BIOENERGY AND FOOD SECURITY RAPID APPRAISAL (BEFS RA)

User Manual

ETHANOL AND BIODIESEL

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BEFS Rapid Appraisal

Energy End Use Options Module

Transport Sub-Module

Ethanol and Biodiesel

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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II. Country Status Module

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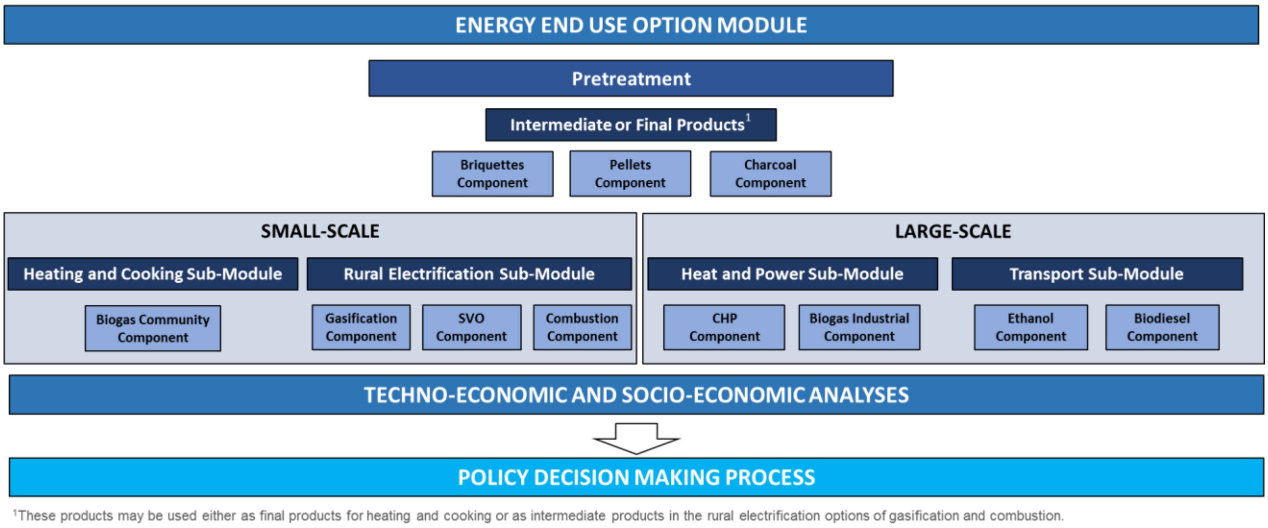
1 Overview of the Energy End Use Option (End Use) Module

As explained in the general introduction of the BEFS RA training manual, the *Energy End Use Option* module is used to assess the techno-economic and socio-economic viability of different bioenergy production pathways. The module is divided into five sections, these are: Intermediate or Final Products, Heating and Cooking, Rural Electrification, Heat and Power and Transport. Each of the sub- modules includes a choice of components of analysis to assess the production of specific biofuels based on particular processing technologies, as depicted in Figure 1. This module builds up from the information generated in the *Natural Resources* modules in relation to feedstock. For a more detailed description of the module, refer to the general introduction of the training manual.



[1]These products may be used either as final products for heating and cooking or as intermediate products in the rural electrification options of gasification and combustion.

Figure 1: The Structure of the Energy End Use Option Module

A general description of each of the sub-modules and their respective components of analysis are presented below. A more detailed discussion on each of the components of analysis will be provided in the respective user manual.

The **Intermediate or Final Products** sub-module is used to assess the viability of producing briquettes, pellets and charcoal. The **Briquettes/Pellets** components are used to evaluate the potential to develop the production of biomass briquettes/pellets to supply energy for heating and cooking in rural and urban households. The objective of the analysis is to generate information on production cost, biomass requirements and financial viability and social parameters to help users in their decision to promote briquette/pellet production in the country. The **Charcoal** component is used to compare existing charcoal production technologies with improved and more efficient technologies. The aim of the analysis is to assess the required upfront capital cost of the improved technologies, the financial viability from the standpoint of charcoal producers and the social and environmental benefits that improved technologies can trigger when compared to existing charcoal production technologies. The results generated by the analysis inform on potential barriers for the uptake of the improved charcoal technologies by producers and help define how to effectively disseminate their introduction.

The **Heating and Cooking** sub-module is used to assess the viability of producing biogas at the community level. The **Biogas Community** component is used to evaluate the potential to develop biogas production from livestock manures at the household and community levels and compares three different types of technologies. The component generates information on: 1) the amount of biogas that can be produced based on manure availability, 2) the size of biodigester needed to harness the energy, 3) the installation cost of three types of biodigester technologies. The component also provides financial social and economic parameters to help the user understand the potential opportunities and the requirements needed for deploying biogas technology in their countries.

The **Rural Electrification** sub-module is used to assess the viability of supplying electricity from local biomass resources in remote areas without access to the electric grid. The sub-module is comprised of three decentralized-based technology pathways for electrification, these are: gasification, use of straight vegetable oil (SVO) and combustion. The results from this sub-module generate estimates of the cost of electricity generation and distribution, calculates the financial viability of electrification and informs on the associated social and economic outcomes for each alternative technology pathway. The **Gasification** component analyses the partial burning of biomass to generate a gas mixture that is subsequently combusted in gas engines to produce electricity. The **Straight Vegetable Oil (SVO)** component builds on from the Crops component in the Natural Resources module. It assesses the potential to substitute diesel with SVO in generators to produce electricity. The **Combustion** component assesses the burning of biomass to produce steam which drives a turbine to produce electricity.

The **Heat and Power** sub-module is used to assess the viability of the production of electricity and heat from local biomass resources. The sub-module is comprised of two decentralized-based technology pathways for electrification and heat, these are: CHP (cogeneration) and biogas industrial. The results from this sub-module generate estimates of the cost of electricity/heat generation and distribution, calculates the financial viability of electrification/heat and informs on the associated social and economic outcomes for each alternative technology pathway. The **CHP (cogeneration)** component examines the potential for the simultaneous production of electricity and heat from a biomass source, allowing the user to analyse a factory integrated production or a standalone operation for pure grid electricity generation. The **Biogas Industrial** component evaluates the potential to develop a biogas-based industry for electricity, heat, CHP or upgraded biogas. This is done by using waste water, high moisture solids, low moisture solids or a combination of these. All technology pathways are based on simple and readily available technologies that can be easily adaptable to remote rural areas.

The **Transport** sub-module is used to assess the viability of producing liquid biofuels for transport, namely ethanol and biodiesel. The analysis builds on the results generated from the Natural Resources' components in terms of feedstock availability and the crop budget. The tool covers ethanol and biodiesel. In the ethanol sections the users can assess the potential for developing the ethanol industry in the country. Likewise in the biodiesel section, the potential for developing the biodiesel industry is assessed. The analyses generates results on the cost estimates for the production of the selected biofuel based on feedstock origin, i.e. smallholder, combination smallholder/commercial or commercial, and according to four predefined plant capacities, namely 5, 25, 50 and 100 million litres/year[4]. The results also consist of information on economic feasibility and socio-economic parameters. In this component, the user has the

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[4] The selection of the predefined plant capacities is based on a review of relevant literature; please see the Transport manual for further details.

option to include into the assessment a GHG emissions analysis that covers the whole supply chain of the selected biofuels.

Another option for the user is to utilise the **Pretreatment Calculator** prior to using the Energy End Use tools[5]. This allows the user to calculate the additional costs of pre-processing the biomass selected in order to obtain the specific conditions required for the final biomass conversion for energy end use.

2 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.

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[5] The Pretreatment Calculator can be used prior to utilising the Energy End Use Tools. The exceptions are the *Biogas Community and Transport Tools*, as these tools already include pretreatment.

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 2.

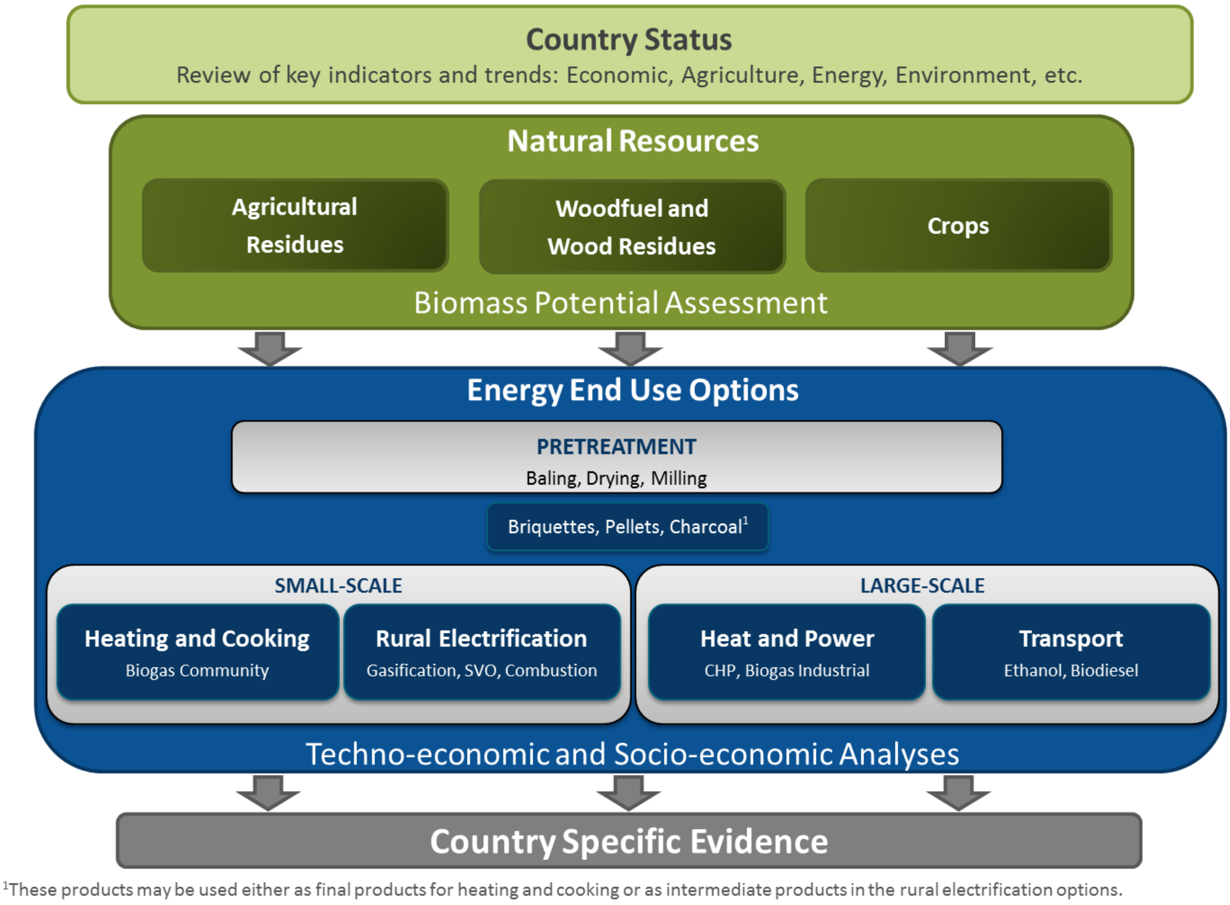

Figure 2: Overview of the BEFS Rapid Appraisal

3 Terms and Definitions in the *Transport Sub-Module*

This section defines specific terms used in the *Transport Sub-Module*, with reference to the variety of agricultural production systems taken into account in the BEFS RA. The different concepts and methodological approaches followed in the module are also explained. Some of the terms are also used in other tools and components, especially in the *Crop Budget Tool*.

3.1 Feedstock production technology

In order to assess the cost of feedstock production, the methodology used in the *Transport Sub-Module* builds upon the methodology adopted in the *Crops Component*. Therefore, the approach and definitions from the Global Agro-Ecological Zones (GAEZ) methodology (IIASA/FAO, 2012b) also apply here.

Input level of agricultural production (technology level)

GAEZ defines three generic input levels for agricultural production: low, intermediate and high. In GAEZ, this variety in management and input levels is translated into yield differences (IIASA/FAO, 2012b)[6].

- **Low input:** Under a low input level, the farming system is mainly subsistence-based. Production is based on the use of local cultivars (if improved cultivars are used, they are treated in the same way as local cultivars) and labour intensive techniques. Under this level, chemicals for pests and disease control, along with nutrients, are not utilized. There are minimum conservation measures.
- **Intermediate input:** Under an intermediate input level, the farming system is partly subsistence-based and partly market-oriented. Production is based on improved varieties, on manual labour with hand tools and/or animal traction and some mechanization. Under this level, the labour is medium intensive, and some fertilizer and chemicals for pests, disease and weed control are applied. Additionally, the fallow planting strategy is implemented, as well as other conservation measures.
- **High input:** Under a high input level, the farming system is mainly market-oriented. Production is based on improved or high yielding varieties and is fully mechanized with low labour intensity. Under this level, there are optimum applications of nutrients and chemicals for pests, disease, and weed control.

3.2 Feedstock production schemes

In order to estimate the feedstock needed to implement biofuel production, the model uses three different production schemes: outgrowers, own-production and mixed.

- **Outgrowers scheme:** Under this production scheme the price paid at the processing gate to the outgrowers is the market price (computed based on average national prices)[7]. Outgrowers are smallholder farmers. It is assumed that there is a direct purchase agreement between the smallholders and the biofuel processors and that no middleman is involved in the transaction. The level of technology applied in this scheme makes use of different crop yields, depending on the comparison between the current yield of the selected crop recorded in the area of analysis and the yield derived from GAEZ database. Specifically:
    - If the current yield of the selected crop is lower than the low input yield reported in the GAEZ dataset, the sub-module assumes that feedstock is produced by low input level farmers;
    - If the current yield of the selected crop assumes a value between the low input and intermediate input yields reported in the GAEZ dataset, the sub-module assumes that feedstock is produced by intermediate input level farmers;

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[6] Definitions for input levels described here are adopted/simplified from those in the GAEZ Model Documentation, thus for detailed description please see: IIASA/FAO, 2012b.

[7] The user can also utilise the farm gate price (production price), if this price is available. The market price overestimates the remuneration of outgrowers. The price paid to the outgrower is between the producer price and the market price. The market price is easier to individuate (many national statistical offices should register such prices). This price represents the maximum threshold for the producer of biofuels and determines the highest cost of production for liquid biofuel.

  - If the current yield of the selected crop is higher than the intermediate-input yield reported in the GAEZ dataset, the sub-module assumes that feedstock is produced by low input level farmers.

- **Own production scheme:** Under this production scheme the cost of raw material at the factory gate is the feedstock production cost. The total feedstock production is produced by the factory itself. Own producers always produce feedstock at high input level (large-scale or commercial farmers).
- **Mixed Outgrowers-Own production scheme:** Under this scheme raw material is partly supplied by outgrowers (40%) and partly (60%) by commercial farmers (own producers). The cost of raw material under this production scheme is computed on the basis of a combination of the price paid to the outgrowers and the cost borne under the own production scheme. The objective of this scheme is to assess if liquid biofuel can be produced competitively when smallholders are included in the production chain. It should be noted that the shares of raw material contribution by farmer typology reported above could change depending on country context. In order to define a more realistic country context, the user has the option to change these shares in the *Cost_Fs* sheets (see section 5.3), which refer to production costs for each of the crops selected in the *Transport Sub-Module*.

3.3 Comparison between production cost of biodiesel/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 fossil fuels; or a net importer/exporter interested in exporting liquid biofuels. 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.

3.3.1 Comparison with fossil fuels

Scenario 1 – Net importing country

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

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 biodiesel/ethanol (in oil equivalent) with the FOB price of gasoline/diesel 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 biodiesel/ethanol (in oil equivalent) with the Refinery Gate Price (RGP) of gasoline/diesel.

3.3.2 Comparison with liquid biofuels

Scenario 1 – Net importing country

The sub-module compares the production cost of biodiesel/ethanol with the Free on Board (FOB) price of biodiesel/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 biodiesel/ethanol (in oil equivalent) with the FOB price of gasoline/diesel 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 biodiesel/ethanol with the average factory gate price of biodiesel/ethanol in the country[8].

Scenario 3 – Interested in exporting

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

3.4 Liquid biofuels production

The sub-module considers these indicators based on the total amount required to meet the mandatory blending as indicated in the Biofuel Demand sheet (see section 5.1) and the number of plants potentially supplied (see sections 7.1.2 and 7.2).

- **Maximum attainable biofuel production:** The maximum attainable biofuel production indicates whether the liquid biofuel obtained from the selected crops is enough to meet the amount proposed under mandatory blending, which is included under biofuel demand (see section on Target Biofuel Production in the Country).
- **Number of plants potentially supplied:** This indicates the number of plants potentially supplied based on the available biomass, selected plant sizes and targeted crops.

3.5 Financial analysis

The financial analysis examines the profitability of investing in biofuel processing plants of different sizes. The sub-module computes the following indicators[9]:

- **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

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

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

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.

3.6 Labour and land requirement

The *Transport Sub-Module* estimates labour and land requirements for biofuel processing plants of different sizes.

- **On-farm labour:** The labour used in various agricultural operations has been divided into manual and machinery and includes Land Preparation, Sowing, Other Field Operations, Harvesting and Miscellaneous. For land preparation the use of animal traction is assumed. Manual labour includes both family and hired labour and is expressed in man-days/hectare assuming 8 hours of labour per day. Machinery labour includes manpower for the operations (i.e. driver) and is expressed in hours of work per hectare.
- **On-plant labour (processing):** The plants are assumed to operate 8000 hours per year (i.e. 24 hours per day, 333 days per year) on a three eight-hour shifts cycle (3 x 8hr). The number of workers per shift was calculated based on the rule of thumb reported by Van Gerpen (2008) which states that at least 1 unskilled worker is required per million gallon of biodiesel produced. The number of skilled workers required is assumed to be one for every four unskilled workers working in the plant.
- **Working day:** A day on which work is done for an agreed number of hours in return for a salary.

4 Scope and Objective of the *Transport Sub-Module*

The aim of the *Transport Sub-Module* is to provide the user with preliminary information on feedstock requirements, profitability and socio-economic aspects of liquid biofuel production schemes based on the origin of the feedstock (outgrowers only, own production, or mixed outgrowers and own production scheme) and the pre-defined plant sizes (capacities) of biofuel production (5, 25, 50 and 100 million litres per year). The biodiesel/ethanol sections calculate the production cost and assess the profitability and socio-economic implications for biodiesel and ethanol production for different production schemes at the pre-defined plant capacities.

The two sections of the *Transport Sub-Module* calculate the biofuel production costs taking into account the prices of feedstock (raw material) and other operating inputs such as skilled and unskilled labour, transport of feedstock from farm to processing plant, investments required to build a biodiesel/ethanol plant and the operating cost for running it (maintenance, storage plant overheads and general and administrative costs) to calculate the biofuel production cost. The user obtains an estimated unitary biofuel production cost for each of the four plant sizes included in the tool. The user can then compare the costs of different production pathways on parameters such as different feedstock, origin of the feedstock and the biofuel production sizes. The user can also compare between the estimated cost of biofuel production and the equivalent prices of diesel/gasoline. This is useful information to have since it gives the user an indication which plant sizes are more competitive.

