costs and maintenance costs (Figure 11, label 6); and
- General and administrative costs (rent, insurance, managerial and administrative staff salaries), expressed as a percentage of the sum of plant overheads, maintenance, total labour costs and the other costs except the expenditure for feedstock purchase (Figure 11, label 7).
- Miscellaneous costs comprise the cost of operating supplies and laboratory charges required for the daily processing activity. A default value of 25% was established as default (Figure 11, label 8)

Figure 11: Input cost for ethanol production from molasses (labour and Other costs)

3. Updating the investment cost and storage costs

The costs of the investment required to set up the plant can be updated using the 'Plant Cost index' (Figure 12, label 9).

The user has to enter the feedstock storage cost (USD/t), ethanol storage cost (USD/l) and the percentage of ethanol in storage (Figure 12, label 10). This percentage represents the share of the total product that is stored before transportation and/or as a safety storage rate in case of stops or failures in production. The standard value for this is 20-30%. These values need to be determined by the user according to the country situation.

Finally, the user has to insert the feedstock transportation cost from farm gate to the processing plant (USD per t per km) and the distance from the collection point to the processing plant (km) (Figure 12, label 11).

The analysis does not consider the transportation cost of the final product from the plant to the distribution point.

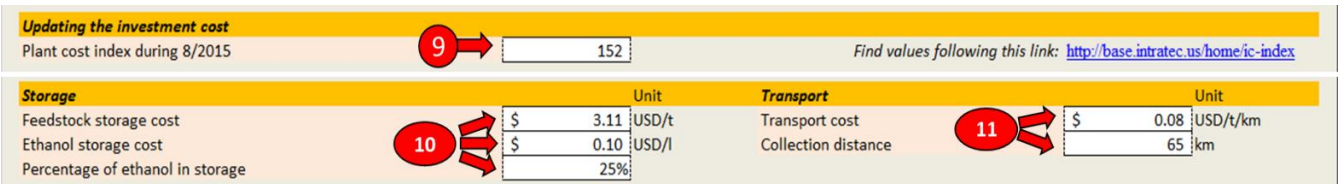

Figure 12: Input cost for ethanol production from molasses (Investment cost and storage costs)

5.4 Step 4: Price comparison

In this section, the user is asked to enter data related to prices of fuels for comparison according to the scenarios detailed in Section 3.1.

1. Price of fuels for comparison

As mentioned in Step 1, the FOB price of gasoline will be used for comparison if the country is a net importer (Figure 13, label 2). Otherwise, if the country is a net exporter, the Factory Gate Price (FGP) of gasoline price will be considered.

As for ethanol, if the country is a net importer, the FOB price of ethanol will be considered. Otherwise, the average factory gate price of ethanol will be used. Finally, in the case of a country interested in exporting, the FOB price of ethanol to which the transport cost from the main city to the exit port is subtracted, should be considered (Figure 13, label 1).

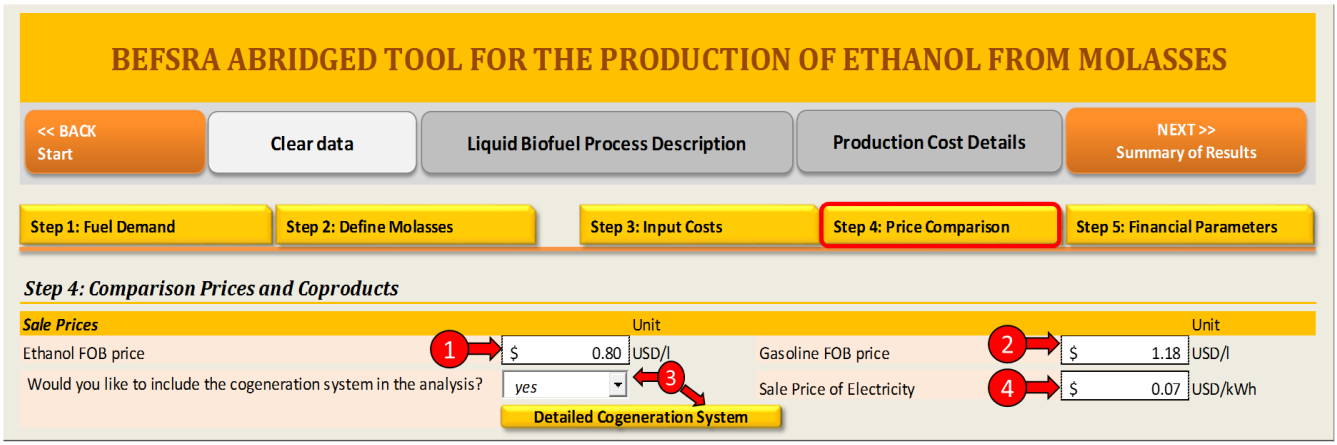

Figure 13: Comparison prices and coproducts

Next, the user needs to enter the sale price for the electricity (USD per kWh) to be produced by the cogeneration system (Figure 13, label 4).

