Food and Agriculture Organization of the United Nations

WORLD BANK GROUP

Energizing Agriculture Assessment Tool

USER MANUAL

Development Project for FAO and the World Bank

Energizing Agriculture Assessment Tool

User manual

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SUMMARY

The EAAT tool is oriented towards the energy characterization of food industry supply chains, which allows users to make a comparison between a current scenario and improvement scenarios proposing the use of alternative equipment and energy sources. After comparing these scenarios, the tool shows the economic, technical, social and environmental impact that the intervention has for decision making according to the user's interests.

The first level of analysis is defined by choosing between two possible analyses: energy and economic.

Energy analysis allows users to examine their supply chain from a purely energetic point of view, that is, excluding all economic factors. This level of analysis requires minimal information on the part of the user, as they only have to specify the machinery associated with the process and the sources of electricity supply, heating and cooling. This stage was designed to allow users with minimal information to perform a quick analysis.

On the other hand, the economic analysis makes it possible to obtain a more advanced level of detail, by including both energy and economic factors. It should be noted that the information required by the user is much more specific and extensive, for this reason it is recommended to choose this analysis only if detailed information on the supply chain is available.

More specifically, the EAAT tool is divided into six specific modules according to each agro-chain:

- agriculture module;
- agricultural intervention module;
- industrial module;
- industrial intervention module;
- energy saving practices module;
- co-products module;
- summary of results.

It should be noted that each module is divided into subsequent stages that will be explained in detail later. The definition of each of the modules and their functions are described in more detail below.

Agriculture module

This section on the tool analyses the supply chain including all activities related to rural areas, livestock, cultivation and land. This stage mainly focuses on production but not on the processing of raw material.

Agricultural intervention module

In this section the user can change the machinery specified in the agriculture module, thus allowing them to evaluate the impact of implementing different machinery from what they currently own. Furthermore, an alternative source of electricity can be specified as a means of evaluating potential savings from changes in technology.

Industrial module

This section provides all information related to the processing of raw material and offers the possibility to evaluate the industrialization process of each supply chain process. It is assumed that the product obtained in the agriculture module is the raw material that enters the industrial module. It should be noted that all industrial stages relevant to the chain under analysis were included, regardless of whether the country for which the database was prepared reached this level of industrialization.

Industrial intervention module

This module allows for an assessment of the impact of a change in the selection of industrial machinery, furthermore, an analysis can be made of changes in electricity, heating, and cooling supply sources.

It is important to highlight that, in order to cover any existing possibility, in the selection of both agricultural or industrial machinery, current and intervened, the user can enter their own values in order to specify any equipment not included in the tool's database.

Energy saving practices module

The purpose of this section is to allow the user to evaluate the potential energy savings for indirect process issues: lighting, preventive maintenance and insulation. The lighting step enables the user to analyse the impact that a change in the lighting systems would have on the total amount of electric energy consumed. Subsequently, the preventive maintenance step will allow the user to evaluate the impact the performance or non-performance of this maintenance has on the energy consumption of the equipment, and its useful lifespan. Finally, the insulation step allows for an evaluation of the potential energy and monetary potential savings, which could be obtained by applying a series of changes to systems exchanging heat with the environment.

Co-products module

The purpose of this module is to show the user the co-products associated with the chain under analysis that are produced in greater proportion and the stage at which they are generated. Furthermore, it provides a series of parameters of particular relevance to carry out yield calculations of possible future uses of co-products, while mitigating the environmental impact and generating an alternative source of income.

Summary of results

This module provides a summary of the previous modules that have been classified in sections and divided into two large groups: economic results and energy results. The description of the agricultural and industrial stages is done by means of user-friendly graphics that facilitate a quick interpretation and understanding of the results obtained.