This information together with a projection in revenue and financial parameters is used to build the financial budget. The financial analysis estimates the profitability of investing in biofuel production at different scales of production. The Net Present Value (NPV) and the Internal Rate of Return (IRR) are calculated. Respectively, these financial indicators provide a discounted measure of the project value and the maximum interest rate that a project can pay for the resources used.

The socio-economic analysis of liquid biofuel production provides the user with information on the potential employment generation in rural areas under different production schemes as well as the amount of land required to produce the feedstock needed to supply the different plant sizes. Potential employment opportunities, both at feedstock production and processing plant level, are calculated based on labour coefficients, biofuel conversion factors and operating inputs related to each biodiesel/ethanol processing plant. The *Transport Sub-Module* also allows the user to assess the land requirements based on the biomass requirements of the different plant sizes, according to the specific biofuel crop and considering the difference in productivity levels of feedstock associated and to the origin of the feedstock (i.e. smallholder vs. commercial production level).

Table 1: A Summary of the Information Provided by the *Transport Sub-Module*

	Question	Information Provided by the Tool
Feedstock Production	▪ What is the profitability of the selected plant sizes with the participation of smallholders as the feedstock providers and how do they differ? ▪ What is the production cost of liquid biofuels based from different crops?	▪ Estimation of biofuel production cost for selected plant sizes with and without the participation of outgrowers as feedstock suppliers. ▪ Estimation of key profitability indicators: - Estimation of key indicators on investment returns: Net Present Value (NPV) and Internal Rate of Return (IRR) - Comparison between liquid biofuels production cost and equivalent fossil fuels prices ▪ Identification of key parameters which affect profitability of biofuel production
Land Requirement	▪ How much land will be needed if liquid biofuel production is implemented in the country, at different production scales, considering feedstock from different crops and based on the crop productivity levels of different feedstock providers?	▪ Estimation of the potential impact of biodiesel/ethanol production on cropland requirements for different plant sizes, considering different feedstock crops options and productivity levels of feedstock providers.
Labour Requirement	▪ How many jobs will be created along the value chain (feedstock production and processing) if liquid biofuel production is implemented in the country? ▪ How many jobs might be created at different scales of production? ▪ What effect on job creation can be attributed to the participation of outgrowers as feedstock providers versus their lack of participation in the value chain ?	▪ Estimation of the potential impact of biodiesel/ethanol production on labour generation for different plant sizes, feedstock crops and based on the integration of outgrowers in the value chain as feedstock providers.

The following section describes the structure of the sub-module and the options available to the user. The background methodologies for processing budget and labour and land requirement are described in detail in Annex.

5 Running the *Transport Sub-Module*[10]

The *Transport Sub-Module* runs using Microsoft© Excel software.

During the analysis, the user is navigated step by step through each of the options and is asked to enter the data needed in order to obtain the final results. When the required data are limited or unavailable, then the default values provided by the tool can be used. 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 the previous section with the "<<BACK" button.

The following sub-chapters describe each step of the analysis, using Malawi as the example.

The user should follow a sequence of steps in order to obtain final results. Nevertheless, an experienced user can run the sub-module following a different order or even omitting some steps or options (e.g. biofuel demand).

The user should enter the required data in the white cells, while calculations are shown in the grey cells. If the information is not readily available, the user will be guided through web links in order to find the corresponding country-specific information.

5.1 Step 1: Biofuel demand at country level

This step aims at estimating the amount of biodiesel and ethanol needed to reach a given national biofuel blending mandate, computed on the basis of diesel/gasoline consumed in the country. The share of biodiesel and ethanol are obtained by applying the coefficients of mandatory blending for diesel and gasoline, respectively.

The user has to enter:

1. Data on diesel and gasoline domestic consumption in ML/year. Information provided in the *Country Status* module can be used here (Figure 3, label 1).
2. Data indicating the level of biodiesel and ethanol blending planned at the domestic level. Information provided in the *Country Status* module can be used here (Figure 3, label 2).

The amount of biodiesel and ethanol the country should produce is generated by the tool based on the information provided (Figure 3, label 3).

Under Biofuel Production and Trade, the user can determine the amount of liquid biofuels consumed in the country. This value is obtained by adding the imported quantity to domestic production and subtracting the quantity exported (Figure 3, label 4). If the given country only imports, then the value will simply be the import value.

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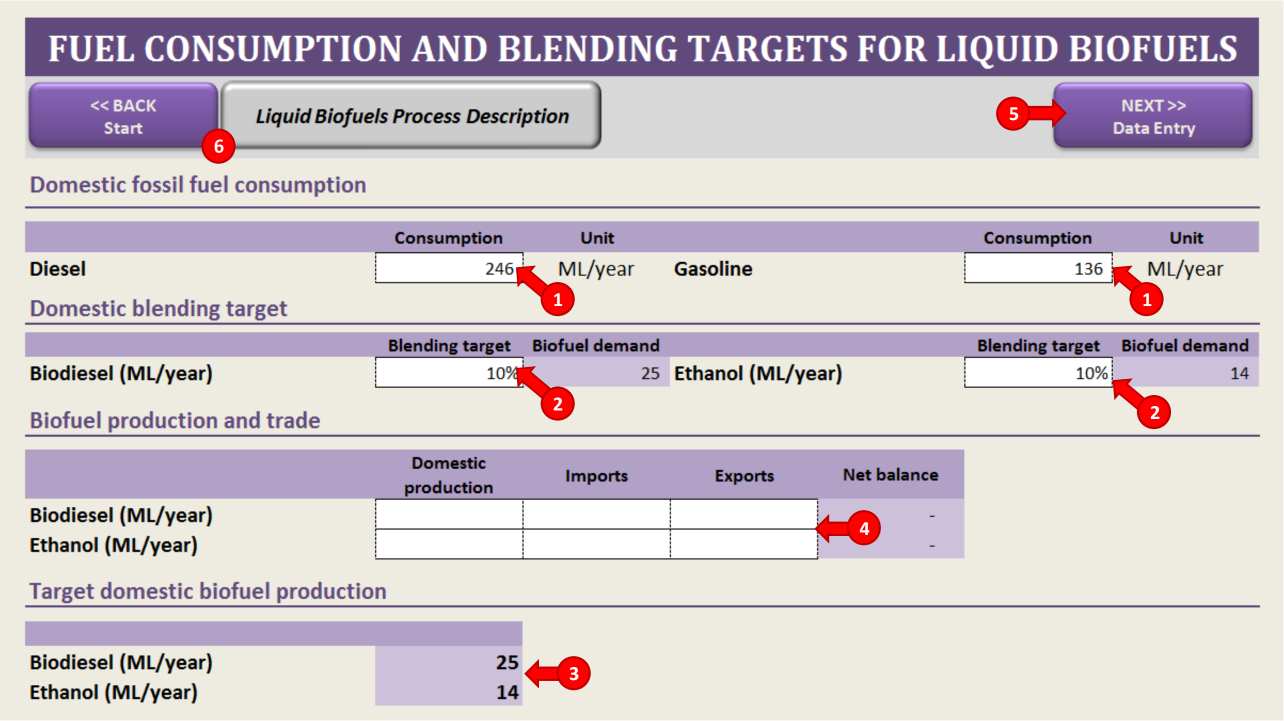
[10] A complete and detailed description of the processing budget structure both for the calculation of the production costs of biodiesel and ethanol and for the estimation of land and labour requirements is presented in Annex.



FUEL CONSUMPTION AND BLENDING TARGETS FOR LIQUID BIOFUELS

Domestic fossil fuel consumption

	Consumption	Unit		Consumption	Unit
Diesel	246	ML/year	**Gasoline**	136	ML/year

Domestic blending target

	Blending target	Biofuel demand		Blending target	Biofuel demand
Biodiesel (ML/year)	10%	25	**Ethanol (ML/year)**	10%	14

Biofuel production and trade

	Domestic production	Imports	Exports	Net balance
Biodiesel (ML/year)				-
Ethanol (ML/year)				-

Target domestic biofuel production

Biodiesel (ML/year)	**25**
Ethanol (ML/year)	**14**

Figure 3: Biofuel Demand (Fuel Consumption and Blending Targets)

5.2 Step 2: Data entry sheet

Information provided in the Data Entry sheet is useful in assessing the possibility of producing biodiesel and ethanol from selected crops based on specific technical production coefficients. The Data Entry sheet is composed of the following sections:

- Feedstock Availability and Cost – The user enters feedstock data.
- Biofuel Production Cost and Financial Parameters - The user enters data on inputs used in the production processes (e.g. chemical inputs, utilities, labour, transportation and storage) as well as financial parameters (i.e. discount rate, loan interest rate, loan term and loan ratio).
- Labour and Land Parameters – The user enters data related to labour and land requirements (i.e. yields, manual and machinery labour).

Before proceeding with the analysis, the user can choose to load the default values for running this component by clicking on the "Load Default Values" button as shown in Figure 4, label A.

5.2.1 Defining the feedstock

In this section the user is asked to select the feedstock crops used for liquid biofuel production from a long list of options[11]. Up to four crops can be analysed at the same time and they are selected from a dropdown list. The list includes 25 key food and cash crops, among which 13 are suitable for the production of liquid biofuels: coconut, jatropha, rapeseed, soybean, oil palm and sunflower for straight vegetable oil (SVO) for biodiesel; and barley, cassava, maize, sugar beet, sugarcane, sorghum and wheat for ethanol. Up to four crops can be chosen at the same time.

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[11] The information available from the *Country Status* module can help in the selection of the bioenergy crops.

In order to select the crops, the user has to first decide what type of liquid biofuel (biodiesel or ethanol) will be produced and then decide from which crop the feedstock will be produced (Figure 4, label 1). For each selected crop, the user should enter[12]:

1. Total feedstock availability (computed in the *Crop Production Tool* and expressed in t/year) (Figure 4, label 2; see section 8.2.1).
2. Feedstock prices (expressed in USD per t), which differs depending on the different production schemes (outgrowers, own production or mixed outgrowers-own production). It should be noted that the own production price stems out of the production cost calculated by *Crop Budget Tool*, while the price of feedstock produced by outgrowers is assumed to be the market price based on the current average national prices (Figure 4, label 3; see section 8.2.1).
3. Storage cost (expressed in USD per t) (Figure 4, label 4) – the user has two options to determine this data:
    A. The user can enter *the existing prices* of storage of agricultural products in the country as a proxy. The price should be entered in the respective cell for each feedstock (USD/t). If this information is not available, then the user should go to the next step.
    B. The user can determine *a proxy* for this value. The user will need to do the following:
        - Identify a type of feedstock storage likely associated with conditions in their country from the options presented in Table 2 or Table 3. Table 2 is the estimated cost of storage for feedstock that can be used for ethanol production and Table 3 is the estimated cost of storage in steel bins for feedstock that can be used for biodiesel production.
        - For the selected storage option, look up the global building cost provided in Table 2 or Table 3.
        - Enter the proxy value (USD/tonne) in the respective cell for each feedstock.

Table 2: Estimated Cost of Storage for Ethanol Feedstock

Estimated Cost of Storage	Unit	Min	Average	Max
Enclosed structure with crushed rock floor	USD/tonne	10	12.5	15
Open structure with crushed rock floor	USD/tonne	6	7	8
Reusable tarp on crushed rock	USD/tonne	n/a	3	n/a
Outside unprotected on crushed rock	USD/tonne	n/a	1	n/a
Outside unprotected on ground	USD/tonne	n/a	0	n/a

Source: (EPA, 2007)

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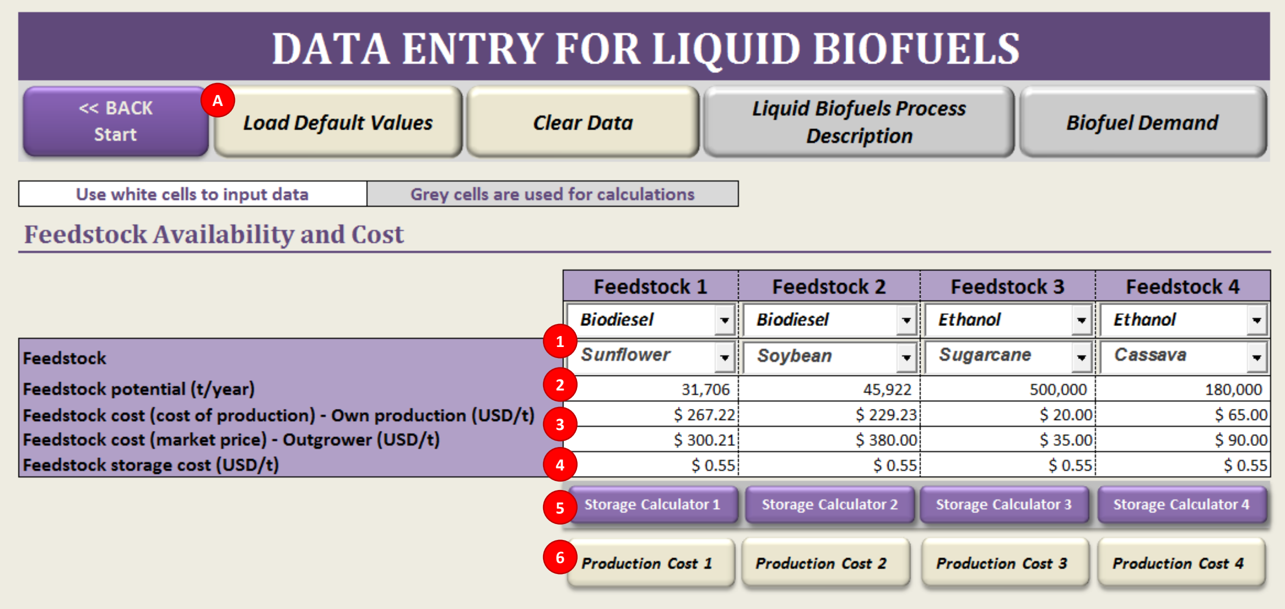
[12] The user can refer to Table 2 in the Appendix (section 8.2) where data needed to run the *Transport Sub-Module* are summarized. An indication of what data can be found in other modules, sub-modules or components are also provided.

Table 3: Estimated Cost of Storage for Biodiesel Feedstock

Storage Capacity (t)	Cost Without Floor (USD/t/year)	Steel Floor (USD/t/year)	Concrete Floor (USD/t/year)	Ventilated Floor (USD/t/year)	FAN AND HEAT (USD/t/year)
Coconut	$ 6.8	$ 7.3	$ 7.6	$ 8.6	$ 8.9
Jatropha	$ 5.3	$ 5.7	$ 5.9	$ 6.7	$ 6.9
Oil palm	$ 4.8	$ 5.2	$ 5.4	$ 6.2	$ 6.3
Rapeseed	$ 4.4	$ 4.7	$ 4.9	$ 5.6	$ 5.7
Soybeans	$ 4.8	$ 5.2	$ 5.4	$ 6.2	$ 6.3
Sunflower	$ 9.7	$ 10.4	$ 10.8	$ 12.3	$ 12.7

Calculated from: (State of Michigan 2003) and (Agriculture and Rural Development of Alberta 2014)

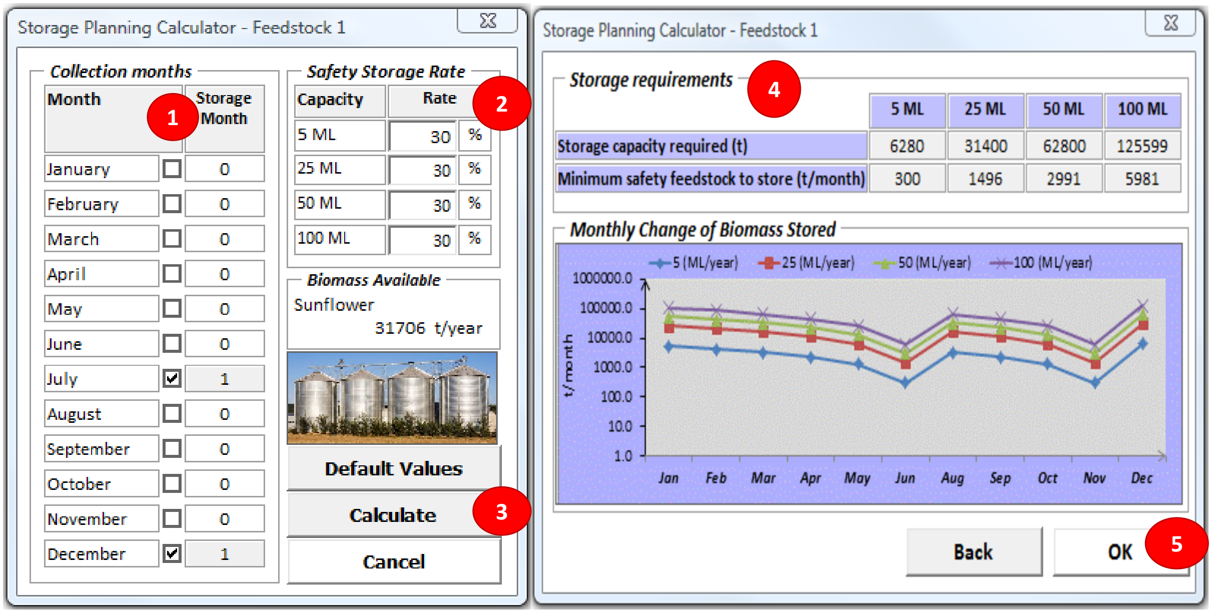


	Feedstock 1	Feedstock 2	Feedstock 3	Feedstock 4
	Biodiesel	Biodiesel	Ethanol	Ethanol
Feedstock	Sunflower	Soybean	Sugarcane	Cassava
Feedstock potential (t/year)	31,706	45,922	500,000	180,000
Feedstock cost (cost of production) - Own production (USD/t)	$ 267.22	$ 229.23	$ 20.00	$ 65.00
Feedstock cost (market price) - Outgrower (USD/t)	$ 300.21	$ 380.00	$ 35.00	$ 90.00
Feedstock storage cost (USD/t)	$ 0.55	$ 0.55	$ 0.55	$ 0.55

Figure 4: Data Entry for Liquid Biofuels: Feedstock Availability and Cost

In order to calculate the storage capacity needs, the user needs to click on the "Storage Calculator" (Figure 4, label 5). This will take the user to the Biomass Storage Calculator (Figure 5). In this worksheet, the user will need to:

1. Selects the harvesting month(s) of the crop (Figure 5, label 1).
2. Enter the biomass safety stock rate (%). This is the percentage of biomass needed to secure continuous supply of feedstock to deal with uncertainty in production due to seasonal availability, flood, drought, and other factors. This stock rate % is used to estimate the storage capacity (Figure 5, label 2).
3. Click on "Calculate" (Figure 5, 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 5, label 4).
4. Clicks "OK" to return to the Data Entry Needs sheet (Figure 5, label 5).
5. Repeat the same steps for all feedstock.