2. Cogeneration system

The component allows to analyse the inclusion of a cogeneration system for the generation of electricity and/or heat at the industrial level. In order to include a cogeneration system, the user needs to select "yes" from the dropdown menu and click on the "Detailed Cogeneration System" button (Figure 13, label 3). This will take the user to the Rapid Selection of Cogeneration Systems worksheet (Figure 14). In this worksheet, the user will need to:

1. Select the fuel for the cogeneration system (Figure 14, label 1). The types of fuels considered includes the following:
    - Fossil fuels: Gasoline, diesel, used oils, LPG, natural gas, butane, propane, coal
    - Biomass: Bagasse, firewood
    - Liquid biofuels: Ethanol, biodiesel, methanol
2. Enter the price (USD/kg) of the selected fuel (Figure 14, label 2).
3. Click Back to return to the Data Entry Needs sheet (Figure 14, label 3).

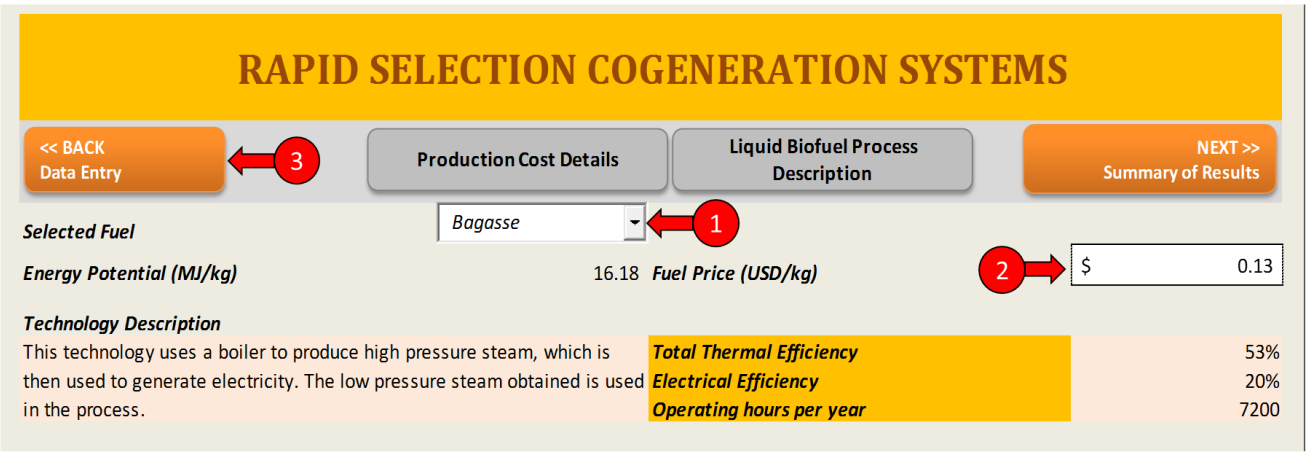

Figure 14: Rapid Selection of Cogeneration Systems worksheet

5.5 Step 5: Financial parameters

A set of financial parameters should be entered in order to estimate the NPV and IRR indicators.

First, the user has to enter the discount rate percentage. The usual value is the interest rate charged by the country's central bank on government securities (Figure 15, label 1).

Second, since the tool takes into consideration the option of receiving a loan for realizing the investment, the loan interest rate (in percentage) and the number of years planned for repayment (loan term) are taken into account (Figure 15, label 2). The tool allows the user to set the loan amount through a specific coefficient that can be inserted for each plant size. The loan amount is computed as a percentage (the so called 'loan ratio') of the investment costs (Figure 15, label 3).

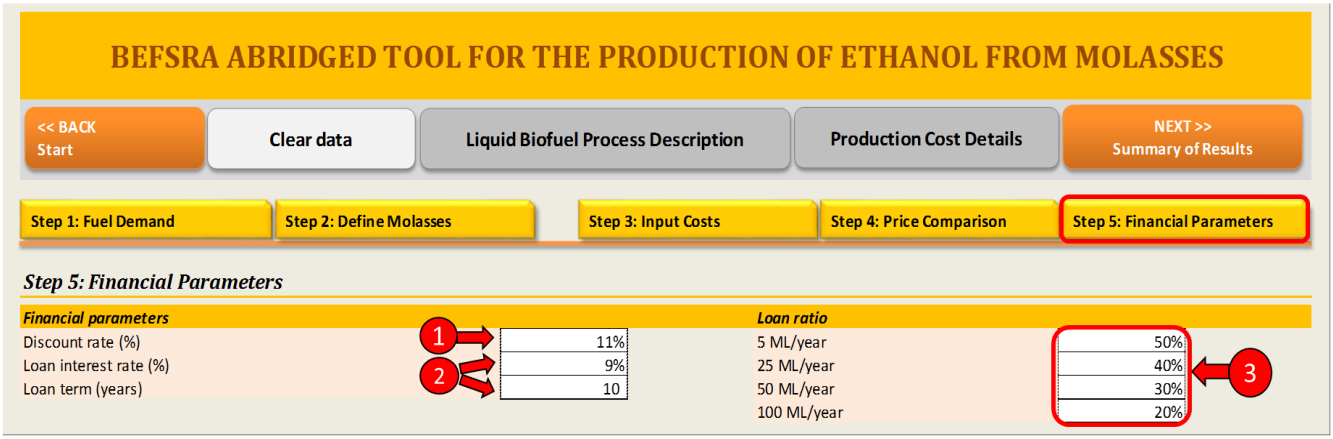

Figure 15: Financial parameters

6 Assumptions and Limitations of the *Ethanol from molasses Component*

Before starting the analysis, the user should get familiar with the assumptions and limitations of the tool and take them into consideration during the analysis and most especially when interpreting the results.