SCOPE AND OBJECTIVE

The objective of the EAAT tool is to allow users to make a primarily energy assessment of the production and processing of an agricultural value chain. The said evaluation is carried out through a comparison between alternative equipment, techniques, and technologies alternatives for each stage in the process that are shown in parallel with the current situation of the agro-industry. Taking both scenarios, current and intervened, the impact that each one has on key decision parameters is shown in the first instance, energetic accompanied by other economic, environmental, technical, and social parameters.

The results obtained through this tool can be used for political decision making about agricultural practices in the region or country, as well as decision making at the level industries that want to improve their process performance. It is important to remember that the tool is mainly of an energetic nature. Therefore, the economic parameters do not represent an objective, but serve as an instrument for evaluating the impact that the optimization of certain stages in on the process has on the costs of the agro-industry.

TERMS AND DEFINITIONS

- **Autogenerated:** the electric energy used by the plant is generated internally.

- **Heating:** it is related to energy required in the form of steam.

- **Cooling:** equipment that uses electricity to handle compressors in the cooling cycle with R-134a to chill water.

- **Operation costs:** the sum of all variable costs in each stage: water consumption, combustibles, energy (electricity, heating, cooling) and manpower (labour).

- **Production cost:** the sum of all fixed costs (where fixed cost is depreciation) in addition to variable costs (manpower/labour, inputs and energy) and other costs (general and administrative contingencies, and depreciation).

- **Production cost:** (as an option for the cost of raw material in the industrial module*)*. This option should be selected when the price of the raw material is not known. The price would be based on the production cost calculated in the agriculture stage.

  Cost of crop establishment*:* this variable represents the initial investment to be made in order to establish a crop: plot layout, hole-digging, purchase of seeds or plants, weeding. In general, it is made up of all activities related to the crop that are not specified in the mapping corresponding to each agro-chain.

- **User defined**: this option was created in order to cover all possible options in terms of machinery. Each time it is selected, the use will be prompted to specify the parameter required by each piece of equipment for subsequent calculations.

- **Equipment efficiency***:* refers to the percentage of the product that the machine can produce in relation to the total product that could be produced without losses.

- **Inputs:** inputs that have to be spent to sustain the crop or process e.g., drugs, fertilizers, nutrients, water. In this tool the energy costs are in a separate section.

- **Labour intensity (man-hours/t***)*: this parameter indicates how many hours one man must work to produce 1 tonne of product.

- **Unskilled labour:** operational personnel who do not require and have not had training in order to perform their activities.

- **Semi-skilled labour:** operational personnel who require and have had prior training in order to perform their activities.

- **Skilled labour:** non-operational personnel who require and have had preparation for the development of their activities.

- **Mapping:** it consists of a flowchart containing the stages into which each agri-chain is divided. Its function is to provide the user with a specific view of the stages that are included in the tool's database.

- **Not performed:** this option allows the user to specify that the step displayed in the tool is not being performed in their current process or is not intended to be performed in their intervened process.

- **Number of producers***:* if the annual production entered in Step 3 is not within the range of the production size initially selected, the tool auto-calculates the number of producers needed to supply the indicated production.

- **Market price:** (as an option for raw material costs in the industrial module). This option should be selected when the user knows the price of the raw material. It should then be specified in the appropriate field.

- **Central grid:** the electrical energy that supplies the plant is taken from the energy distributed throughout the country or region.

- **Internal Rate of Return (IRR***)*: it is defined as the rate that makes the Net Present Value (NPV) equal to zero. In the case of investment projects, the IRR is the discount rate that equals the present value of cash flows with a negative sign (cash outflows) to the present value of cash flows with a positive sign (cash inflows) (Mondino and Pendas, 2007).

- **Cooling tower:** a system that carries out the heat transfer between a stream of water and an air stream in order to dissipate heat into the atmosphere and thus cool the water. During heat transfer to air, fractions of water are lost. Air can be supplied by fans or naturally.

- **Production unit:** number of machines required to perform or carry out the target production. In case the operation is manual (no use of machines or equipment) a '1' should be entered. If the user does not have the information, the user can choose to calculate it automatically

- **Net Present Value (NPV*)*:** it is defined as the sum of the present value of net cash flows, minus the sum of the present value of net investments (Morales Castro and Morales Castro, 2022).