Collection months

Month		Storage Month
January	☐	0
February	☐	0
March	☐	0
April	☐	0
May	☐	0
June	☐	0
July	☑	1
August	☐	0
September	☐	0
October	☐	0
November	☐	0
December	☑	1

Safety Storage Rate

Capacity	Rate	
5 ML	30	%
25 ML	30	%
50 ML	30	%
100 ML	30	%

Biomass Available

Sunflower
31706 t/year

Storage requirements

	5 ML	25 ML	50 ML	100 ML
Storage capacity required (t)	6280	31400	62800	125599
Minimum safety feedstock to store (t/month)	300	1496	2991	5981

Figure 5: Storage Calculator of Feedstock

At this stage, the user may choose either to look at how production costs are structured (Figure 4, label 6) or continue to insert data into the Data Entry sheet. The user can find a detailed explanation of the structure of the Processing Budget in the Annex.

5.2.2 Biofuel production cost and financial parameters

In this section, the user is asked to enter data related to inputs used in feedstock processing, specifically: chemical inputs, heat carrier, electricity and water, and labour. Additional data related to transport and storage costs as well as other costs and the price of co-products are also required here.

1. Chemical inputs and utilities (heat carrier, water and electricity)

Chemical inputs used in feedstock processing are: methanol, sodium hydroxyde and hexane for biodiesel production (Figure 6, label 1) and ammonia, yeast, sulfuric acid, lime, alpha-amylase and glucoamylase (Figure 6, labels 2) for ethanol production. The user has to enter input prices in USD/t and can research online for current prices[13]. The user also has to insert the prices of heat carrier (USD per tonne), water (USD per m^3) and electricity (USD per kWh) employed in the transformation process (Figure 6, label 3).

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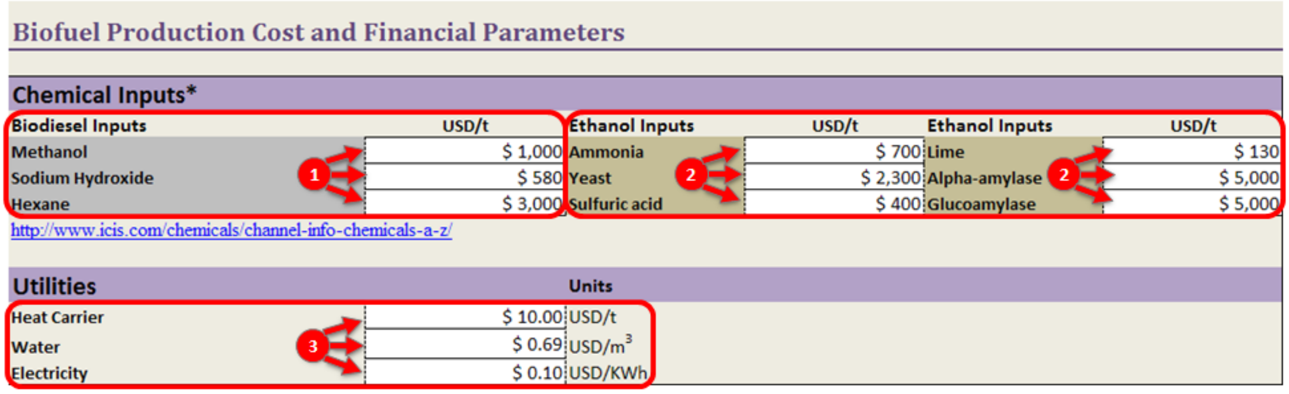
[13] For example, see http://www.icis.com/chemicals/channel-info chemicals-a-z/.



Biofuel Production Cost and Financial Parameters

Chemical Inputs*

Biodiesel Inputs	USD/t	Ethanol Inputs	USD/t	Ethanol Inputs	USD/t
Methanol	$ 1,000	Ammonia	$ 700	Lime	$ 130
Sodium Hydroxide	$ 580	Yeast	$ 2,300	Alpha-amylase	$ 5,000
Hexane	$ 3,000	Sulfuric acid	$ 400	Glucoamylase	$ 5,000

http://www.icis.com/chemicals/channel-info-chemicals-a-z/

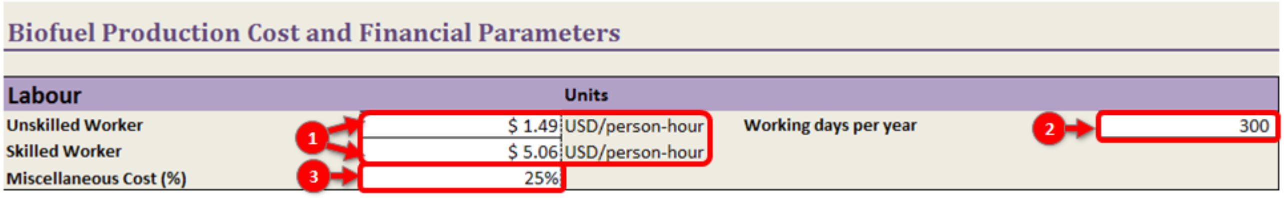
Utilities		Units
Heat Carrier	$ 10.00	USD/t
Water	$ 0.69	USD/m^3
Electricity	$ 0.10	USD/KWh

Figure 6: Data Entry for Liquid Biofuels: Chemical Inputs and Utilities

2. Labour cost, working days per year and miscellaneous 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 7, label 1). The number of 300 working days per year was assumed for the case of Malawi (Figure 7, label 2). 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.

The user should also indicate the share of miscellaneous costs expressed as percentage of total labour cost (Figure 7, label 3). 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.



Biofuel Production Cost and Financial Parameters

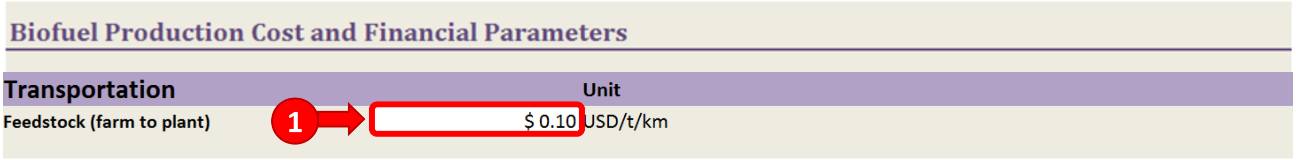
Labour		Units		
Unskilled Worker	$ 1.49	USD/person-hour	Working days per year	300
Skilled Worker	$ 5.06	USD/person-hour		
Miscellaneous Cost (%)	25%			

Figure 7: Data Entry for Liquid Biofuels: Labour Cost, Working Days per Year and Miscellaneous Costs

3. Transportation cost

In this section, the user has to insert the feedstock transportation cost from farm gate to the processing plant (Figure 8, label 1), expressed in USD per t per kilometre.

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



Biofuel Production Cost and Financial Parameters

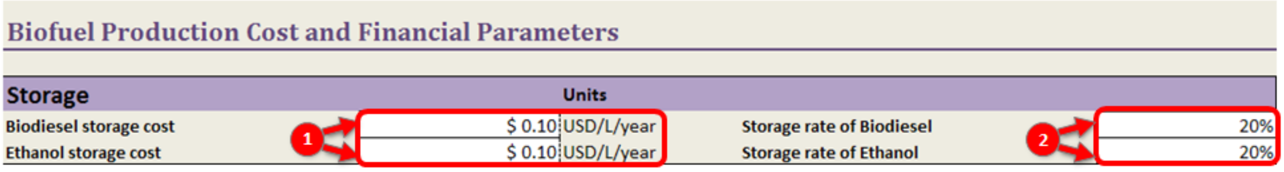
Transportation		Unit
Feedstock (farm to plant)	$ 0.10	USD/t/km

Figure 8: Data Entry for Liquid Biofuels: Transportation Cost

4. Storage parameters

The user has to enter the storage cost for liquid biofuels (USD per litre per year) in the country (Figure 9, label 1). The tool provides a general guidance for this value depending on the storage tank, but this value needs to be determined by the user according to their country situation.

The storage rate of biodiesel/ethanol (%) is also defined by the user (Figure 9, label 2). In an industrial operation, a portion of the total product 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%.



Biofuel Production Cost and Financial Parameters

Storage		Units		
Biodiesel storage cost	$ 0.10	USD/L/year	Storage rate of Biodiesel	20%
Ethanol storage cost	$ 0.10	USD/L/year	Storage rate of Ethanol	20%

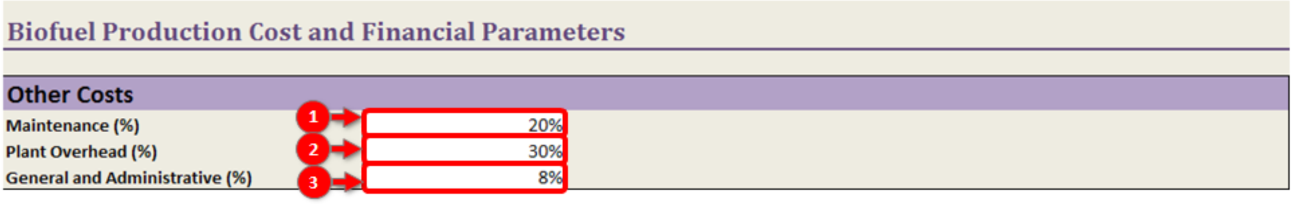
Figure 9: Data Entry for Liquid Biofuels: Storage Parameters

5. Other costs

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 (default value is 20%) (Figure 10, label 1);
- Plant overhead (general expenditures), expressed as a percentage of the sum of labour costs and maintenance costs (default value is 20%) (Figure 10, label 2); 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 (default value is 8%) (Figure 10, label 3).

The user can choose different percentages in order to define a more realistic country context.



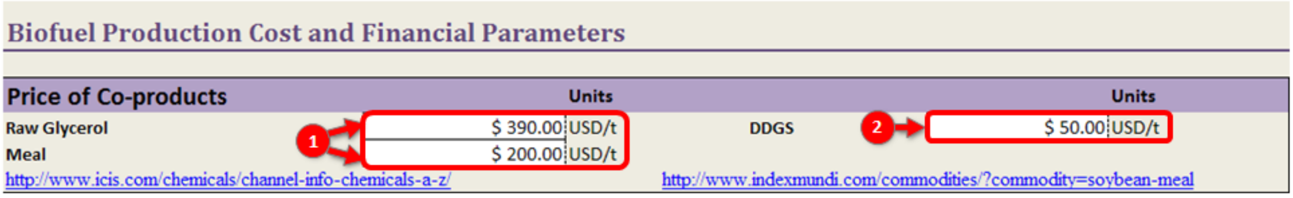
Biofuel Production Cost and Financial Parameters

Other Costs	
Maintenance (%)	20%
Plant Overhead (%)	30%
General and Administrative (%)	8%

Figure 10: Data Entry for Liquid Biofuels: Other Costs

6. Price of co-products

The co-products resulting from processing activity are considered in the general inputs section. However, since earnings from co-products are revenues (expressed in USD per t), their total amount is subtracted from total production costs. The following co-products are considered: *raw glycerol* and *meal* from biodiesel production (Figure 11, label 1) and dried distillers grains with soluble (*DDGS*) from cassava-based ethanol production (Figure 11, label 2).



Biofuel Production Cost and Financial Parameters

Price of Co-products

		Units			Units
Raw Glycerol	$ 390.00	USD/t	DDGS	$ 50.00	USD/t
Meal	$ 200.00	USD/t			

http://www.icis.com/chemicals/channel-info-chemicals-a-z/

http://www.indexmundi.com/commodities/?commodity=soybean-meal

Figure 11: Data Entry for Liquid Biofuels: Price of Co-products

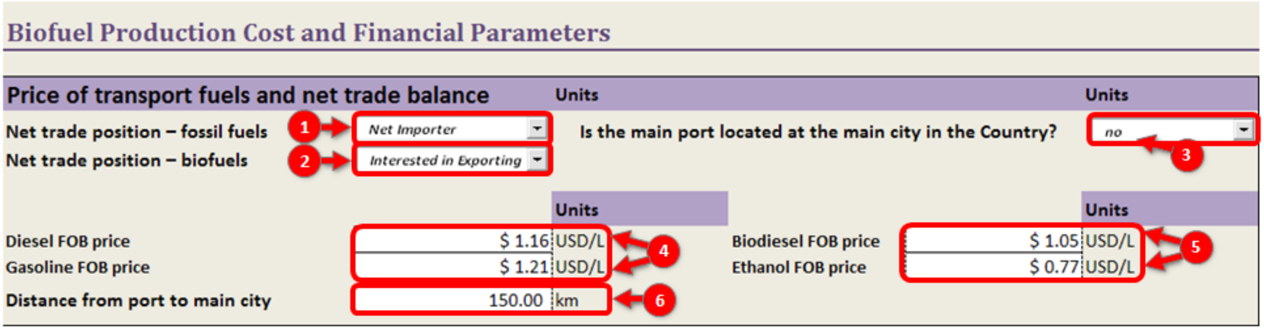
7. Price of transport fuels and net trade balance

Fossil fuels and liquid biofuels prices are taken into consideration in order to compare the production cost of liquid biofuel with the prices of alternative energy sources (international price of liquid biofuels and fossil fuel equivalent prices).

The user is asked to specify whether the country considered in the analysis is: a net importer or exporter of fossil fuels (Figure 12, label 1); a net importer, net exporter, or interested in exporting liquid biofuels (Figure 12, label 2). The user has also to indicate whether the main port is located next to the main city in the country (Figure 12, label 3). Depending on the selections made, the user is confronted with different scenarios, which entail different price comparisons and data requirements (see section 3.3.2).

For fossil fuels, the FOB price of gasoline/diesel will be used if the country is a net importer (Figure 12, label 4). Otherwise, if the country is a net exporter, the Factory Gate Price (FGP) of gasoline/diesel 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 12, label 6).

As for liquid biofuels, if the country is a net importer, the FOB price of biodiesel/ethanol will be considered. Otherwise, the average factory gate price of biodiesel/ethanol will be used[14]. 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 12, label 6). Finally, in the case of a country interested in exporting, the FOB price of biodiesel/ethanol to which the transport cost from the main city to the exit port is subtracted, should be considered (Figure 12, label 5).



Biofuel Production Cost and Financial Parameters

Price of transport fuels and net trade balance

Net trade position – fossil fuels: Net Importer
Net trade position – biofuels: Interested in Exporting
Is the main port located at the main city in the Country?: no

		Units			Units
Diesel FOB price	$ 1.16	USD/L	Biodiesel FOB price	$ 1.05	USD/L
Gasoline FOB price	$ 1.21	USD/L	Ethanol FOB price	$ 0.77	USD/L
Distance from port to main city	150.00	km			

Figure 12: Data Entry for Liquid Biofuels: Price of Transport Fuels and Net Trade Balance

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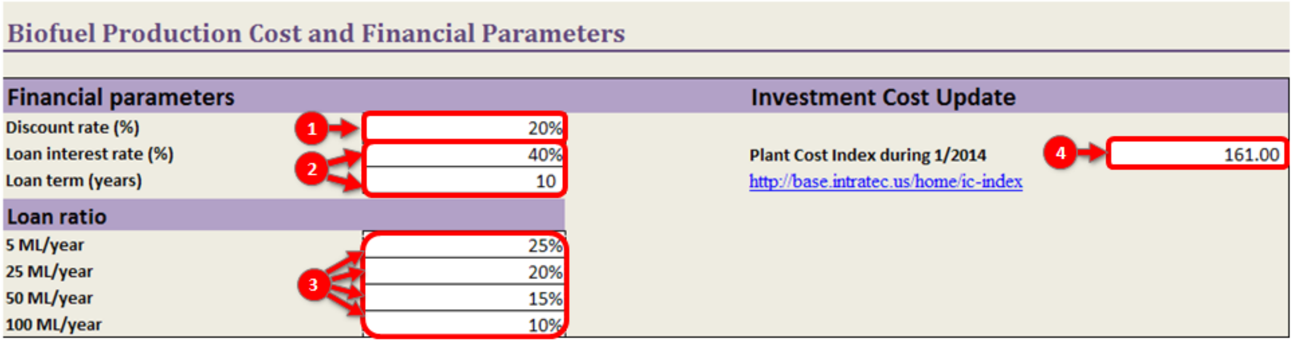
[14] This is useful, for instance, when assessing the competitiveness of alternative feedstock for the biodiesel/ethanol already produced in the country.

8. 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 default value is the interest rate charged by the country's central bank on government securities (Figure 13, 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 13, label 2). The tool allows the user to set the loan amount through a specific coefficient that can be inserted for each plant size (Figure 13, label 3). The loan amount is computed as a percentage (the so called 'loan ratio') of the investment costs. The costs of the investment can be updated using the 'Plant Cost index' (Figure 13, label 4).



Biofuel Production Cost and Financial Parameters

Financial parameters

Discount rate (%)	20%
Loan interest rate (%)	40%
Loan term (years)	10

Loan ratio

5 ML/year	25%
25 ML/year	20%
50 ML/year	15%
100 ML/year	10%

Investment Cost Update

Plant Cost Index during 1/2014: 161.00

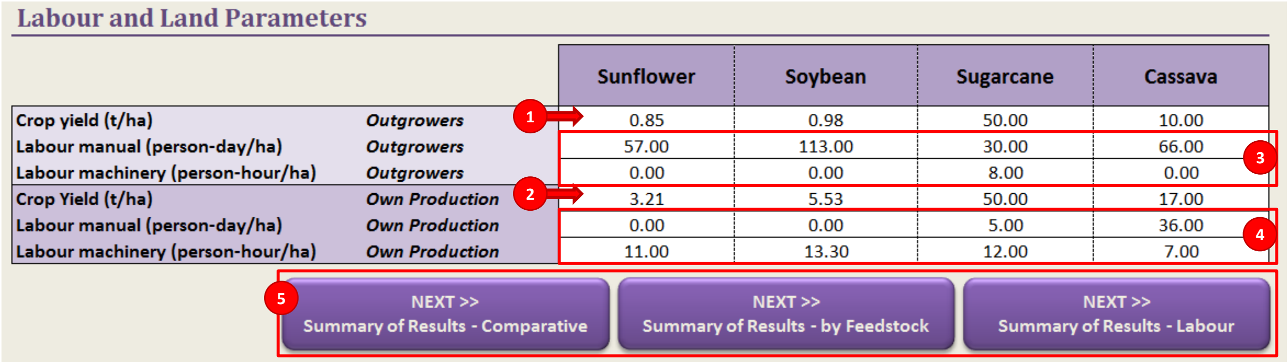
http://base.intratec.us/home/ic-index

Figure 13: Data Entry for Liquid Biofuels: Financial Parameters

5.2.3 Labour and land parameters

In order to estimate labour requirements under different biofuel production schemes, the tool makes use of crop yields (Figure 14, labels 1 and 2), labour manual and labour machinery parameters (Figure 14, labels 3 and 4). These data can be obtained directly by the *Crop Budget Tool*, for different selected feedstock crops and under different production schemes (see section 8.2.1). However, the users may insert data which better reflects the country reality.

At this stage, the user may choose either to look at the Summary of Results-Comparative, Summary of Results-By Feedstock or Summary of Results-Labour (Figure 14, label 5).