The basic assumptions of the *Ethanol from molasses Component* are:

1. Plant sizes and investment lifetime. Four different processing plant sizes (with annual capacities of 5, 25, 50 and 100 million litres) are considered. The investment lifetime is 20 years.
2. Labour demand. The estimation of the potential impact of ethanol production on labour demand concerns only the workers who will be employed in feedstock production and in processing activities. However, those who work in transporting feedstock from the farm to the plant and liquid biofuels from the plant to the distribution areas are not considered.
3. Cogeneration system. Heat distribution for district heating is not considered.
4. Cogeneration system. The analysis assumes that all electricity produced will be consumed by the own industry facilities.
5. Cogeneration system. No distinction between heat and electricity tracking is considered.

The details of key assumptions and calculation equations are presented in the Annex.

7 The Results of the *Ethanol from molasses Component*

These paragraphs show all the results of the *Ethanol from molasses Component*. The analysis examines the profitability of ethanol production using molasses produced during sugarcane processing, in comparison with a gasoline equivalent price and international price of ethanol. These prices are break-even prices, i.e. prices corresponding to the point at which costs and revenues are equal (profit is zero). An ethanol production cost lower than the break-even price indicates that production is profitable.

Results are reported in different sheets of the Microsoft Excel files, as presented below:

1) Summary of results;
2) Production cost details; and
3) Sensitivity analysis for the sugar/ethanol fraction.

7.1 The Summary of Results

At the top of the "Summary of res" worksheet, the navigation buttons are included. The user can return to the "Data Entry" sheet or got to the "Start" sheet (Figure 16, label 1), or return to the "Cogeneration System Details" or the "Liquid Biofuel Process Description" sheets (Figure 16, label 2). The user can also review the "Production Cost Details" (Figure 16, label 3) or perform a sensitivity analysis at the "Sensitivity Sugar/Ethanol Production" sheet (Figure 16, label 4).

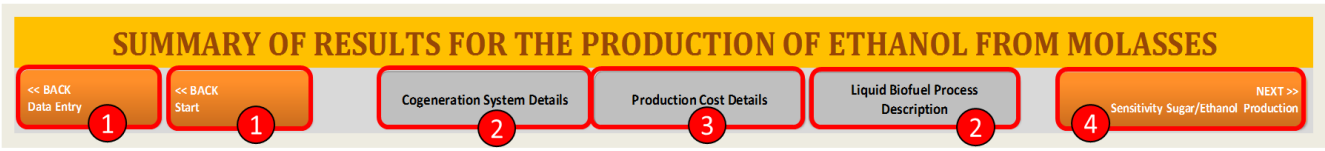

Figure 16: Summary of results

Different indicators of economic profitability of ethanol production from molasses are then reported in different sections of this worksheet:

a) the Production Cost and Investment section focuses on the comparison between the production cost of ethanol obtained by plants of different sizes and the equivalent price of gasoline and ethanol;
b) the Operating Results section reports on the molasses requirement with respect to the national biomass availability; the percentage of obtainable mix based on the potential production of ethanol given the available molasses; and the number of new jobs which might be created by establishing the plant;
c) The Financial Analysis section shows the results of the financial evaluation for each plant by applying the NPV and IRR.

7.1.1 Production Cost and Investment Results

In this section, a comparison between the ethanol production costs and the prices of alternative energy sources for all plant sizes is shown.

Figure 17 shows the comparison of ethanol production cost with the gasoline equivalent price (Figure 17, label 1) and the international prices of ethanol (Figure 17, label 2) compared with ethanol production costs, in order to assess their profitability. Figure 17 shows the case of a gasoline net importer country interested in the option

of exporting ethanol. Given that the country is a net importer, FOB price of gasoline equivalent is used (Figure 17, label 3) and a comparison is made between production costs and FOB prices of ethanol (Figure 17, label 4). Moreover, the tool allows the user to compare a range of production costs corresponding to plants of different sizes (Figure 17, labels 5).