  NOTE: Dear user, if you consider that there are additional terms or definitions that should be included in this manual, please write to us at befs-support@fao.org. We appreciate your collaboration for the improvement of the tool.

Assumptions

- For the head yield in cattle, in the case of beef a weight of 800 lbs/head is assumed, with a yield of 60 percent meat of the total weight (Barker, 2001; Guardiola, 2016).

- In the agricultural phase, it is assumed that 8 hours a day and 330 days per year are worked.

In the cost section, when the user selects that they know the production costs, the following is assumed:

- Miscellaneous costs are assumed to be 10 percent of the total labour cost.

- The contingency costs are assumed to be 10 percent of the total cost of labour and maintenance.

- General and administrative costs are assumed to be 5 percent of the sum of inputs plus labour, plus energy, plus maintenance, plus contingencies.

- Maintenance costs are assumed to account for 15 percent of the total cost of production.

- The skilled labour force is 1/5 of the semi-skilled labour force.

- For the automatic calculation of production units, it is assumed that the effective processing capacity of the equipment is equal to the average of the capacities of all equipment of the same type with the size selected by the user. For example, if a medium size was chosen in the agricultural phase but the user uses small scythes for pruning, the tool calculates the number of scythes as the ratio between the actual capacity of the

equipment (average of the capacities of the medium-sized scythes) and the capacity reported for the scythe selected by the user.

- For the calculation of the price of electricity when it is self-generated, and of heating and cooling when its cost is not known, it is assumed that the price is equal to the sum of the investment cost of the technology depreciated over 20 years and the cost of operation and maintenance reported in the tool's databases.

- For the calculation of the Net Present Value (NPV) it is assumed that the inflation rate is constant over time and the project duration period is 20 years.

- The useful life of the civil works and installation is assumed to be equal to the useful life of the equipment.

- The cost of the civil works is assumed to be equal to 50 percent of the total cost of the equipment.

- The cost of installation is assumed to be equal to 40 percent of the total cost of the equipment.

Disclaimer

In the summary of results, the diagram presented for the energy results is represented in this way to be more comparative, but in the current scenario values below zero do not mean negative values

INPUT DATA

To run the tool in the energy analysis the user is not required to enter data into the tool. However, to run the economic analysis it is necessary for the user to enter several input data, which can be minimal or slightly more extensive depending on one single data, whether they know the production costs or not. This is type of analysis is described later in the GUIDED NAVIGATION.

Thus, there are two cases for the input data: one when the user does not know the production costs and other when he does. The tables hereunder show examples of a possible scenario with the data required in both cases for the coffee agro-chain. For other agro-chains, the information required is quite similar and can be found in the annexes.

Input data where production costs are known

When the user knows the production cost of their product, the information required to run the tool is reduced by almost half. Table 1 and 2 show the minimum parameters that the user must know in order to run the tool when they know the production costs in the industrial and agriculture modules. These parameters are required for the calculation of financial indexes and other variables.

Table 1. Input data with known costs, agriculture module in the case of coffee

MINIMUM INFORMATION TO EXECUTE EAAT (COFFEE)			
Agriculture Module			
Step	Data	Value	Units
STEP 2	Price of electricity (agriculture)		USD/kWh
STEP 3	Crop yield per harvest		tonne/ha
	Number of crops		n°/year
	Cultivation area		ha
STEP 4	Discount rate		%
	Interest rate		%
	Inflation rate		%
	Sale price of product		USD/tonne
	Salary for unskilled agricultural labour		USD/h-h
	Salary for semi-skilled agricultural labour		USD/h-h
	Price of water (Agriculture)		USD/m3
	Price of gasoline (Agriculture)		USD/litre
	Price of diesel (Agriculture)		USD/litre
	Price of propane (Agriculture)		USD/litre
	Price of natural gas (Agriculture)		USD/litre
	Production costs		USD/ha or /tonne or /year