Labour and Land Parameters

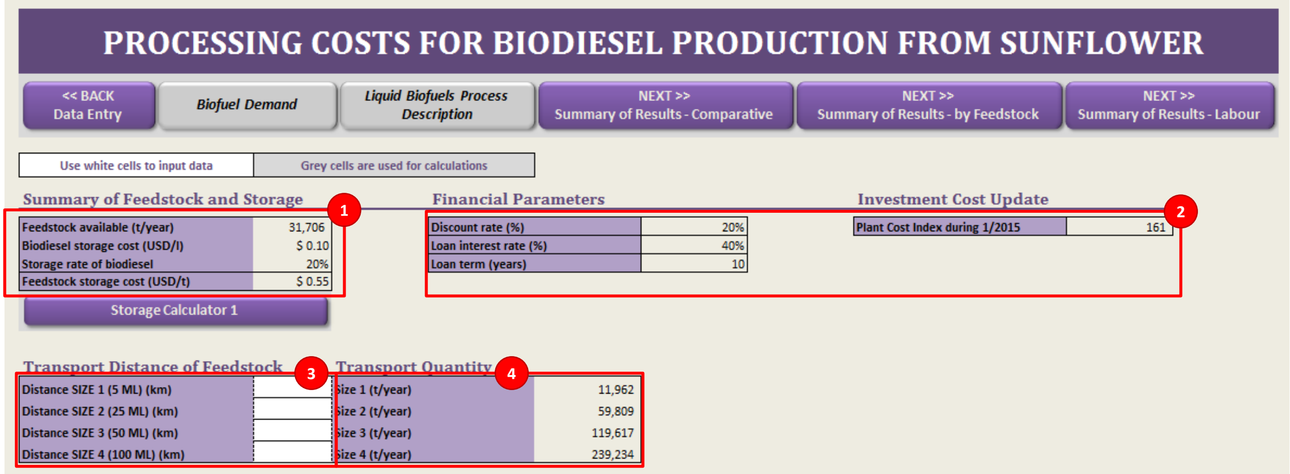
		Sunflower	Soybean	Sugarcane	Cassava
Crop yield (t/ha)	*Outgrowers*	0.85	0.98	50.00	10.00
Labour manual (person-day/ha)	*Outgrowers*	57.00	113.00	30.00	66.00
Labour machinery (person-hour/ha)	*Outgrowers*	0.00	0.00	8.00	0.00
Crop Yield (t/ha)	*Own Production*	3.21	5.53	50.00	17.00
Labour manual (person-day/ha)	*Own Production*	0.00	0.00	5.00	36.00
Labour machinery (person-hour/ha)	*Own Production*	11.00	13.30	12.00	7.00

Figure 14: Data Entry for Liquid Biofuels: Labour and Land Parameters

5.3 Step 3: Processing costs

Overall, liquid biofuel production costs for any production scheme are included in the *Cost_Fs* sheets (there is one sheet for each selected crop). This section reports summary information in reference to feedstock and storage and financial parameters (Figure 15, labels 1 and 2).

The transport distance section considers the average distance from the farm to the processing plant (Figure 15, label 3) and the amount of feedstock (Figure 15, label 4) for each plant size.



Summary of Feedstock and Storage

Feedstock available (t/year)	31,706
Biodiesel storage cost (USD/l)	$ 0.10
Storage rate of biodiesel	20%
Feedstock storage cost (USD/t)	$ 0.55

Financial Parameters

Discount rate (%)	20%
Loan interest rate (%)	40%
Loan term (years)	10

Investment Cost Update

Plant Cost Index during 1/2015	161

Transport Distance of Feedstock

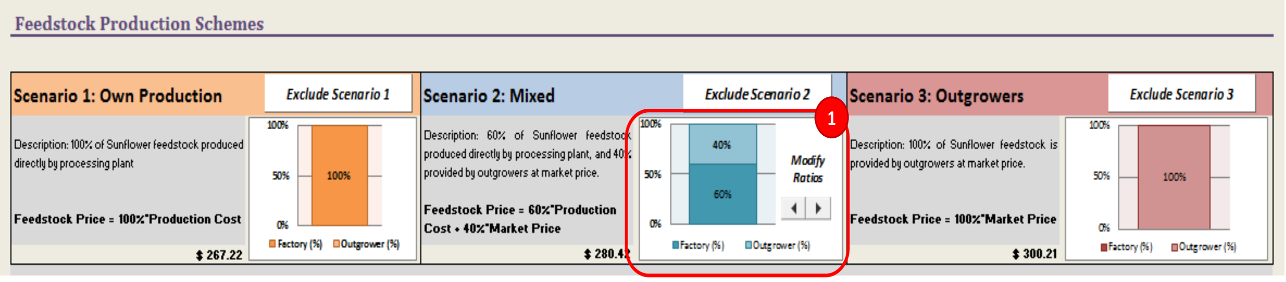
Distance SIZE 1 (5 ML) (km)	
Distance SIZE 2 (25 ML) (km)	
Distance SIZE 3 (50 ML) (km)	
Distance SIZE 4 (100 ML) (km)	

Transport Quantity

Size 1 (t/year)	11,962
Size 2 (t/year)	59,809
Size 3 (t/year)	119,617
Size 4 (t/year)	239,234

Figure 15: Processing Costs for Liquid Biofuel Production

The production schemes considered (outgrowers, own producion and mixed outgrowers-own production) (see section 3.2) reflect the analytical scenarios which can be built using the tool. This is shown in Figure 16. As mentioned previously, in Scenario 2 (mixed scheme) the share of different farmer types involved in feedstock production could change depending on the country context (the user can use the “Modify Ratios” buttons to make any adjustments) (Figure 16, label 1).



Scenario 1: Own Production

Description: 100% of Sunflower feedstock produced directly by processing plant

Feedstock Price = 100%*Production Cost

$ 267.22

Scenario 2: Mixed

Description: 60% of Sunflower feedstock produced directly by processing plant, and 40% provided by outgrowers at market price.

Feedstock Price = 60%*Production Cost + 40%*Market Price

$ 280.4

Scenario 3: Outgrowers

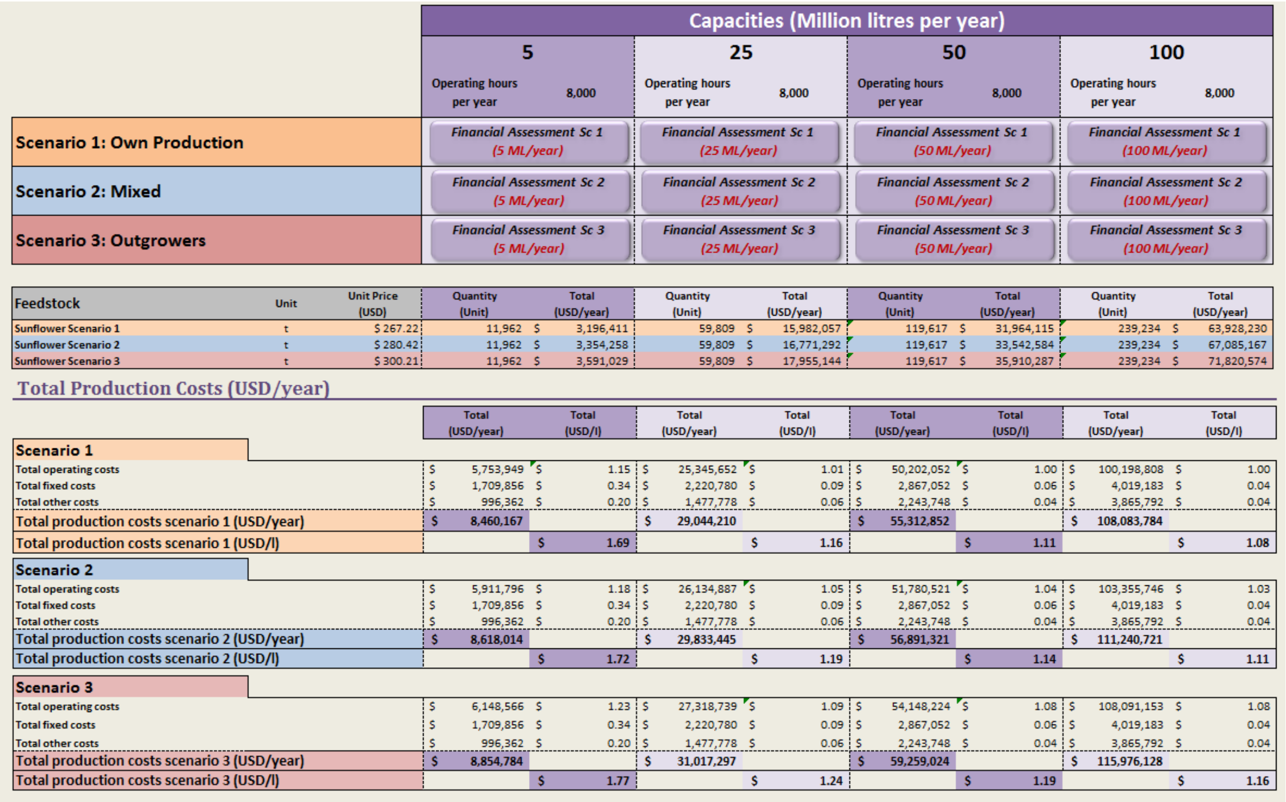
Description: 100% of Sunflower feedstock is provided by outgrowers at market price.

Feedstock Price = 100%*Market Price

$ 300.21

Figure 16: Feedstock Source Scenarios

The liquid biofuel processing budget allows computing production cost for biodiesel and ethanol production for plants of different capacities. The processing budget includes the costs of: inputs (raw materials), labour (skilled and unskilled), transport cost from farm to processing plant, investments, maintenance activities, and storage. Additional costs, such as plant overhead, general and administrative costs, are also computed. These values are used to estimate the production cost per litre for each plant size. The results calculated with this tool are indicative under a global context and are applicable to different developing countries[15].



Capacities (Million litres per year)

	5	25	50	100
	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	*Financial Assessment Sc 1 (5 ML/year)*	*Financial Assessment Sc 1 (25 ML/year)*	*Financial Assessment Sc 1 (50 ML/year)*	*Financial Assessment Sc 1 (100 ML/year)*
Scenario 2: Mixed	*Financial Assessment Sc 2 (5 ML/year)*	*Financial Assessment Sc 2 (25 ML/year)*	*Financial Assessment Sc 2 (50 ML/year)*	*Financial Assessment Sc 2 (100 ML/year)*
Scenario 3: Outgrowers	*Financial Assessment Sc 3 (5 ML/year)*	*Financial Assessment Sc 3 (25 ML/year)*	*Financial Assessment Sc 3 (50 ML/year)*	*Financial Assessment Sc 3 (100 ML/year)*

Feedstock	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Sunflower Scenario 1	t	$ 267.22	11,962	$ 3,196,411	59,809	$ 15,982,057	119,617	$ 31,964,115	239,234	$ 63,928,230
Sunflower Scenario 2	t	$ 280.42	11,962	$ 3,354,258	59,809	$ 16,771,292	119,617	$ 33,542,584	239,234	$ 67,085,167
Sunflower Scenario 3	t	$ 300.21	11,962	$ 3,591,029	59,809	$ 17,955,144	119,617	$ 35,910,287	239,234	$ 71,820,574

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)
Scenario 1								
Total operating costs	$ 5,753,949	$ 1.15	$ 25,345,652	$ 1.01	$ 50,202,052	$ 1.00	$ 100,198,808	$ 1.00
Total fixed costs	$ 1,709,856	$ 0.34	$ 2,220,780	$ 0.09	$ 2,867,052	$ 0.06	$ 4,019,183	$ 0.04
Total other costs	$ 996,362	$ 0.20	$ 1,477,778	$ 0.06	$ 2,243,748	$ 0.04	$ 3,865,792	$ 0.04
Total production costs scenario 1 (USD/year)	$ 8,460,167		$ 29,044,210		$ 55,312,852		$ 108,083,784	
Total production costs scenario 1 (USD/l)		$ 1.69		$ 1.16		$ 1.11		$ 1.08
Scenario 2								
Total operating costs	$ 5,911,796	$ 1.18	$ 26,134,887	$ 1.05	$ 51,780,521	$ 1.04	$ 103,355,746	$ 1.03
Total fixed costs	$ 1,709,856	$ 0.34	$ 2,220,780	$ 0.09	$ 2,867,052	$ 0.06	$ 4,019,183	$ 0.04
Total other costs	$ 996,362	$ 0.20	$ 1,477,778	$ 0.06	$ 2,243,748	$ 0.04	$ 3,865,792	$ 0.04
Total production costs scenario 2 (USD/year)	$ 8,618,014		$ 29,833,445		$ 56,891,321		$ 111,240,721	
Total production costs scenario 2 (USD/l)		$ 1.72		$ 1.19		$ 1.14		$ 1.11
Scenario 3								
Total operating costs	$ 6,148,566	$ 1.23	$ 27,318,739	$ 1.09	$ 54,148,224	$ 1.08	$ 108,091,153	$ 1.08
Total fixed costs	$ 1,709,856	$ 0.34	$ 2,220,780	$ 0.09	$ 2,867,052	$ 0.06	$ 4,019,183	$ 0.04
Total other costs	$ 996,362	$ 0.20	$ 1,477,778	$ 0.06	$ 2,243,748	$ 0.04	$ 3,865,792	$ 0.04
Total production costs scenario 3 (USD/year)	$ 8,854,784		$ 31,017,297		$ 59,259,024		$ 115,976,128	
Total production costs scenario 3 (USD/l)		$ 1.77		$ 1.24		$ 1.19		$ 1.16

Figure 17: Budget Structure: Processing Costs

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[15] ASPEN Plus™ V7.1 (http://www.aspentech.com/products/aspen-plus.aspx) process simulation software was employed in the development of the technical processing model for the production of 5, 25, 50, 100 million litres per year.

6 Assumptions and Limitations of the *Transport Sub-Module*

Before starting the analysis, the user should become 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 *Transport Sub-Module* are:

1. <u>Plant sizes and investment lifetime</u>. 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. <u>Labour demand</u>. The estimation of the potential impact of biodiesel/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. <u>Other assumptions</u>. The number of 300 working days per year is assumed. However, the user may insert a different number in order to allow for country differences.

The main limitations of the *Transport Sub-Module* are:

1. <u>Form and level of analysis</u>: The tool itself does not support spatial analysis, but provides only quantitative elements which can be used in the analysis. Also, default values provided by the tool represent only a country level average, thus not revealing differences at the sub-national and local levels. For sub-national or spatially defined assessments, the user should provide specific data.
2. <u>Use of GAEZ database</u>. Land suitability and associated potential yields are modelled and presented with the resolution of 5 arc-minutes[16]. The information included in the BEFS RA tool includes aggregated information about potential yields for rain-fed agricultural production of 26 crops for three types of suitability classes (country average, very high/high and medium) under three input levels (only 10 crops are suitable for production of liquid biofuels: coconut, jatropha, rapeseed, soybean, oil palm and sunflower for straight vegetable oil and biodiesel; and barley, cassava, maize, sugar beet, sugarcane, sorghum and wheat for ethanol).
3. <u>Selection of the feedstock production scheme</u>. As already explained in section 3.2 above, in the tool three different schemes are taken into consideration, namely “own production”, “outgrowers” and “mixed own production-outgrowers”. In the “mixed” scheme, it is assumed that outgrower farmers produce 40% of the feedstock needed to supply different plant sizes (outgrowers use a level of input depending on how the current yield of the selected crop obtained in the area of analysis matches the input level from GAEZ), and the remaining 60% is provided by own producers (which use only high input technology level). However, the shares among the type of farmers in feedstock production could change based on the country context. Therefore, in the *Cost_Fs* sheets the user has the option to define the weight of the production scheme to be used in the simulation (see section 5.3 and Figure 16).
4. Labour demand is estimated only with reference to direct job opportunities which could be generated in the implementation of liquid biofuel production activity (people who work in agricultural operations in feedstock production and workers employed in the manufacturing sectors for feedstock processing) and may represent an underestimation. In fact, total labour

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[16] Each cell (for which the suitability class is presented) represents approximately land area of 10x10 km.

demand should also include indirect employment, which is usually computed using economic input-output tables.

7 The Results of the *Transport Sub-Module*

These paragraphs show all the results of the *Transport Sub-Module*. The analysis examines the profitability of liquid biofuels production using different feedstock crops in comparison with a diesel/gasoline equivalent price and international price of liquid biofuels. These prices are break-even prices, i.e. prices corresponding to the point at which costs and revenues are equal (profit is zero). A liquid biofuel production cost lower than the break-even price indicates that liquid biofuel production is profitable.

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

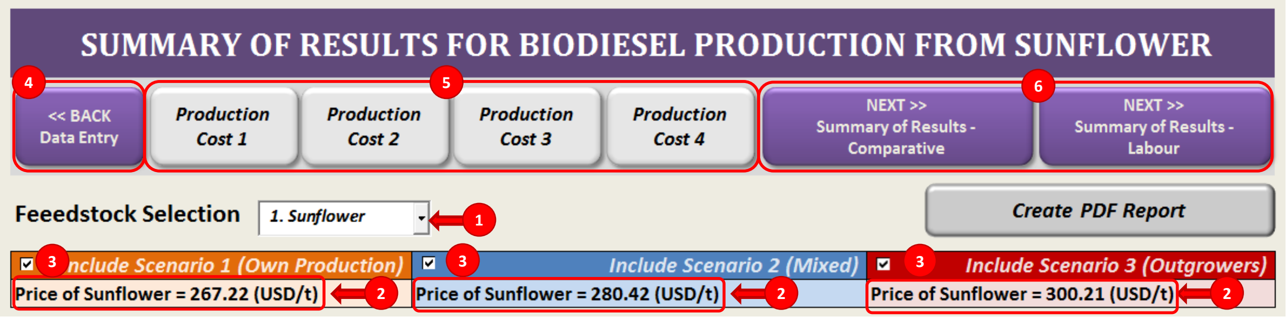
1) Summary of results by feedstock;
2) Summary of results - comparative; and
3) Labour analysis.

7.1 The summary of results by feedstock

At the top of the worksheet, summary information is reported. Feedstock selection specifies the selected crop. For example, Figure 18, label 1 refers to sunflower-based biodiesel production while label 2 shows the production cost for each selected scheme. For each production scheme, Figure 18, label 3 exhibits a window (titled *Include Scenario*) where the user has the option to show the results of the selected scheme in the Summary of Results by Feedstock sheet. Furthermore, the user can return to the Data Entry sheet (Figure 18, label 4), or go to the sheets which show the processing budget structure (Figure 18, label 5) at any time. Finally, the other results are included in the Summary of Results Comparative and Labour Analysis (Figure 18, label 6).

Different indicators of economic profitability of liquid biofuel production by feedstock type 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 biodiesel/ethanol obtained by plants of different sizes and the equivalent price of diesel/gasoline;
b) the Operating Results section reports on the biomass requirement for each crop with respect to the national biomass availability; the number of plants which could be implemented based on the available biomass; the maximum attainable production on biodiesel/ethanol given the available biomass; 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.