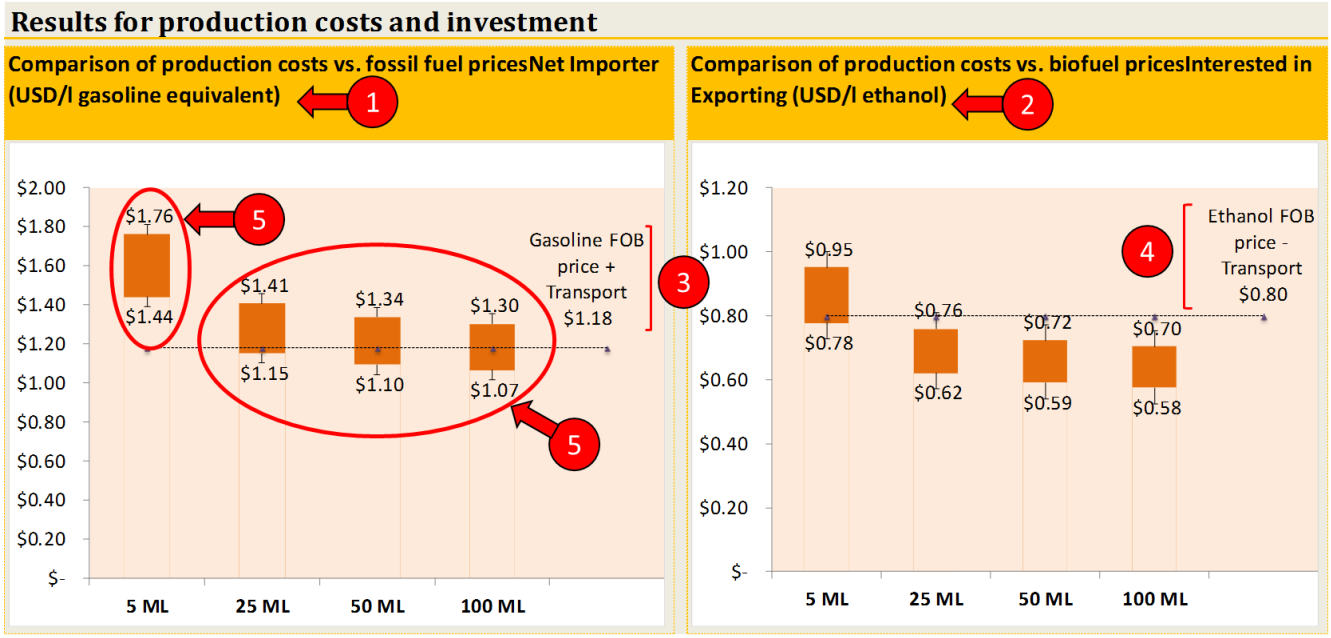

Figure 17: Production costs compared with fuel prices

The results in Figure 17 shows that large-sized plants are found to be more competitive than small-sized ones. However, the transition from 25 to 50 million litres and from 50 to 100 million litres exhibits a lower reduction in production costs than between 5 and 25 million litres (Figure 17, label 5). This shows that there is a strong advantage of scaling up the production capacity of ethanol plants.

Figure 18 shows the composition of the production cost for all selected plant sizes (Figure 18, label 1). Figure 18 shows the different elements which compose the production cost of different schemes for a plant: feedstock, labour, services, logistics, depreciation and maintenance, and other costs (Figure 18, label 2). For example, in the case of a 5 ML plant, feedstock contributes with 45% to the overall ethanol production cost.

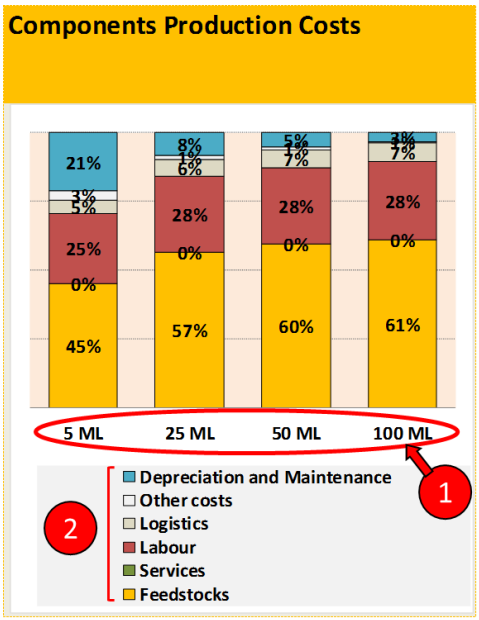

Figure 18: Share of Production Costs according to Plant Size

Figure 19 shows the total investment costs of implementing production through plants of different sizes (5, 25, 50, 100 million litres) (Figure 19, label 1).

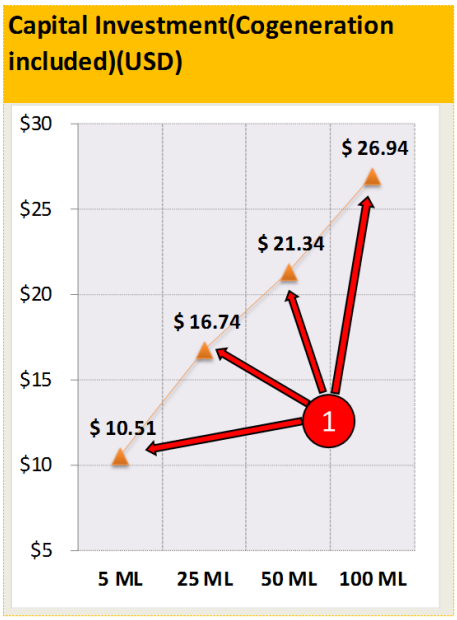

Figure 19: Capital Investments by Plant Size

7.1.2 Operating Results

This section reports information on the opportunity to produce ethanol based on the feedstock availability for each selected crop, predefined mandates for ethanol mix with gasoline and potential job creation.