Source: Elaborated by the authors

Table 2. Input data with known costs, industrial module in the case of coffee

MINIMUM INFORMATION TO EXECUTE EAAT (COFFEE)			
Industrial Module			
Step	Data	Value	Units
STEP 2	Cost of electricity		USD/kWh
	Cost of heating		USD/GJ
	Cost of cooling		USD/GJ
PASO 3	Process yield		tonnes product/tonnes MP
	Hours of performance per year		h
	Annual production		tonnes/year
PASO 4	Discount rate		%
	Interest rate		%
	Inflation rate		%
	Sale price of product		USD/tonne
	Salary for semi-skilled labour		USD/h-h
	Salary for skilled labour		USD/h-h
	Cost of water		USD/m^3
	Cost of gasoline		USD/litre
	Cost of diesel		USD/litre
	Cost of propane		USD/litre
	Cost of natural gas		USD/litre
	Production costs		USD/tonne or /year

Source: Elaborated by the authors

Input data in case where production costs are not known

When the user does not know the value of production costs, then it must know and enter more information into the tool, as shown in Table 3 of the agriculture module in the case of the coffee agro-chain. All additional information requested is necessary for calculating the value of production costs and other economic parameters. Tables 3 and 4 show all required input data for the coffee agro-chain in the agricultural and industrial modules, respectively.

Table 3. Total input data from the agriculture module for the coffee agro-chain

INFORMATION TO EXECUTE EAAT (COFFEE)			
Agriculture Module			
Step	Data	Value	Units
STEP 2	Price of electricity (Agriculture)		USD/kWh
STEP 3	Crop yield per harvest		tonnes/ha
	Number of crops		n°/year
	Cultivation area		ha
STEP 4	Discount rate		%
	Interest rate		%
	Inflation rate		%
	Selling price of product		USD/tonne
	Salary for unskilled agricultural labour		USD/h-h
	Salary for semi-skilled agricultural labour		USD/h-h
	Price of water (Agriculture)		USD/m^3
	Price of gasoline (Agriculture)		USD/litre
	Price of diesel (Agiculture)		USD/litre
	Price of propane (Agriculture)		USD/litre
	Price of natural gas (Agriculture)		USD/litre
	Cost of crop establishment		USD/ha
	Herbicide price		USD/litre
	Pesticide price		USD/tonne
	Insecticide price		USD/litre
	Nitrogen fertilizers		USD/tonne
	Potassium fertilizers		USD/tonne
	Phosphorous fertilizer		USD/tonne
	NPK1 complex fertilizer		USD/tonne
	Price of organic fertilizers		USD/tonne
	Loan percentage		%
	Loan period		years
	Useful life of the equipment		years
	Useful life of the crop		years
STEP 5	Seasonal water supply		m3/ha/year
	Crop water deficit		mm/year
	Average depth		m
	Inversion		USD
	Irrigated area		ha
	Average useful life		years
	Pumping energy demand		kWh
STEP 6	Nitrogen(N)		kg/ha/year
	Potassium (K)		kg/ha/year
	Phosphorous (P)		kg/ha/year
	Organic fertilizers		kg/ha/year
	Pesticide		kg/ha/year
	Herbicide		litres/ha/year
	Insecticide		litres/ha/year
	Other- Miscellaneous		%
	Maintenance costs		%
	Other costs - contingencies		%
	Other general and administrative costs		%