SUMMARY OF RESULTS FOR BIODIESEL PRODUCTION FROM SUNFLOWER

Feeedstock Selection: 1. Sunflower

☑ Include Scenario 1 (Own Production) — Price of Sunflower = 267.22 (USD/t)

☑ Include Scenario 2 (Mixed) — Price of Sunflower = 280.42 (USD/t)

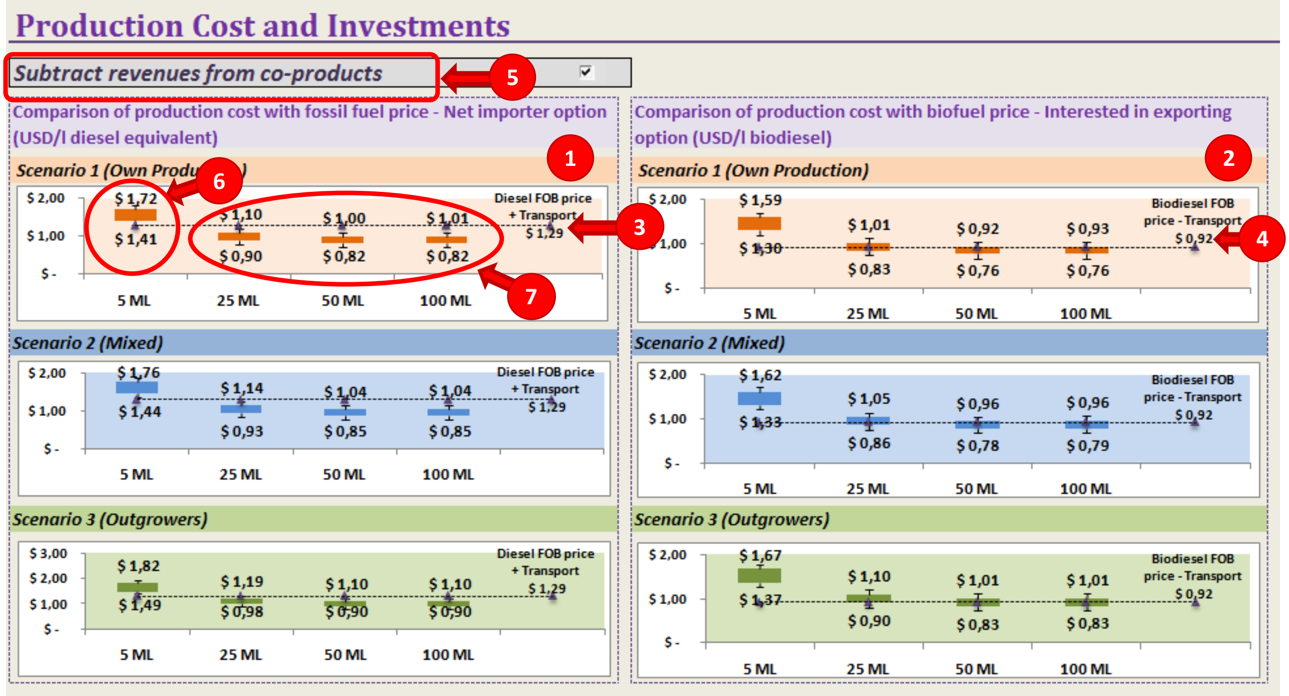
☑ Include Scenario 3 (Outgrowers) — Price of Sunflower = 300.21 (USD/t)

Figure 18: Summary of Results by Feedstock

7.1.1 Production cost and investment results

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

The fossil fuel equivalent prices and the international prices of liquid biofuel are compared with biofuel production costs under any production scheme in order to assess their profitability. Figure 19 shows the case of a fossil fuel net importer country (label 1) and refers to sunflower-based biodiesel. Given that Malawi is a net importer, FOB price of diesel equivalent is used (Figure 19, label 3) and a comparison is made between production costs and FOB prices of biodiesel (Figure 19, label 4). The user can also decide to include the value of co-products in the production costs by clicking in the appropriate window (Figure 19, label 5). Moreover, the tool allows the user to compare a range of production costs corresponding to plants of different sizes (Figure 19, labels 6 and 7).


Production Cost and Investments

Subtract revenues from co-products ☑

Comparison of production cost with fossil fuel price - Net importer option (USD/l diesel equivalent)

Comparison of production cost with biofuel price - Interested in exporting option (USD/l biodiesel)

Figure 19: Production Cost and Investment Results: Comparison of Fossil Fuels and Biofuels Basis

Figure 20 (label 1) shows the total investment costs of implementing production through plants of different sizes (5, 25, 50, 100 million litres).

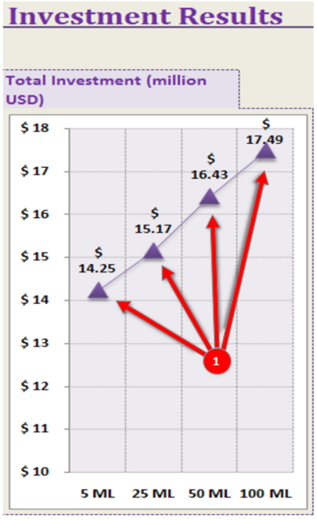


Figure 20: Production Cost and Investment Results: Investments by Plant Size

The next section shows the composition of the production cost for all selected plant sizes and for any production scheme. Figure 21 shows the different elements which compose the production cost of different schemes for a plant: feedstock, other chemical inputs, energy, depreciation and maintenance, and other costs. For example, in the case of biodiesel production from sunflower, feedstock is the principal contributor to the overall biofuel production cost.

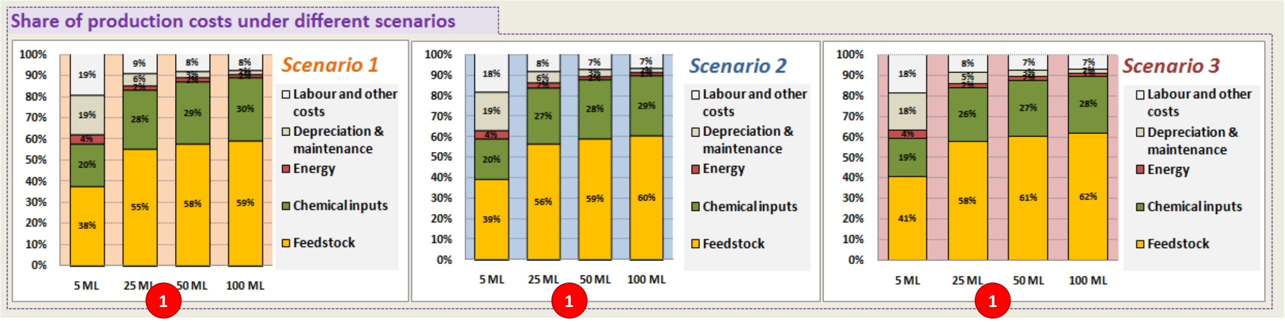


Figure 21: Production Cost and Investment Results: Share of Production Costs under Different Scenarios

Under all production schemes, 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 19, label 7). Figure 19 shows the strong advantage of plants with an annual capacity exceeding 5 million litres.

7.1.2 Operating results

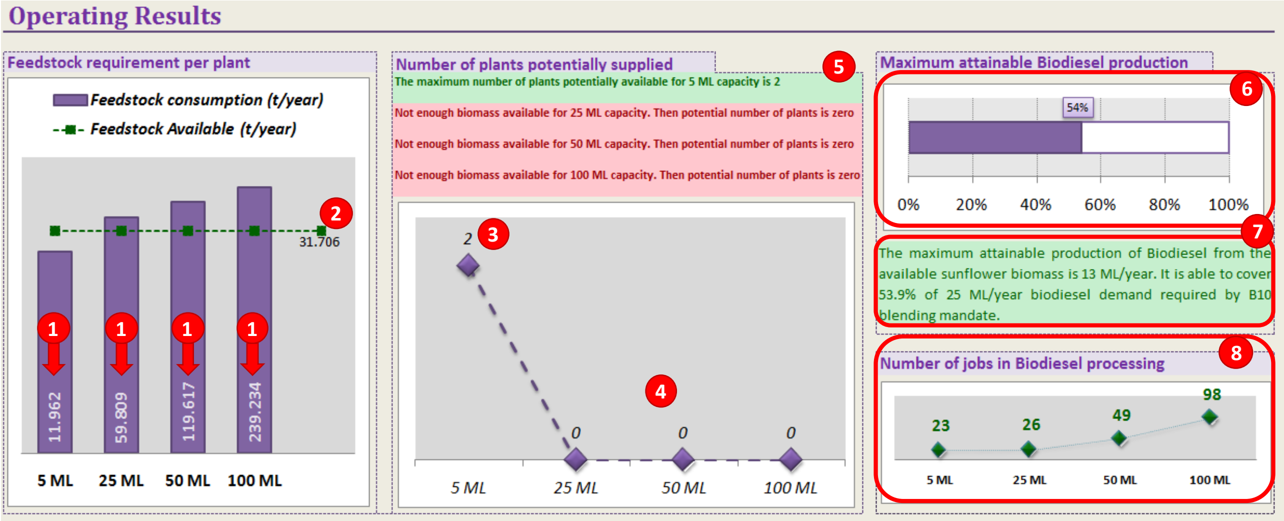
This section reports information on the opportunity to produce biofuel production based on the feedstock availability for each selected crop.

Figure 22 shows whether the biomass requirement (label 1) for each plant size can be satisfied by the available biomass (label 2): the production is feasible only for plant sizes for which the requirement is lower than the available biomass.

Furthermore, Figure 22 includes the number of plants potentially supplied based on the available feedstock for bioenergy purposes. For the example of Malawi, it would be feasible to implement 2 plants of 5 million litres (label 3) for sunflower-based biodiesel, while it is unfeasible to install a plant of 25, 50 or 100 million litres (label 4). Further information on the plant sizes is reported above this figure. It is important for the user to note that if biomass is available for a certain plant size, then a sentence stating this will be highlighted in green. If this is not the case, then the sentence will be highlighted in red (label 5).

Figure 22 also shows the maximum attainable biodiesel production for the selected crops based on the total amount required to respect the mandatory blending indicated in the Biofuel Demand sheet (see the target biofuel production in country, sub-paragraph 5.1). In this example, sunflower-based biofuel is feasible to completely produce the required amount (label 6). Additionally, the total amount of liquid biofuel which is possible to produce from the selected crops is reported (label 7).

Finally, the figure indicates the number of jobs created in biodiesel/ethanol processing for any plant size (label 8).



The maximum number of plants potentially available for 5 ML capacity is 2

Not enough biomass available for 25 ML capacity. Then potential number of plants is zero

Not enough biomass available for 50 ML capacity. Then potential number of plants is zero

Not enough biomass available for 100 ML capacity. Then potential number of plants is zero

The maximum attainable production of Biodiesel from the available sunflower biomass is 13 ML/year. It is able to cover 53.9% of 25 ML/year biodiesel demand required by B10 blending mandate.

Figure 22: Operating Results: Feedstock Consumption, Number of Plants, Biofuels Production

7.1.3 Financial analysis results

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

When using 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 liquid biofuels is more profitable in bigger plant sizes: in fact, NPV is negative for a 5 million litres plant (Figure 23), showing that such a plant size does not represent a profitable investment. On the contrary, NPV is positive for larger plant sizes (Figure 23).

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.

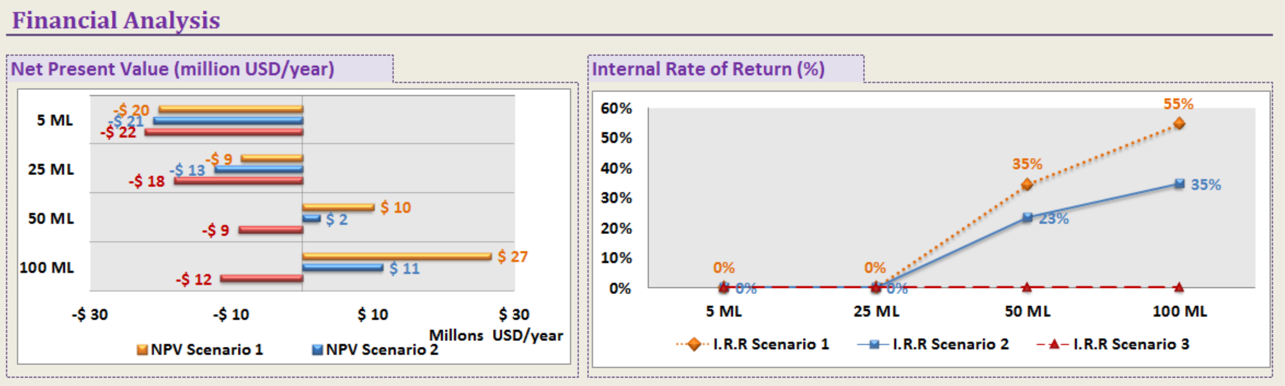


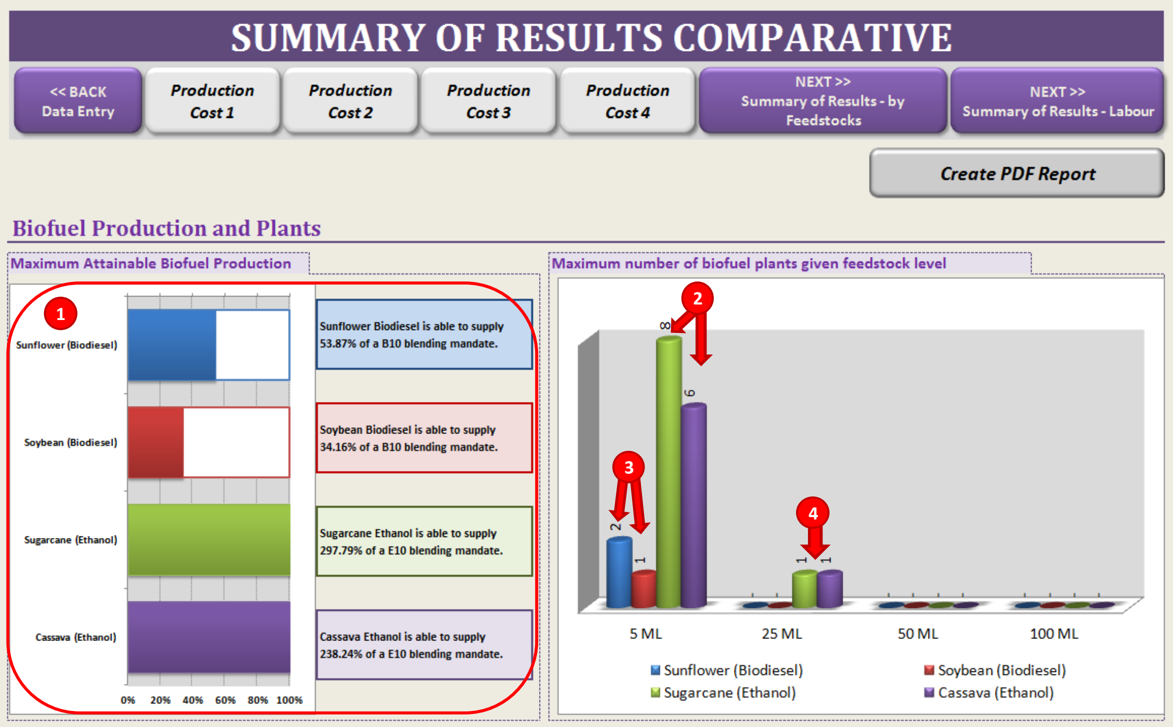
Figure 23: Financial Indicators of Liquid Biofuels Production

7.2 The summary of comparative results

In the Summary of Results by Feedstock sheet it is possible to look at the results selecting one crop at a time, however in this Summary of Results Comparative sheet all of the key results for the 4 targeted crops are simultaneously reported. The following indicators are reported: the maximum attainable biofuel production; the maximum number of plants potentially supplied; and a comparison of production costs, NPV and IRR.

The maximum attainable biofuel production indicates whether liquid biofuel obtained from the selected crops is enough to respect the amount expected in mandatory blending included in the Biofuel Demand section (see target biofuel production in country, sub-paragraph 5.1). For the example of Malawi, both sorghum and maize-based ethanol and sunflower and oil palm-based biodiesel are feasible for the production of the considered biofuels amount (Figure 24, label 1).

The number of plants potentially supplied is based on the available biomass, selected plant sizes and targeted crops (Figure 24, labels 2 to 4).



Sunflower Biodiesel is able to supply 53.87% of a B10 blending mandate.

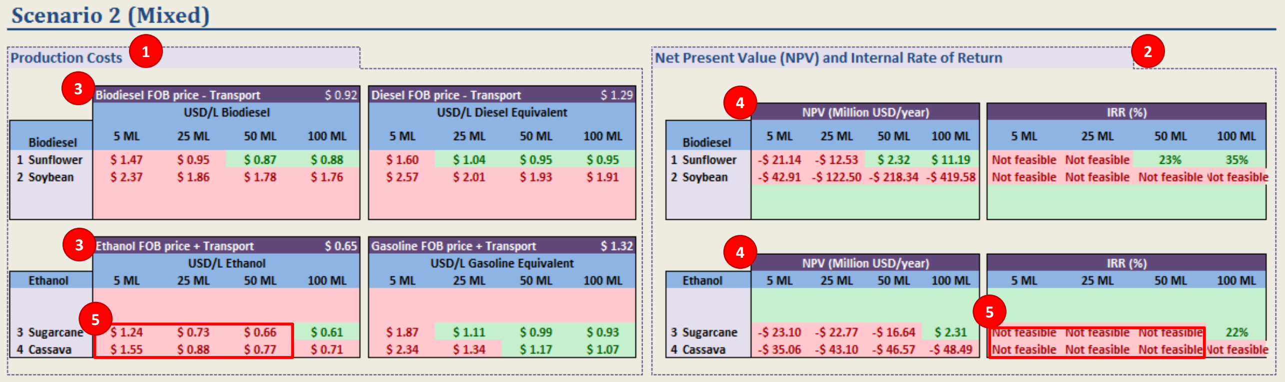
Soybean Biodiesel is able to supply 34.16% of a B10 blending mandate.

Sugarcane Ethanol is able to supply 297.79% of a E10 blending mandate.

Cassava Ethanol is able to supply 238.24% of a E10 blending mandate.

Figure 24: Maximum Attainable Biofuel Production and Number of Plants Potentially Supplied

Figure 25 presents the overall results of the production costs (label 1) and financial analysis (label 2) for sunflower and oil palm-based biodiesel and for sorghum and maize-based ethanol under the mixed scheme. Production costs of biodiesel/ethanol are compared with the prices of liquid biofuels and fossil fuels (Figure 25, labels 3 and 4). If the production costs are competitive, the number is highlighted in green. If not, then it is highlighted in red (label 5).