Figure 20 shows whether the biomass requirement (Figure 20, label 1) for each plant size can be satisfied by the available biomass (Figure 20, label 2): the production is feasible only for plant sizes for which the requirement is lower than the available biomass. For example, Figure 20 shows that the available feedstock is not enough to cover the demand of a 100 ML plant.

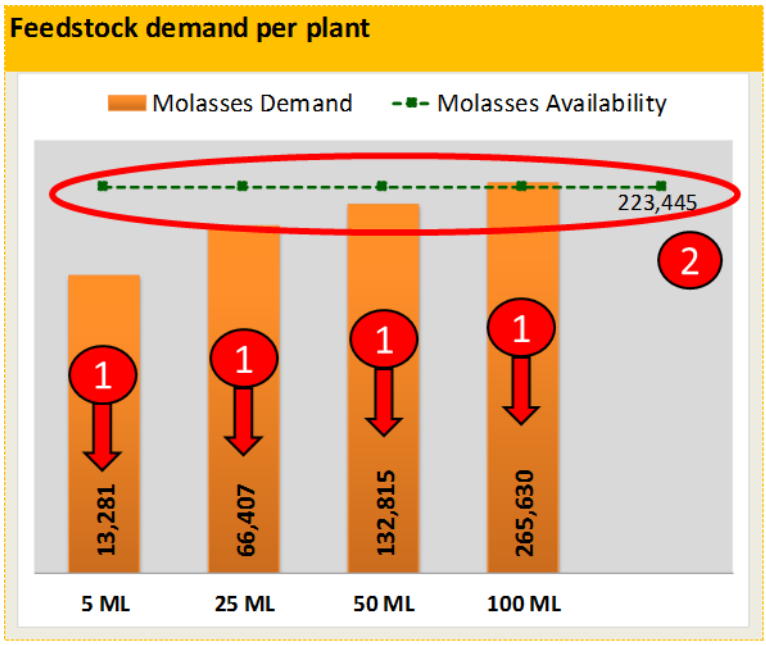

Figure 20: Feedstock Consumption per plant

Figure 21 shows the maximum attainable ethanol production according to 5 predefined mandates for ethanol mix with gasoline (E5, E10, E15, E20, E100) (Figure 21, label 2) based on the gasoline demand in the country, maximum production of ethanol with available molasses and current domestic ethanol production (Figure 21, label 1). Figure 21 also shows the demand of mix that each mandate would create for the country (Figure 21, label 3). In this example, Figure 21 shows that an E15 mandate would require 108.6 ML/year of mix to be covered, potential production accounts only for 84.1 ML/year (77% of the mandate).

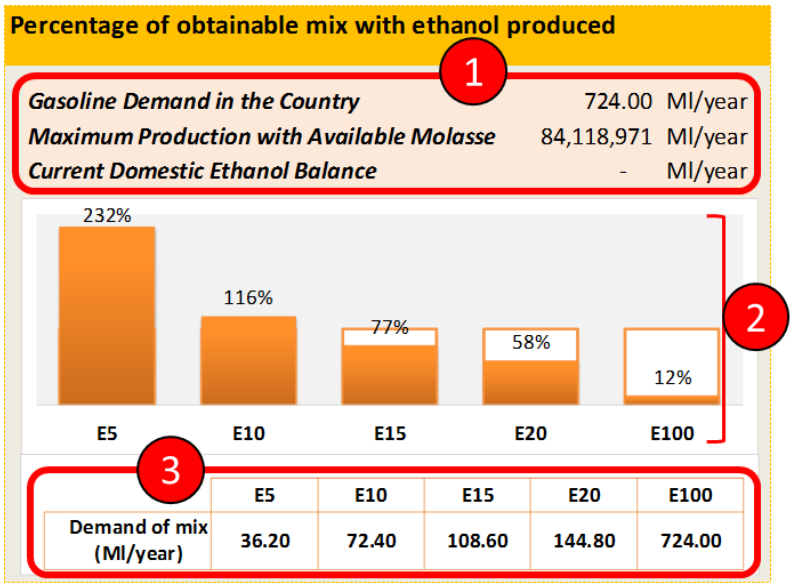

Figure 21: Percentage of obtainable mix with ethanol production

Finally, Figure 22 indicates the total number of jobs created in ethanol processing for any plant size (Figure 22, label 1) and number of fixed jobs created and temporary jobs required during the harvesting period (Zafra) (Figure 22, label 2).