Source: Elaborated by the authors

Table 4. Total input data of the industrial module for the coffee agro-chain

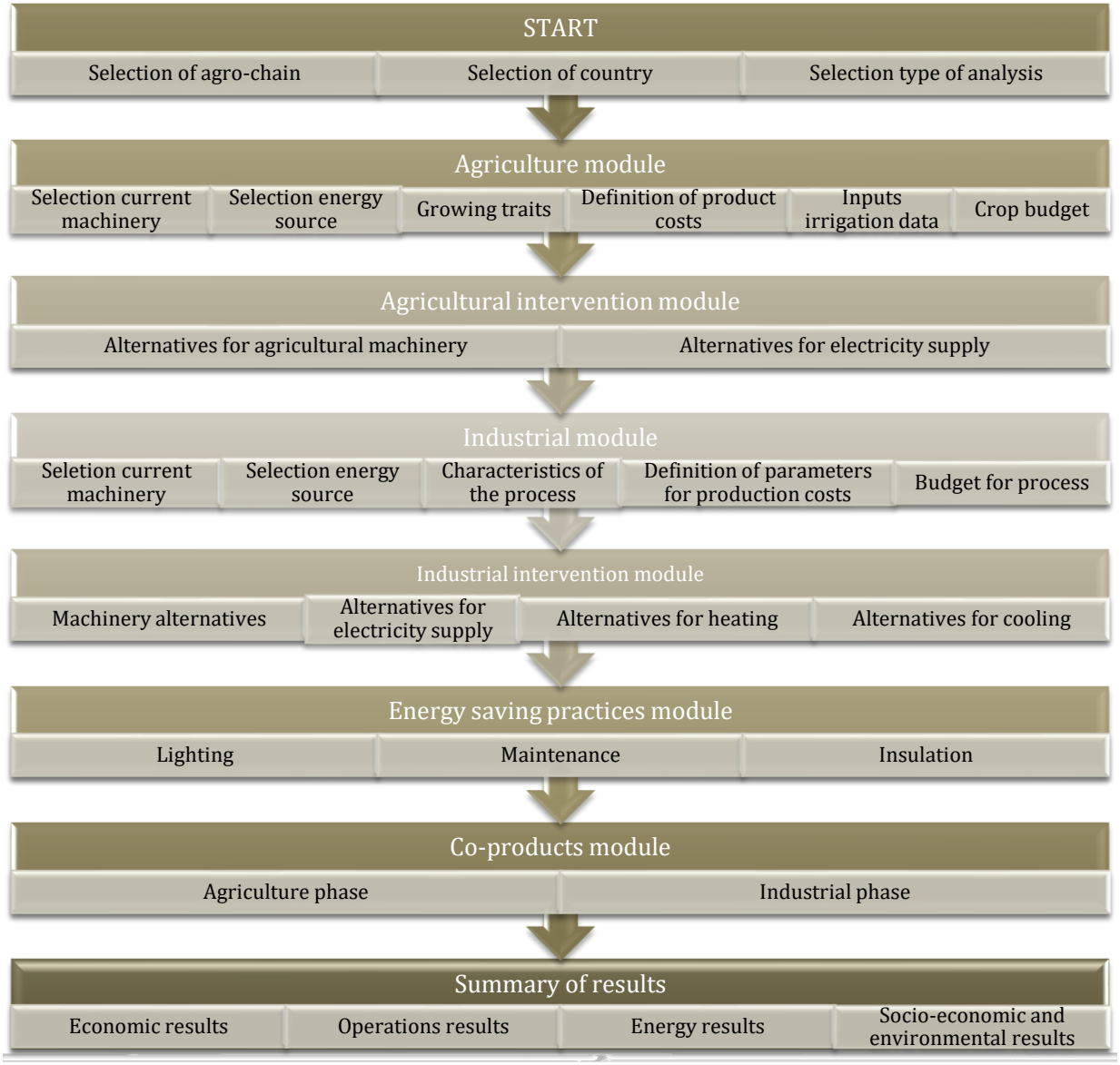
INFORMATION TO EXECUTE EAAT(COFFEE)			
Industrial Module			
Step	Data	Value	Units
STEP 2	Cost of electricity		USD/kWh
	Cost of heating		USD/GJ
	Cost of cooling		USD/GJ
STEP 3	Process performance		tonne-prod/tonne MP
	Hours of operation per year		h
	Annual production		tonnes/year
STEP 4	Discount rate		%
	Interest rate		%
	Inflation rate		%
	Selling price of product		USD/tonne
	Salary for semi-skilled labour		USD/h-h
	Salary for skilled labour		USD/h-h
	Cost of water		USD/m^3
	Cost of gasoline		USD/litre
	Cost of diesel		USD/litre
	Cost of propane		USD/litre
	Cost of natural gasoline		USD/litre
	Cost of other chemicals 1		USD/tonne
	Cost of other chemicals 2		USD/tonne
	Cost of other chemicals 3		USD/tonne
	Cost of other chemicals 4		USD/tonne
	Cost of other chemicals 5		USD/tonne
	Cost of raw material		USD/tonne
	Pourcentage for loan		%
	Period of loan		years
	Equipment service life		years
STEP 5	Other chemicals 1		tonnes/year
	Other chemicals 2		tonnes/year
	Other chemicals 3		tonnes/year
	Other chemicals 4		tonnes/year
	Other chemicals 5		tonnes/year
	Miscellaneous costs		%
	Maintenance costs		%
	Other costs- Contingencies		%
	Other costs- General and administrative costs		%