Scenario 2 (Mixed)

Production Costs

	Biodiesel FOB price - Transport $ 0.92				Diesel FOB price - Transport $ 1.29			
	USD/L Biodiesel				USD/L Diesel Equivalent			
Biodiesel	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
1 Sunflower	$ 1.47	$ 0.95	$ 0.87	$ 0.88	$ 1.60	$ 1.04	$ 0.95	$ 0.95
2 Soybean	$ 2.37	$ 1.86	$ 1.78	$ 1.76	$ 2.57	$ 2.01	$ 1.93	$ 1.91

	Ethanol FOB price + Transport $ 0.65				Gasoline FOB price + Transport $ 1.32			
	USD/L Ethanol				USD/L Gasoline Equivalent			
Ethanol	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
3 Sugarcane	$ 1.24	$ 0.73	$ 0.66	$ 0.61	$ 1.87	$ 1.11	$ 0.99	$ 0.93
4 Cassava	$ 1.55	$ 0.88	$ 0.77	$ 0.71	$ 2.34	$ 1.34	$ 1.17	$ 1.07

Net Present Value (NPV) and Internal Rate of Return

	NPV (Million USD/year)				IRR (%)			
Biodiesel	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
1 Sunflower	-$ 21.14	-$ 12.53	$ 2.32	$ 11.19	Not feasible	Not feasible	23%	35%
2 Soybean	-$ 42.91	-$ 122.50	-$ 218.34	-$ 419.58	Not feasible	Not feasible	Not feasible	Not feasible

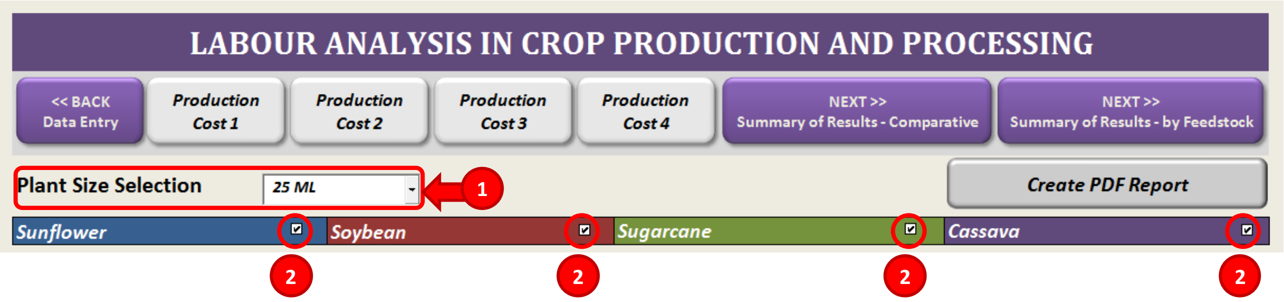
	NPV (Million USD/year)				IRR (%)			
Ethanol	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
3 Sugarcane	-$ 23.10	-$ 22.77	-$ 16.64	$ 2.31	Not feasible	Not feasible	Not feasible	22%
4 Cassava	-$ 35.06	-$ 43.10	-$ 46.57	-$ 48.49	Not feasible	Not feasible	Not feasible	Not feasible

Figure 25: Summary of Results - Comparative (comparison among production costs, NPV and IRR)

7.3 The labour analysis results

This worksheet reports the specific results related to the biofuel production impact on labour demand and on land use[17].

In this section, the user is able to compare the estimation of the number of workers and land area required for implementing biodiesel and biofuel processing activity. One plant size at a time can be examined: at the top of the worksheet the user should identify the appropriate plant size (Figure 26, label 1). Figure 26 shows a window where the user is able to select which feedstock crops to include (label 2). For example, the user can highlight two feedstock crops selected for biodiesel and ethanol production. Another option is to show all selected feedstock crops as reported in Figures 26 and 27.



Plant Size Selection: 25 ML

Sunflower ☑ Soybean ☑ Sugarcane ☑ Cassava ☑

Figure 26: Labour and Land Requirements Analysis

The user can estimate the total number of people potentially employed (on and off-farm) as a result of the implementation of different plant sizes under different production schemes. Figure 27 reports the results of the Malawi country example simulation. On the left side of Figure 27 (label 1), the results for the outgrowers scheme are shown, while in the middle and on the right side the user can compare, respectively, the results for mixed and own production schemes (labels 2 and 3). The user should note that in general, when the total feedstock is produced by the factory itself (own production scheme), the number of new jobs potentially created tends to be lower than in the other schemes.

Therefore, when moving from the own production scheme to the mixed one (where an increased number of small farmers are involved), social benefits in terms of increased labour demand will be generated. The user should take into account that, as already highlighted under the Assumptions and Limitations section, labour demand is estimated only with reference to direct employment (holdings in agriculture and workers in the manufacturing sectors for feedstock processing and biofuel conversion). This could lead to an underestimation of the total labour demand, due to the exclusion of indirect employment.

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[17] The development of biofuels production is expected to generate employment opportunities at both farm and processing levels. Also, land used for feedstock production is computed on the basis of the quantity of raw material required to supply plants of different sizes under different production schemes.

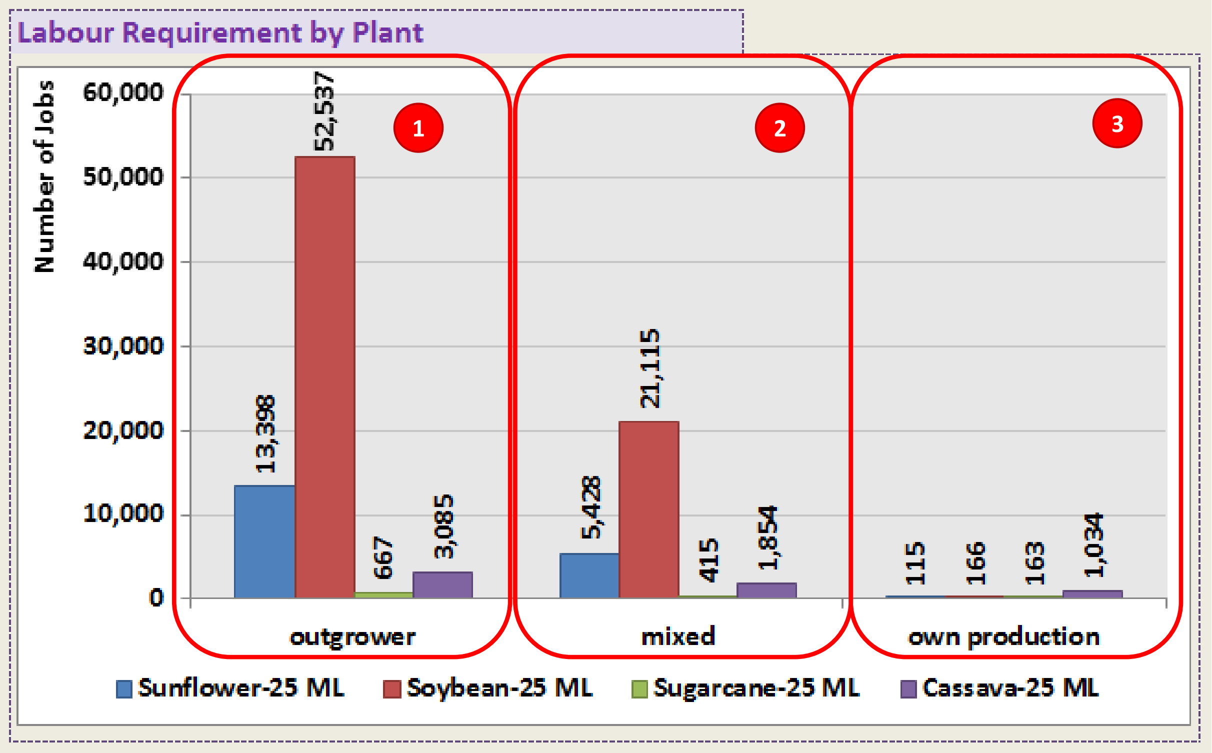


Figure 27: Employment Opportunities Related to Biofuels Production

The previous figure reported the number of workers who would be employed if liquid biofuel production were implemented in the country. Estimations of the potential impact of biodiesel/ethanol production on labour demand were shown for different plant sizes, feedstock crops and production schemes.

The information presented in Figure 28 aims at providing the user with the number of people who would be employed in different levels of the chain (the data refers to a 25 litre plant). For each plant size, feedstock crop and production scheme, this figure reports the share of workers who will be involved in biofuel production both on-farm and on-plant levels: it demonstrates that, when an increasing number of outgrowers is involved in feedstock production, labour used in various agricultural operations (land preparation, sowing and other operations) is higher than labour adopted in plant processing operations.

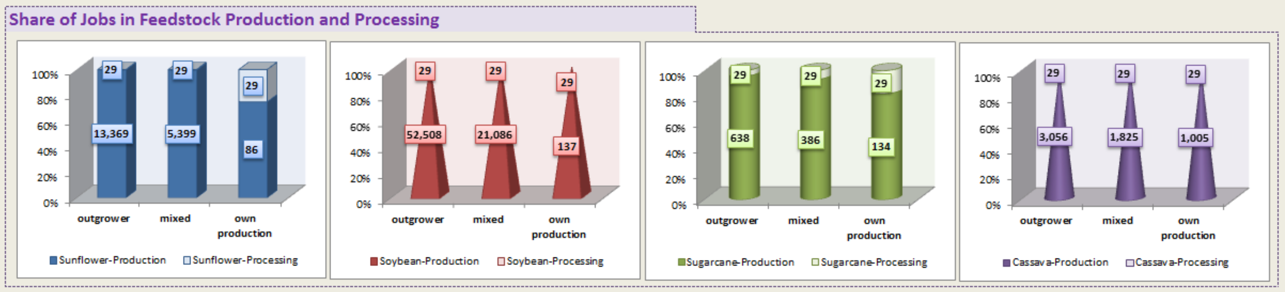


Figure 28: Share of Agriculture - Processing Jobs

In this worksheet, the user can also find information about the land required to produce the feedstock needed to supply the biofuel processing plants. For example, Figure 29 refers to a 25 million litre plant and displays the own production (label 1), mixed (label 2) and outgrower (label 3) schemes. The outgrowers' scheme requires significantly more land than the own-production scheme, as farmers produce feedstock using a higher input level.

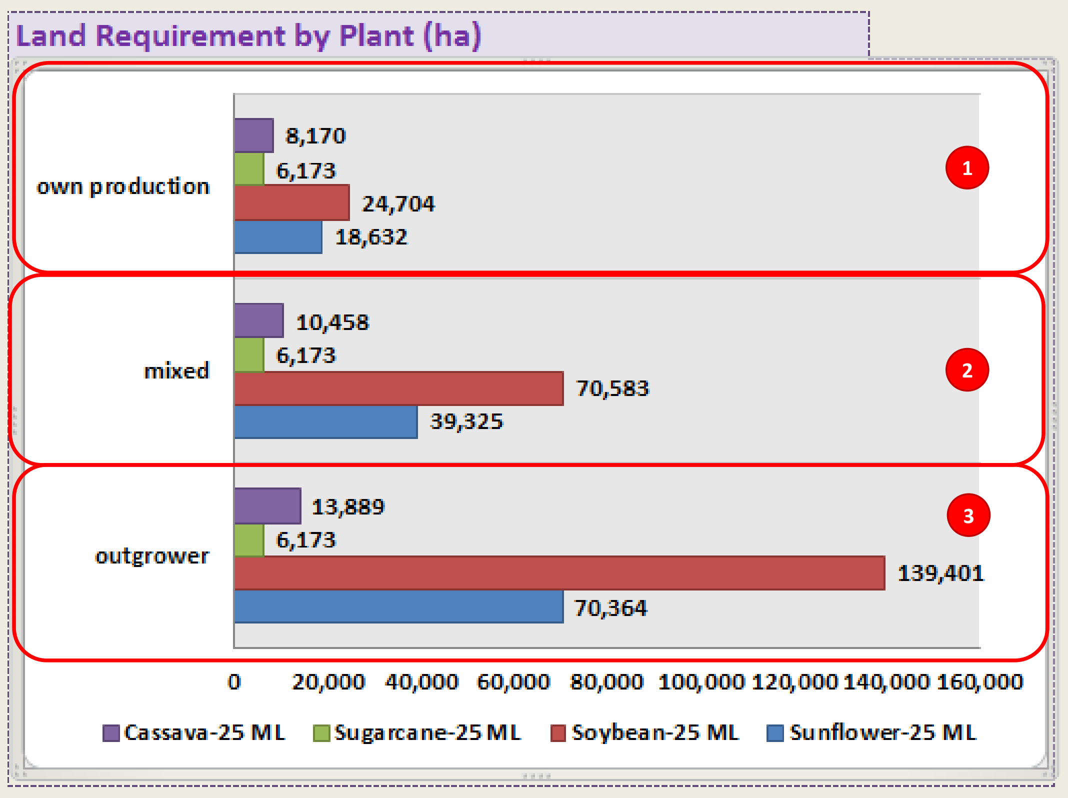


Figure 29: Comparative Land Requirement

8 Annex

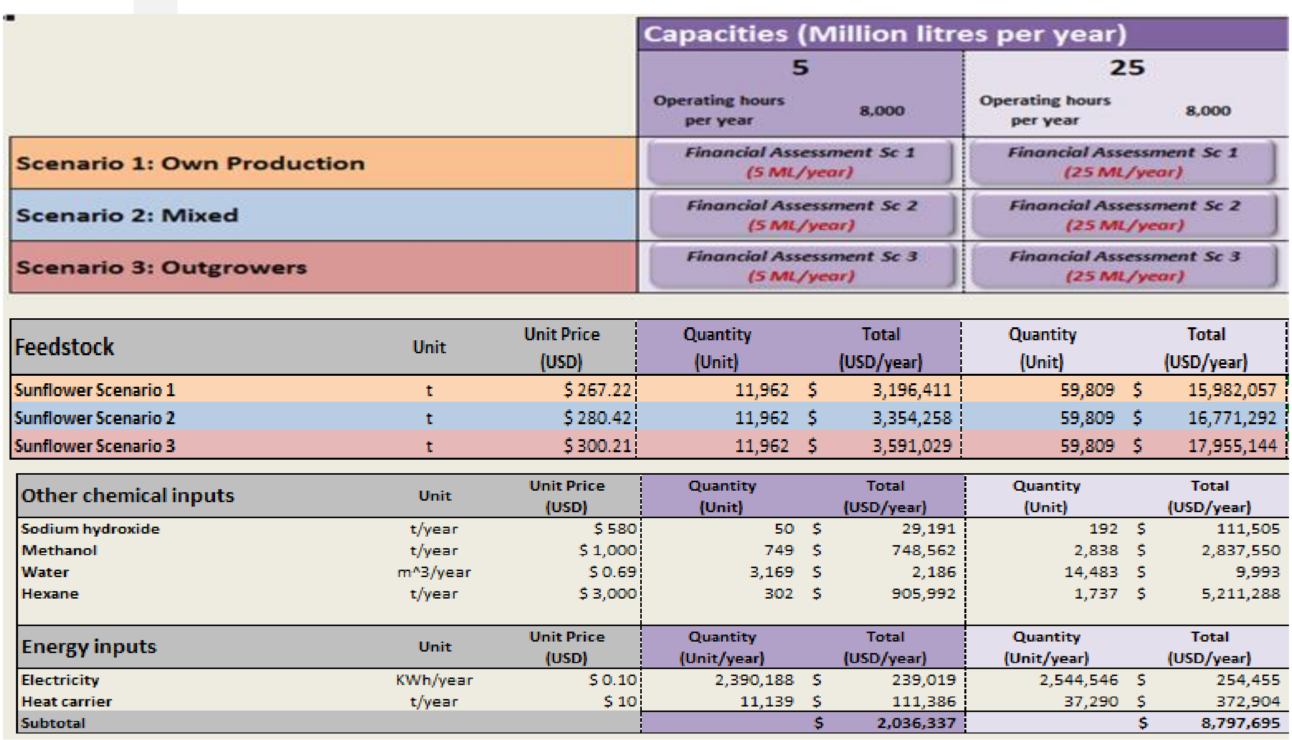
8.1 Methodology and outputs

This section describes the methodology integrated in the *Biodiesel/Ethanol* sections of the *Transport Sub-Module* and includes a description of the databases which support the analysis. The databases are not visible to the user, but their structure and content might be important for those who will update them and/or work on the improvement of the tool.

8.1.1 Processing budget structure: calculation of the production costs of liquid biofuels

i. Inputs

The energy and mass balance data for biodiesel and ethanol production options and specified capacities were obtained from ASPEN Plus™ V7.1. These data were utilized to generate the inputs required for each selected plant capacity (5, 25, 50, 100 million litres per year) as presented in the following table. Some of the inputs differ for biodiesel and ethanol production.



	Capacities (Million litres per year)	
	5	25
	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	Financial Assessment Sc 1 (5 ML/year)	Financial Assessment Sc 1 (25 ML/year)
Scenario 2: Mixed	Financial Assessment Sc 2 (5 ML/year)	Financial Assessment Sc 2 (25 ML/year)
Scenario 3: Outgrowers	Financial Assessment Sc 3 (5 ML/year)	Financial Assessment Sc 3 (25 ML/year)

Feedstock	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Sunflower Scenario 1	t	$ 267.22	11,962	$ 3,196,411	59,809	$ 15,982,057
Sunflower Scenario 2	t	$ 280.42	11,962	$ 3,354,258	59,809	$ 16,771,292
Sunflower Scenario 3	t	$ 300.21	11,962	$ 3,591,029	59,809	$ 17,955,144

Other chemical inputs	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Sodium hydroxide	t/year	$ 580	50	$ 29,191	192	$ 111,505
Methanol	t/year	$ 1,000	749	$ 748,562	2,838	$ 2,837,550
Water	m^3/year	$ 0.69	3,169	$ 2,186	14,483	$ 9,993
Hexane	t/year	$ 3,000	302	$ 905,992	1,737	$ 5,211,288

Energy inputs	Unit	Unit Price (USD)	Quantity (Unit/year)	Total (USD/year)	Quantity (Unit/year)	Total (USD/year)
Electricity	KWh/year	$ 0.10	2,390,188	$ 239,019	2,544,546	$ 254,455
Heat carrier	t/year	$ 10	11,139	$ 111,386	37,290	$ 372,904
Subtotal				$ 2,036,337		$ 8,797,695

Figure 30: Budget Structure: Feedstock, Chemical Inputs, and Energy Inputs

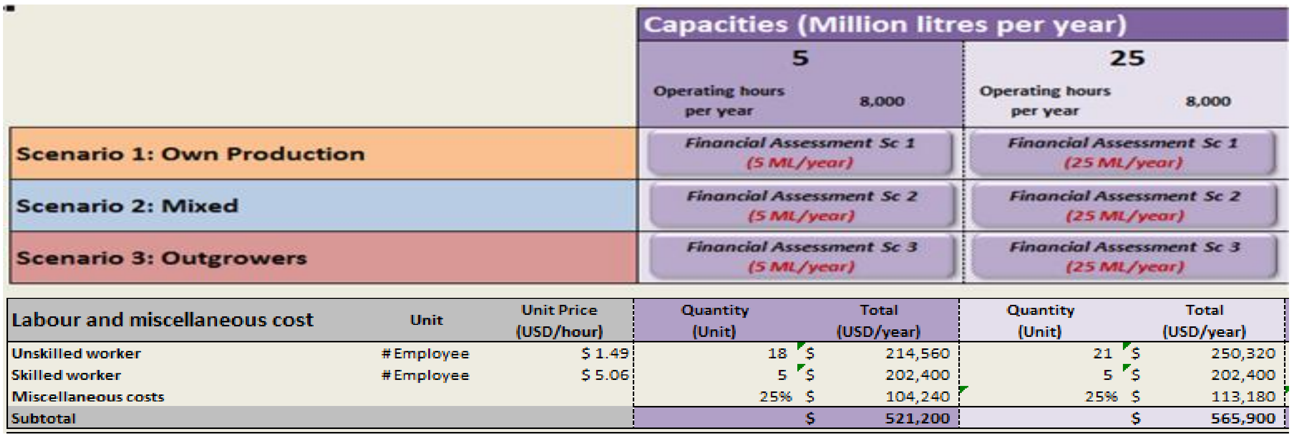
There are three optional sources for feedstock prices. The tool provides the user with a grid to select the feedstock price according to the participation level of factory and out-growers in feedstock production (Figure 30).