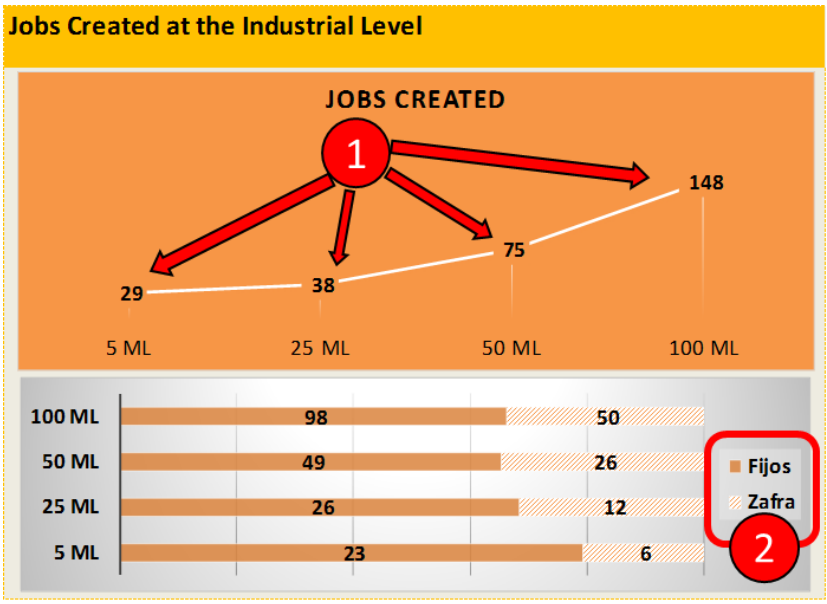

Figure 22: Number of jobs created at the industrial level

7.1.3 Financial results

The information presented in this section aims at providing the user with a summary of financial parameters related to ethanol production from molasses: NPV and IRR.

Figure 23 shows results for the Net Present Value (Figure 23, label 1) and the Internal Rate of Return for all selected plant sizes (Figure 23, label 2)

When using the NPV, the selection criterion is to consider positively all investments with a net present value greater than zero, when discounted at a suitable discount rate, which is most often the opportunity cost of capital. The example reported in Figure 23 shows that the production of ethanol is more profitable in bigger plant sizes: in fact, NPV is negative for a 5 million litres plant, showing that such a plant size does not represent a profitable investment for this specific example. On the contrary, NPV is positive for larger plant sizes.

When using the IRR, the selection criterion is to accept all independent projects with an internal rate of return greater than the discount rate adopted, which generally is the opportunity cost of capital. In the example reported here (Figure 23), IRR increases with increased plant dimensions. The chart shows that there is a strict correlation between NPV and IRR: the latter is zero when the former is negative.

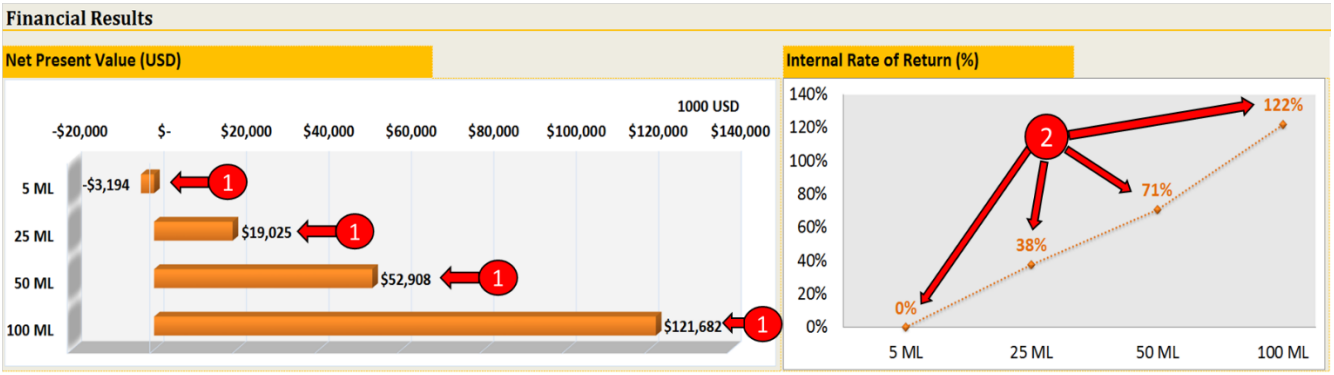

Figure 23: Financial Indicators of Ethanol Production from Molasses

7.2 Production cost details

This section presents in detail the production costs involved in the production of ethanol from molasses at different capacities (Figure 24). The detail of the production costs will allow the user to identify the participation of the different investments in the total investment and of the different operating costs in the cost of production of ethanol from molasses.

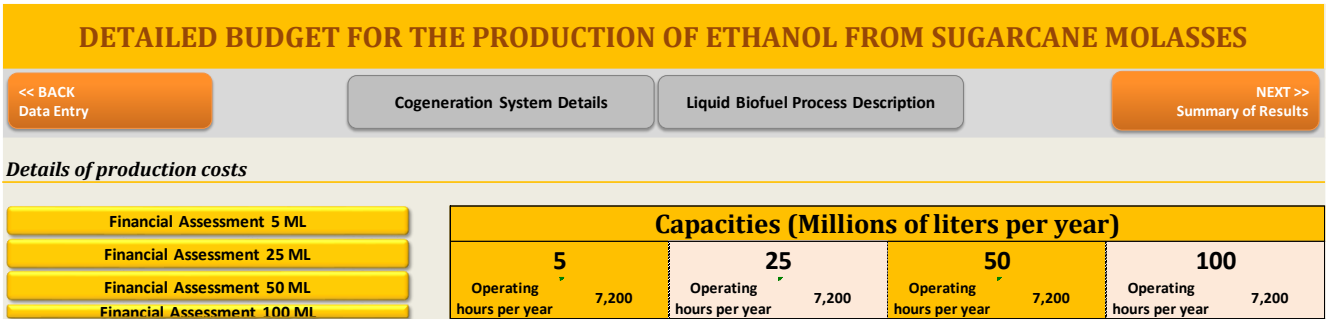

Figure 24: Production cost details according to production capacity

The information presented aim to answer the following questions for each production capacity:

- What is the share of the investment in equipment, construction and installation cost from the total investment?
- How much biomass is required to secure the supply of biomass for the production of ethanol? What is the cost?
- What is the share of other costs such as labour, energy inputs, chemical inputs, transport and storage of feedstock/final product in the production cost of ethanol?
- What is the cost of including a cogeneration system? What are the financial advantages?
- Which is the more suitable feedstock for the cogeneration system?

At the end of the section is the summary showing the total production costs divided into operating costs, fixed costs and other costs (Figure 25, label 1). The section also shows the total production costs per litre of ethanol produced (Figure 25, label 2).

Total production costs (USD/year)

	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)
Total operating costs	$ 3,124,843	$ 0.62	$ 14,890,119	$ 0.60	$ 29,358,610	$ 0.59	$ 58,597,385	$ 0.59
Total fixed costs	$ 1,061,919	$ 0.21	$ 2,157,608	$ 0.09	$ 3,187,438	$ 0.06	$ 4,993,224	$ 0.05
Other total costs	$ 136,700	$ 0.03	$ 217,634	$ 0.01	$ 277,458	$ 0.01	$ 350,311	$ 0.00
Total production costs (USD/year)	$ 4,323,462		$ 17,265,361		$ 32,823,506		$ 63,940,920	
Total production costs per litre (USD/l)		$ 0.86		$ 0.69		$ 0.66		$ 0.64

Figure 25: Production cost details according to production capacity

For the example, the production cost for a 5 ML of ethanol per year capacity is 0.86 USD/l while the production cost for a 100 ML of ethanol per year capacity is 0.64 USD/l. Therefore, the largest plant has a more competitive production cost and therefore represents a more attractive investment.

7.3 Sensitivity analysis for the sugar/ethanol fraction

This section allows the user to perform a sensibility analysis to determine for a sugarcane processing facility the optimal fraction for the production of ethanol and sugar in order to maximize the potential profits. As seen in Figure 26, sugarcane juice can be either used for the production of sugar or for the production of ethanol. The sugarcane juice fraction assigned for ethanol production will be used together with the molasses obtained as by-product from sugar processing for the production of ethanol.

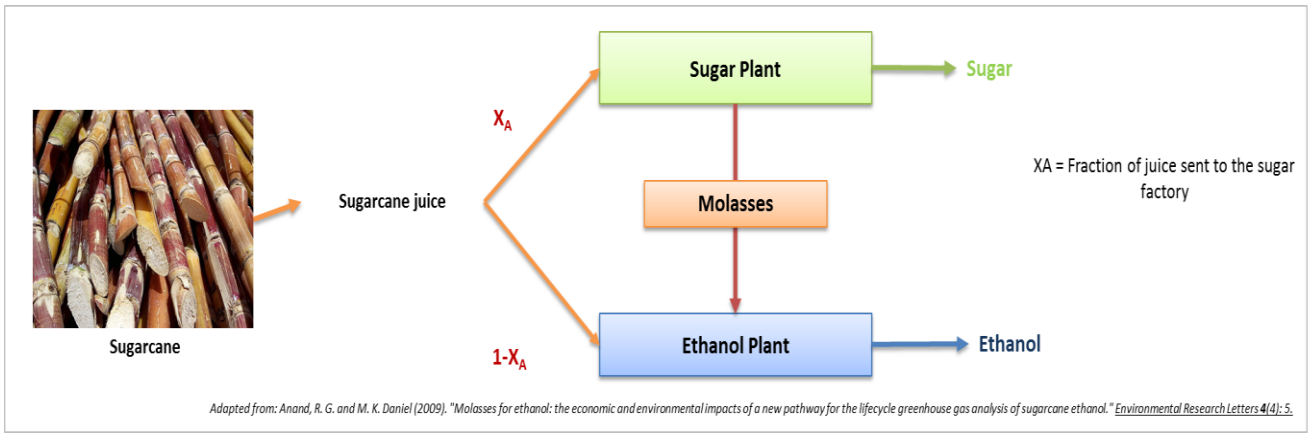

Figure 26: Sugarcane juice fractions for the production of sugar or ethanol

By entering parameters regarding the selling price for sugar (Figure 27, label 1) and the production cost of sugar (Figure 27, label 2) the tool will perform a sensitivity regarding the fraction of juice dedicated to ethanol production at different production capacities (Figure 27, label 3).