Updated prices for Chemical Commodities can be found at: http://www.icis.com/chemicals/channel-info-chemicals-a-z/ (Figure 30). Local commodity prices must be provided by the user.

The heat carrier is low pressure steam. Low pressure steam can be produced using a standard low technology boiler, where the unit price represents its production cost (Figure 30).

ii. Labour and miscellaneous costs

For the labour calculation, it was assumed that the biodiesel plant is operating 24 hours per day during 333 days per year, or its equivalent 8000 hours per year, while the remaining 35 days are employed in maintenance tasks. The daily operation of a plant was divided into three shifts of 8 hours each, and for each shift the number of workers was calculated based on the rule of thumb reported by Van Gerpen (2008). This rule states that a requirement of at least 1 unskilled worker for each 1 million gallons of biodiesel is needed. In the same way, the number of skilled workers should be at least 1 for every 4 unskilled workers.



	Capacities (Million litres per year)	
	5	25
	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	Financial Assessment Sc 1 (5 ML/year)	Financial Assessment Sc 1 (25 ML/year)
Scenario 2: Mixed	Financial Assessment Sc 2 (5 ML/year)	Financial Assessment Sc 2 (25 ML/year)
Scenario 3: Outgrowers	Financial Assessment Sc 3 (5 ML/year)	Financial Assessment Sc 3 (25 ML/year)

Labour and miscellaneous cost	Unit	Unit Price (USD/hour)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Unskilled worker	# Employee	$ 1.49	18	$ 214,560	21	$ 250,320
Skilled worker	# Employee	$ 5.06	5	$ 202,400	5	$ 202,400
Miscellaneous costs			25%	$ 104,240	25%	$ 113,180
Subtotal				$ 521,200		$ 565,900

Figure 31: Budget Structure: Labour and Miscellaneous Costs

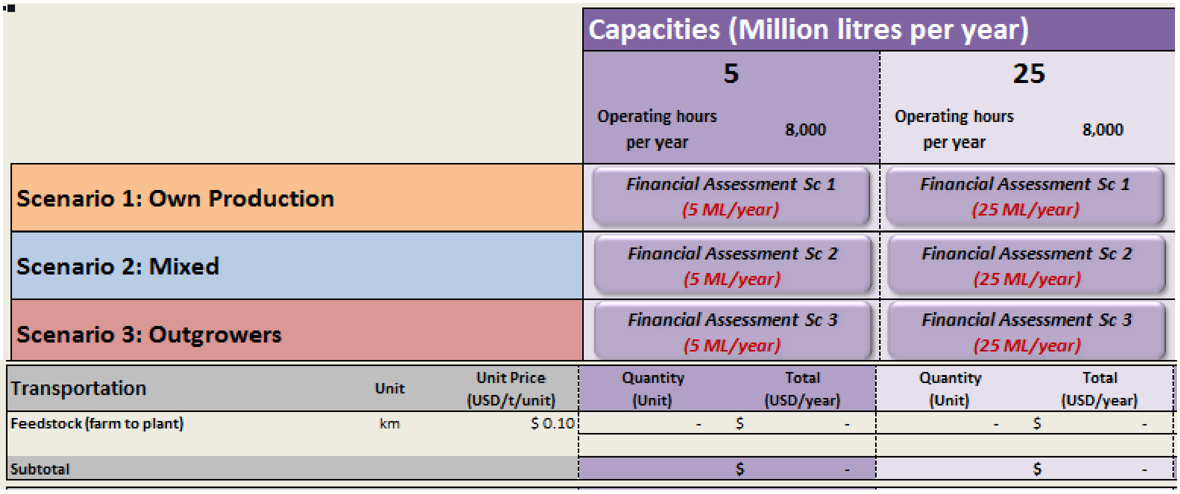
The miscellaneous costs comprise the cost of operating supplies and laboratory charges required for the daily processing of biodiesel. Consequently, 25% of the total labour cost was established as default to cover this expenditure and is identified as a miscellaneous percentage, i.e.:

Miscellaneous Costs (US$/year)

$$\text{Miscellaneous Cost [US\$/year]} = \text{Miscellaneous Percentage [\%]} * \text{Total Labor Cost [US\$/year]}$$

iii. Transport of feedstock

The value of transporting feedstock from farms to plants results from the multiplication of the unit price (USD per t) per quantity (km) per tons of feedstock (Figure 32).



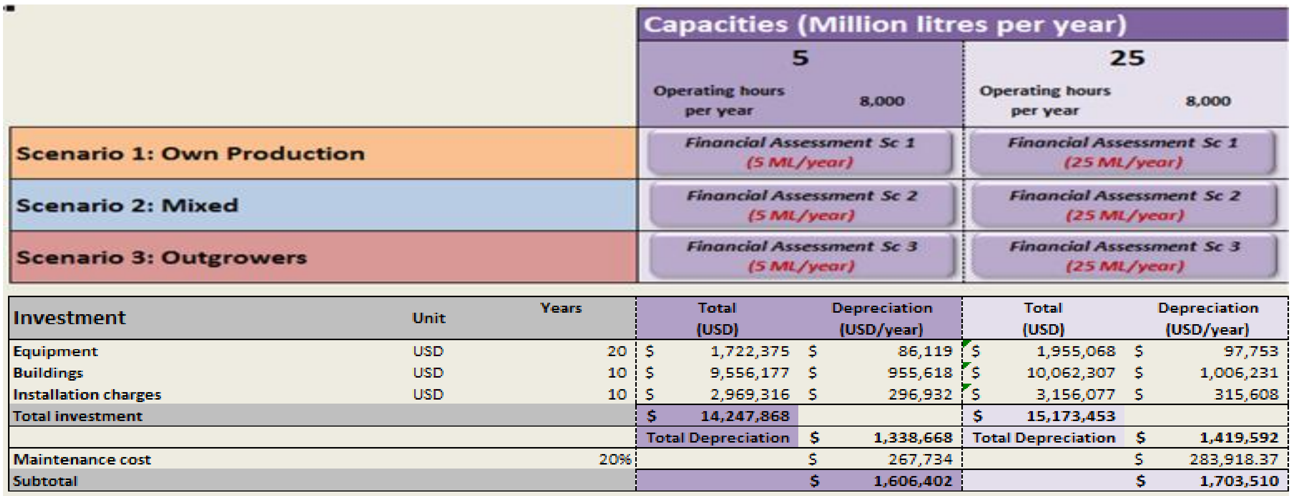
	Capacities (Million litres per year)	
	5 Operating hours per year 8,000	25 Operating hours per year 8,000
Scenario 1: Own Production	Financial Assessment Sc 1 (5 ML/year)	Financial Assessment Sc 1 (25 ML/year)
Scenario 2: Mixed	Financial Assessment Sc 2 (5 ML/year)	Financial Assessment Sc 2 (25 ML/year)
Scenario 3: Outgrowers	Financial Assessment Sc 3 (5 ML/year)	Financial Assessment Sc 3 (25 ML/year)

Transportation	Unit	Unit Price (USD/t/unit)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Feedstock (farm to plant)	km	$ 0.10	-	$ -	-	$ -
Subtotal				$ -		$ -

Figure 32: Budget Structure: Transport Costs of Feedstock

iv. Depreciation and maintenance costs

The depreciation was calculated using the straight line method. It assumes that the item will depreciate by a constant amount over its economic life or depreciation period. The individual investment costs are predefined for each plant size. The values for the specific investment costs were calculated for each of the established capacities (5, 25, 50 and 100 million litres per year) using the Aspen Economic Analyzer V 7.1 tool (http://www.aspentech.com/products/aspen-icarus-process-evaluator.aspx).



	Capacities (Million litres per year)	
	5 Operating hours per year 8,000	25 Operating hours per year 8,000
Scenario 1: Own Production	Financial Assessment Sc 1 (5 ML/year)	Financial Assessment Sc 1 (25 ML/year)
Scenario 2: Mixed	Financial Assessment Sc 2 (5 ML/year)	Financial Assessment Sc 2 (25 ML/year)
Scenario 3: Outgrowers	Financial Assessment Sc 3 (5 ML/year)	Financial Assessment Sc 3 (25 ML/year)

Investment	Unit	Years	Total (USD)	Depreciation (USD/year)	Total (USD)	Depreciation (USD/year)
Equipment	USD	20	$ 1,722,375	$ 86,119	$ 1,955,068	$ 97,753
Buildings	USD	10	$ 9,556,177	$ 955,618	$ 10,062,307	$ 1,006,231
Installation charges	USD	10	$ 2,969,316	$ 296,932	$ 3,156,077	$ 315,608
Total investment			$ 14,247,868		$ 15,173,453	
			Total Depreciation	$ 1,338,668	Total Depreciation	$ 1,419,592
Maintenance cost		20%		$ 267,734		$ 283,918.37
Subtotal				$ 1,606,402		$ 1,703,510

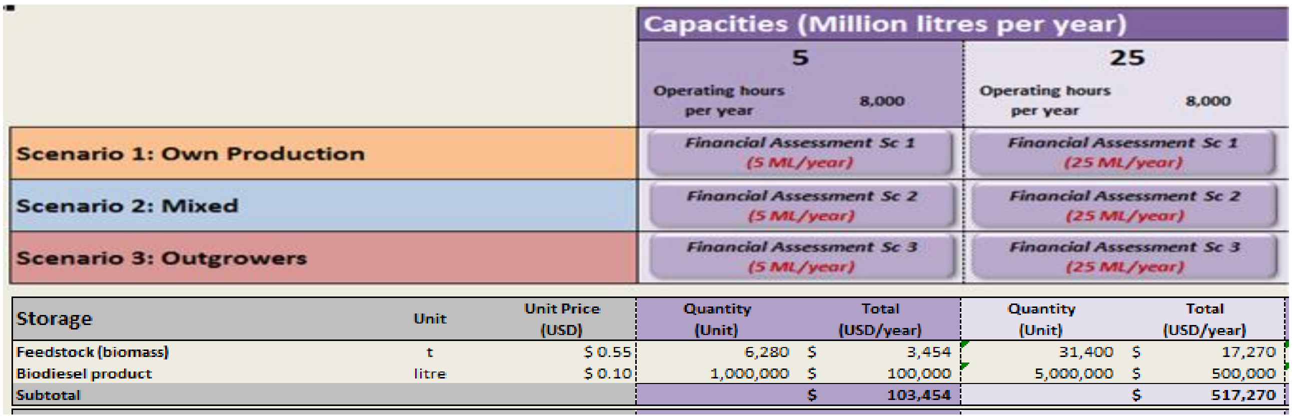
Figure 33: Budget Structure: Investment and Maintenance Costs

Maintenance Costs **(US$/year)**

The maintenance cost of all equipment and devices was established by default as 10% of the total annual depreciation of the investment.

$$\text{Manteinance Cost [US\$/year]} = \text{Maintenance Percentage [\%]} * \text{Total Depreciation Cost [US\$/year]}$$

v. Storage costs



	Capacities (Million litres per year)	
	5	25
	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	Financial Assessment Sc 1 (5 ML/year)	Financial Assessment Sc 1 (25 ML/year)
Scenario 2: Mixed	Financial Assessment Sc 2 (5 ML/year)	Financial Assessment Sc 2 (25 ML/year)
Scenario 3: Outgrowers	Financial Assessment Sc 3 (5 ML/year)	Financial Assessment Sc 3 (25 ML/year)

Storage	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Feedstock (biomass)	t	$ 0.55	6,280	$ 3,454	31,400	$ 17,270
Biodiesel product	litre	$ 0.10	1,000,000	$ 100,000	5,000,000	$ 500,000
Subtotal				$ 103,454		$ 517,270

Figure 34: Budget Structure: Storage Costs

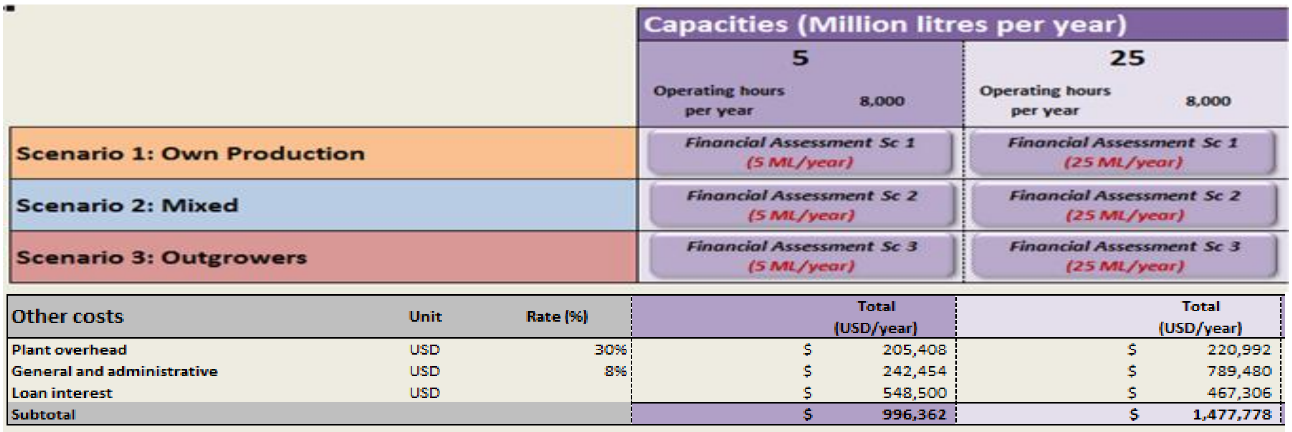
vi. Other costs

Plant overheads are general expenditures defined as a charge to the production for services, facilities, payroll overhead and are established by default as 50% of total labour and maintenance costs.

$$\text{Plant Overhead Cost [US\$/year]} = \text{Plant Overhead Percentage [\%]} * \\ (\text{Maintenance Cost [US\$/year]} + \text{Total Labor Cost [US\$/year]})$$

General and administrative costs (rent, insurance, managerial and administrative staff salaries) are expressed as a percentage of the sum of plant overheads, maintenance, total labour costs and the other costs except the expenditure for the feedstock purchase (default value is 8%).

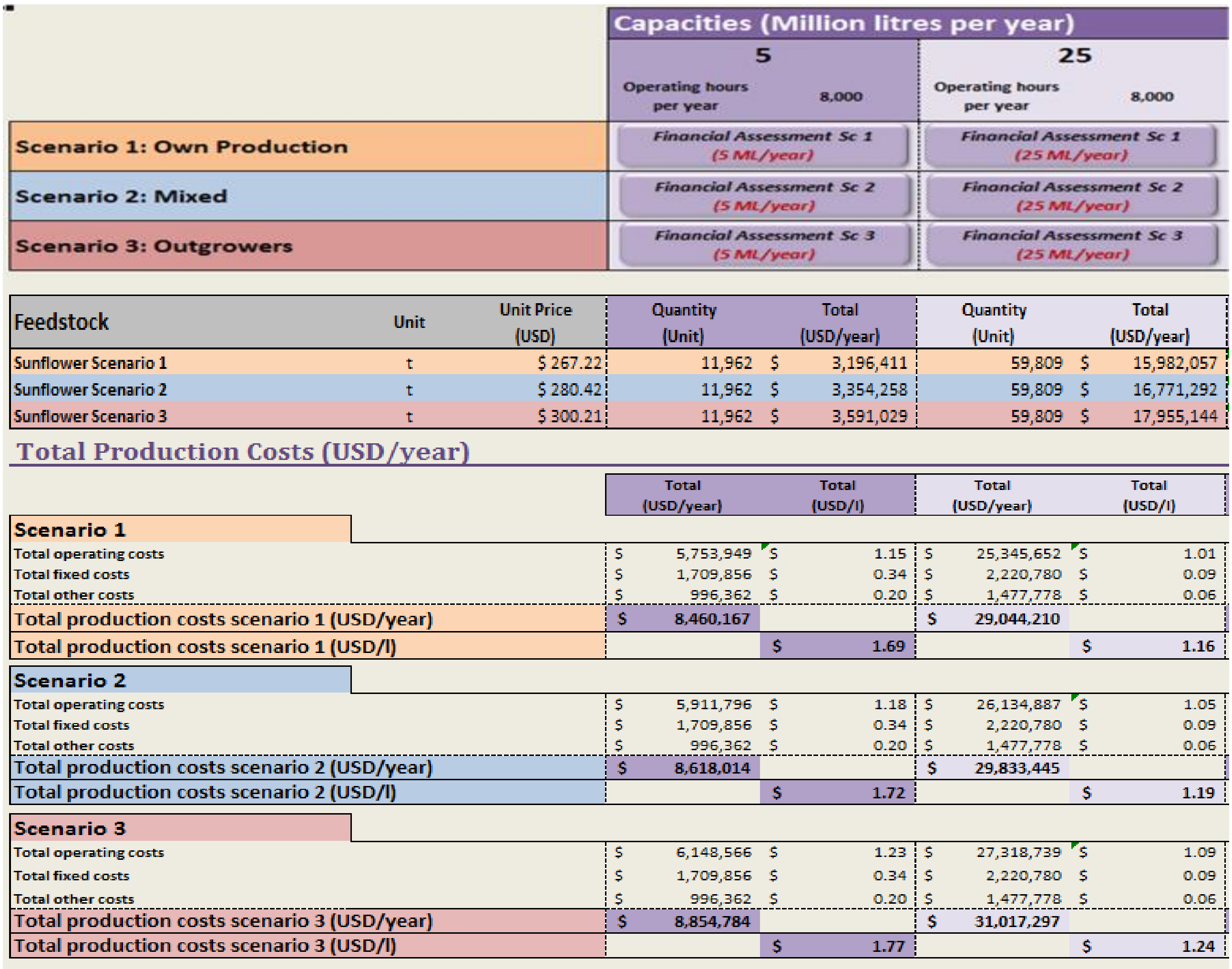
$$\text{General and Administrative Cost [US\$/year]} = \text{Gen. and Admin. Percentage [\%]} * \\ (\text{Plant Overhead Cost [US\$/year]} + \text{Maintenance Cost [US\$/year]} + \\ \text{Total Labour Cost [US\$/year]} + \text{Subtotal Input Cost [US\$/year]})$$



	Capacities (Million litres per year)	
	5	25
	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	Financial Assessment Sc 1 (5 ML/year)	Financial Assessment Sc 1 (25 ML/year)
Scenario 2: Mixed	Financial Assessment Sc 2 (5 ML/year)	Financial Assessment Sc 2 (25 ML/year)
Scenario 3: Outgrowers	Financial Assessment Sc 3 (5 ML/year)	Financial Assessment Sc 3 (25 ML/year)

Other costs	Unit	Rate (%)	Total (USD/year)	Total (USD/year)
Plant overhead	USD	30%	$ 205,408	$ 220,992
General and administrative	USD	8%	$ 242,454	$ 789,480
Loan interest	USD		$ 548,500	$ 467,306
Subtotal			$ 996,362	$ 1,477,778

Figure 35: Budget Structure: Plant Overhead, General and Administrative cost



	Capacities (Million litres per year)	
	5	25
	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	*Financial Assessment Sc 1 (5 ML/year)*	*Financial Assessment Sc 1 (25 ML/year)*
Scenario 2: Mixed	*Financial Assessment Sc 2 (5 ML/year)*	*Financial Assessment Sc 2 (25 ML/year)*
Scenario 3: Outgrowers	*Financial Assessment Sc 3 (5 ML/year)*	*Financial Assessment Sc 3 (25 ML/year)*

Feedstock	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Sunflower Scenario 1	t	$ 267.22	11,962	$ 3,196,411	59,809	$ 15,982,057
Sunflower Scenario 2	t	$ 280.42	11,962	$ 3,354,258	59,809	$ 16,771,292
Sunflower Scenario 3	t	$ 300.21	11,962	$ 3,591,029	59,809	$ 17,955,144

Total Production Costs (USD/year)

	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)
Scenario 1				
Total operating costs	$ 5,753,949	$ 1.15	$ 25,345,652	$ 1.01
Total fixed costs	$ 1,709,856	$ 0.34	$ 2,220,780	$ 0.09
Total other costs	$ 996,362	$ 0.20	$ 1,477,778	$ 0.06
Total production costs scenario 1 (USD/year)	$ 8,460,167		$ 29,044,210	
Total production costs scenario 1 (USD/l)		$ 1.69		$ 1.16
Scenario 2				
Total operating costs	$ 5,911,796	$ 1.18	$ 26,134,887	$ 1.05
Total fixed costs	$ 1,709,856	$ 0.34	$ 2,220,780	$ 0.09
Total other costs	$ 996,362	$ 0.20	$ 1,477,778	$ 0.06
Total production costs scenario 2 (USD/year)	$ 8,618,014		$ 29,833,445	
Total production costs scenario 2 (USD/l)		$ 1.72		$ 1.19
Scenario 3				
Total operating costs	$ 6,148,566	$ 1.23	$ 27,318,739	$ 1.09
Total fixed costs	$ 1,709,856	$ 0.34	$ 2,220,780	$ 0.09
Total other costs	$ 996,362	$ 0.20	$ 1,477,778	$ 0.06
Total production costs scenario 3 (USD/year)	$ 8,854,784		$ 31,017,297	
Total production costs scenario 3 (USD/l)		$ 1.77		$ 1.24

Figure 36: Budget Structure: Total Production Costs

8.1.2 Budget structure: estimates of labour and land requirements

In order to determine the potential impact of biofuel production on employment opportunities, a methodology was built to capture the labour coefficients, biofuel conversions and other inputs of operating biodiesel/ethanol plants and then translate them into potential employment opportunities. The final output includes the workers involved in feedstock production and those operating the processing plant as well. Workers dealing with feedstock transportation are not included. The estimation of the number of jobs potentially employed is based on the following calculation:

Number of jobs (man/year) = [on-farm labour (manual + machinery) + on-plant labour (unskilled + skilled)]

where

> On-farm labour (man/year) = {[(land required (ha) * labour manual coefficient (man day/ha)] + [(land required (ha) * labour machinery coefficient (man/day))] / working day in a year (day)}

and

> On-plant labour (man/year) = unskilled labour (man/year) + skilled labour (man/year)

Estimation of the potential impact of biodiesel/ethanol production on land requirements is based on the following calculation:

Land required (ha) = [plant size (millions of litres) / yield (t/ha) /biofuel conversion (l/t)]

8.2 Data requirements for running the *Transport Sub-Module*

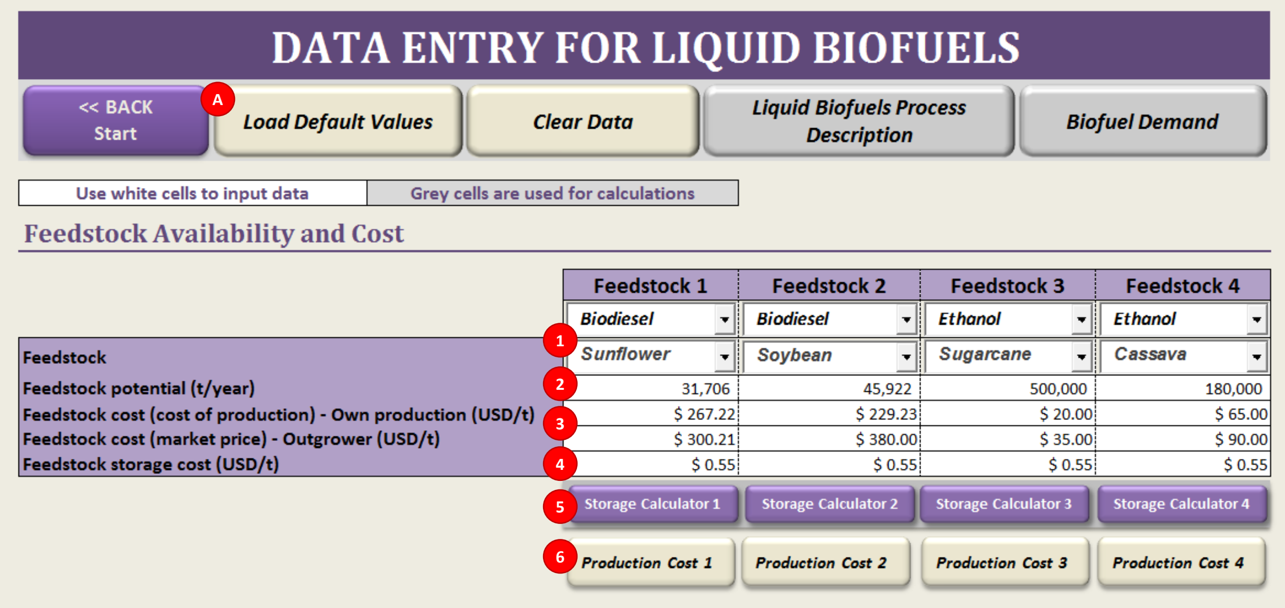
Table 4 includes data requirements for running the *Transport Sub-Module*.

Table 4: Data Requirements for Running the *Transport Sub-Module*

Data required	**From other BEFS RA components (see section 8.2.1)**
	• Feedstock cost: for each crop (USD/t), i.e. market price for outgrowers scheme and cost of production for own production scheme (from *Crop Budget Tool*)
	• Labour coefficients: manual (man day/ha) and machinery (man hour/ha) labour for different crops, input level (high, intermediate and low). Labour coefficients for activities related to feedstock production, such as land preparation, sowing, field operation and harvesting (from *Crop Budget Tool*)
	• Unskilled and skilled labour requirements (man/year) for different crops and plant sizes (from *Crop Budget Tool*)
	• Yield (t/ha) for different crops from GAEZ (from *Crop Production Tool*)
	Additional data required
	• Price of other raw materials: chemical reagents (USD/t), water (USD/m3), electricity (USD/KWh) and heat carrier (USD/t)
	• Labour costs: unskilled and skilled workers' wages (USD per employee per hour) and miscellaneous costs (25% of the total labour costs by default)
	• Cost of feedstock transport from farm to processing plant (USD per t per km)
	    • Transport cost (USD per t per km)
	    • The average distance from the farm to the processing plant for each plant size (km)
	• Storage costs and safety stock rate (for feedstock and liquid biofuel)
	    • Stock rate of feedstock (in percentage); storage cost of feedstock (USD/t)
	    • Stock rate of liquid biofuels (in percentage); storage cost of liquid biofuels (USD/litre)
	• Other costs: plant overhead (50% of maintenance and labour costs) , general and administrative costs (8% of the sum of the plant overhead, maintenance, total labour and total input costs) by default
	• Price of fossil fuels and liquid biofuels
	    • Domestic price of fossil fuels, diesel and gasoline, (USD/litre)
	    • International price of fossil fuels, diesel and gasoline (USD/litre)
	    • Price of fossil fuel equivalent (USD/litre)
	    • International price of liquid biofuel (ethanol and biodiesel) (USD/litre)
	• Financial parameters
	    • Discount rate (%)
	    • Inflation rate (%)
	    • Inflation of raw material price (%)
	    • Change of labour cost (%)
	• Low input share and intermediate input share in outgrower production
	• Share estate/outgrower in feedstock production scheme
	• Number of working days/year

8.2.1 Outputs of *Crops Component* used in the *Transport Sub-Module*

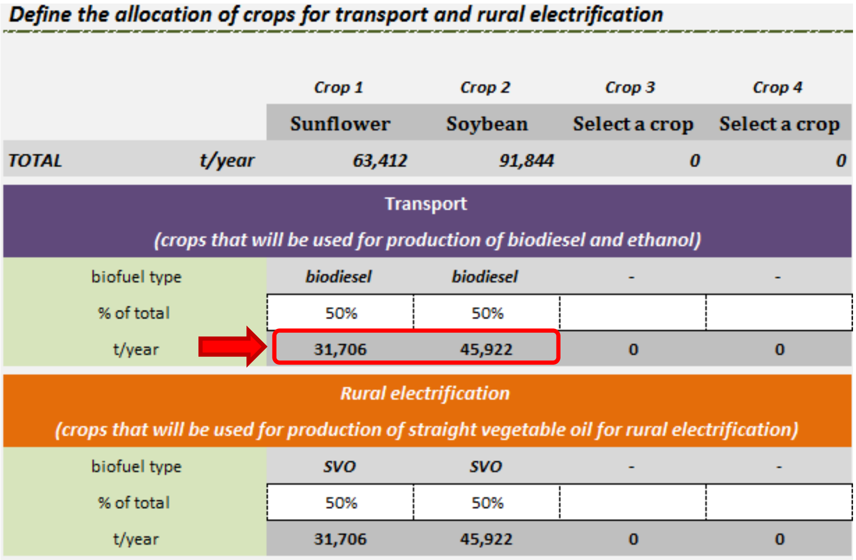
As already mentioned in sections 5.2.1 and 8.2, labels 2 and 3 of Figure 37 are outputs of the BEFS RA *Crops Component*.



	Feedstock 1	Feedstock 2	Feedstock 3	Feedstock 4
	Biodiesel	Biodiesel	Ethanol	Ethanol
Feedstock	Sunflower	Soybean	Sugarcane	Cassava
Feedstock potential (t/year)	31,706	45,922	500,000	180,000
Feedstock cost (cost of production) - Own production (USD/t)	$ 267.22	$ 229.23	$ 20.00	$ 65.00
Feedstock cost (market price) - Outgrower (USD/t)	$ 300.21	$ 380.00	$ 35.00	$ 90.00
Feedstock storage cost (USD/t)	$ 0.55	$ 0.55	$ 0.55	$ 0.55

Figure 37: *Transport Sub-Module* - Feedstock Availability and Cost

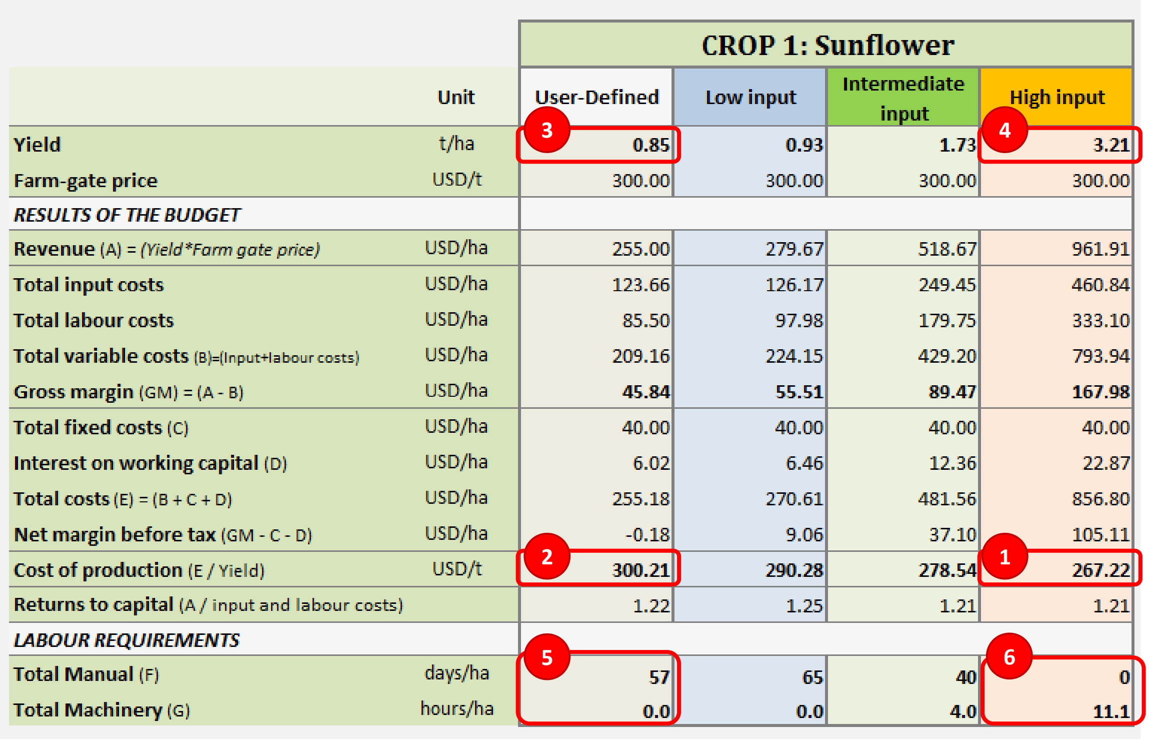
More precisely, label 2 is an output of the *Crop Production Tool*, where the additional volumes of the selected feedstock from intensification, crop-to-crop changes and extensification are shown. In the case of oil crops, users have to enter the share of the additional feedstock that shall be used for the production of biodiesel for transport and of straight vegetable oil for electricity and/or heat (Figure 38).


Define the allocation of crops for transport and rural electrification

		Crop 1	Crop 2	Crop 3	Crop 4
		Sunflower	Soybean	Select a crop	Select a crop
TOTAL	t/year	63,412	91,844	0	0
Transport (crops that will be used for production of biodiesel and ethanol)					
biofuel type		biodiesel	biodiesel	-	-
% of total		50%	50%		
t/year		31,706	45,922	0	0
Rural electrification (crops that will be used for production of straight vegetable oil for rural electrification)					
biofuel type		SVO	SVO	-	-
% of total		50%	50%		
t/year		31,706	45,922	0	0

Figure 38: *Crop Production Tool* – Crop Production Results Sheet

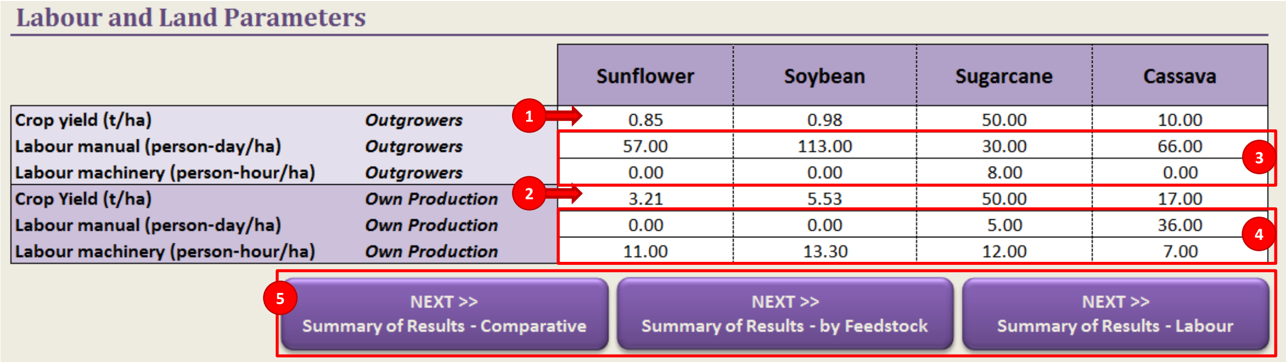
The production costs computed by the *Crop Budget Tool* in the Summary of Results sheet is shown in Figure 39. Label 3 (Feedstock cost - Own production) of Figure 37 is determined by some of these outputs. More specifically, the high input cost of production is assumed to be the farming system of the own production scheme (Figure 39, label 1). Whereas, for label 3 (Feedstock cost – Outgrower) of Figure 37, the output used from the Summary of Results sheet is the user-defined value (Figure 39, label 2).



		CROP 1: Sunflower			
	Unit	User-Defined	Low input	Intermediate input	High input
Yield	t/ha	**0.85**	**0.93**	**1.73**	**3.21**
Farm-gate price	USD/t	300.00	300.00	300.00	300.00
RESULTS OF THE BUDGET					
Revenue (A) = *(Yield*Farm gate price)*	USD/ha	255.00	279.67	518.67	961.91
Total input costs	USD/ha	123.66	126.17	249.45	460.84
Total labour costs	USD/ha	85.50	97.98	179.75	333.10
Total variable costs (B)=(Input+labour costs)	USD/ha	209.16	224.15	429.20	793.94
Gross margin (GM) = (A - B)	USD/ha	**45.84**	**55.51**	**89.47**	**167.98**
Total fixed costs (C)	USD/ha	40.00	40.00	40.00	40.00
Interest on working capital (D)	USD/ha	6.02	6.46	12.36	22.87
Total costs (E) = (B + C + D)	USD/ha	255.18	270.61	481.56	856.80
Net margin before tax (GM - C - D)	USD/ha	-0.18	9.06	37.10	105.11
Cost of production (E / Yield)	USD/t	**300.21**	**290.28**	**278.54**	**267.22**
Returns to capital (A / input and labour costs)		1.22	1.25	1.21	1.21
LABOUR REQUIREMENTS					
Total Manual (F)	days/ha	**57**	**65**	**40**	**0**
Total Machinery (G)	hours/ha	**0.0**	**0.0**	**4.0**	**11.1**

Figure 39: *Crop Budget Tool* – Summary of Results Sheet

Labels 1 to 4 (for both outgrowers and own production) of Figure 40 are also outputs of the *Crop Budget Tool* (Figure 39, labels 3 to 6).



Labour and Land Parameters

		Sunflower	Soybean	Sugarcane	Cassava
Crop yield (t/ha)	*Outgrowers*	0.85	0.98	50.00	10.00
Labour manual (person-day/ha)	*Outgrowers*	57.00	113.00	30.00	66.00
Labour machinery (person-hour/ha)	*Outgrowers*	0.00	0.00	8.00	0.00
Crop Yield (t/ha)	*Own Production*	3.21	5.53	50.00	17.00
Labour manual (person-day/ha)	*Own Production*	0.00	0.00	5.00	36.00
Labour machinery (person-hour/ha)	*Own Production*	11.00	13.30	12.00	7.00

Figure 40: *Transport Sub-Module* - Labour and Land Parameters

Moreover, for the outgrowers scheme, the selection of the yield and of the associated labour requirements depend on the user-defined yield and where it stands in relation to the potential yields under low, intermediate and high input scenarios:

A. If the user-defined yield is close to the potential yield of the low input scenario, it is assumed that outgrowers will be able to move towards the intermediate input level and achieve the associated yield;

B. If the user-defined yield is close to the potential yield of the intermediate input scenario, it is assumed that outgrowers will be able to move towards the high input level and achieve the associated yield; and

C. If the user-defined yield is close to the potential yield of the high input level scenario, it is assumed that outgrowers will produce at this input level and achieve the related yield.

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