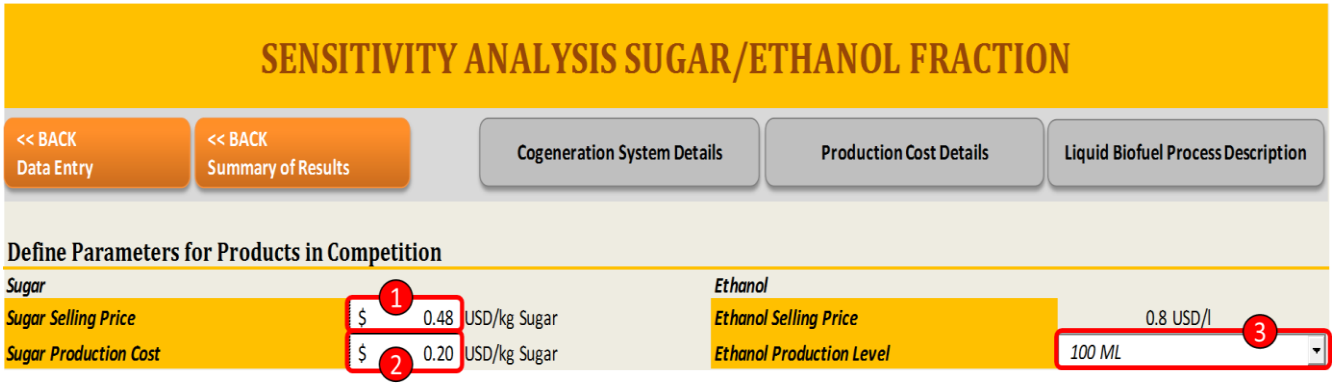

Figure 27: Sensitivity analysis of the sugar/ethanol fraction

Figure 28 presents a snapshot of the sensitivity analysis included in molasses tool to help users to simulate the decision that sugar mills need to make regarding the distribution of sugar cane juice. One of the primary drivers to decide in what extend the available sugar juice is either for ethanol or sugar are the prices of ethanol and sugar.

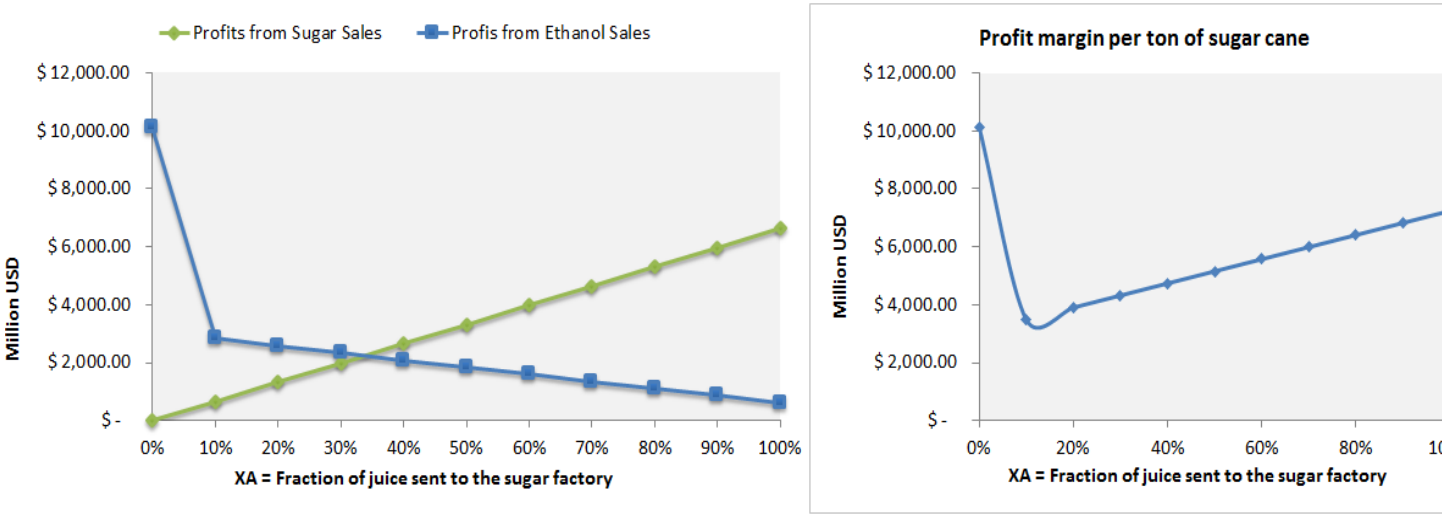

Figure 28: Results of the sensibility analysis of the sugar/ethanol fraction

For this example, the profitability of sugar and ethanol production from the sugar mill point of view is compared.

It can be concluded that:

Given current ethanol and sugar prices, as well as the production costs calculated for a 100 Ml plant (0.64 USD/l). It can be stated that the most profitable option would be to dedicate 100% of sugar cane juice (Xa=0%) to ethanol production. Any combined production in this case would result in a reduced profitability. However, sugar mills need to fulfill market quotas and production agreements. As a result, the final distribution of sugar cane juice will be defined by a combination of profitability results and the specific production objectives of the sugar mill.

It is important to highlight that these results are highly dependent on the inputted prices and under the situation.

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