Source: Elaborated by the authors

GUIDED TOOL NAVIGATION

The EAAT tool is designed as an easy guide for the user throughout the entire analysis. The order the user must follow to navigate correctly is as follows: agricultural characterization, industrial characterization, energy saving practices module, and co-product potential module. The detailed analysis scheme is shown in Figure 1.

Figure 1. EAAT analysis and navigation scheme



Source: Elaborated by the authors

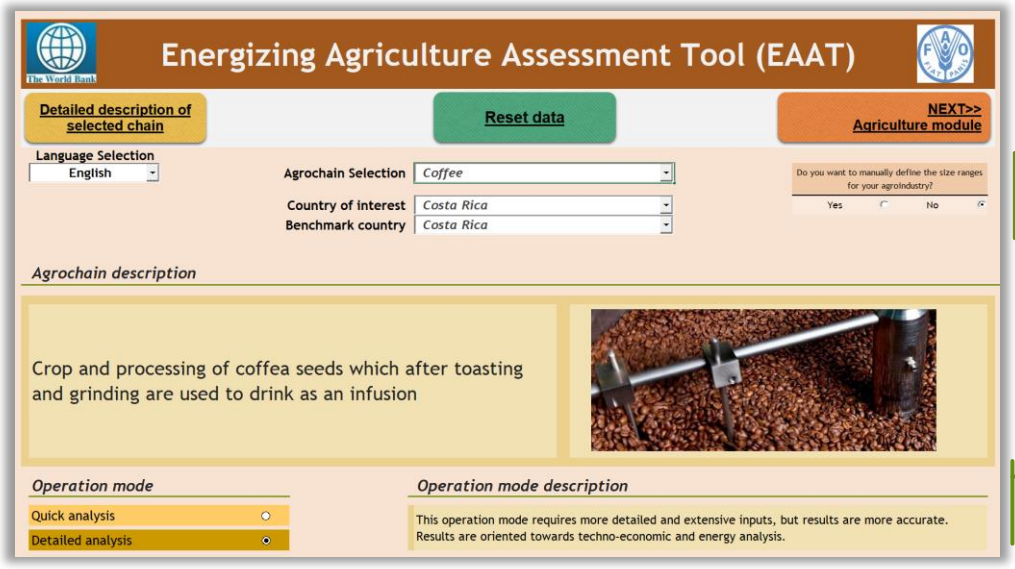
Each module shown in Figure 1 will be expanded upon to show the user how to navigate the tool. The coffee agro-chain is taken as an example of how to use the tool, as follows:

Start

The first section that is shown to the user when opening the tool is the START, as shown in Figure 2. In this section, the user must make the first three selections (Figure 1): (i) selection of the agro-chain (coffee, beef, pork, dairy or chicken), which has a brief description; (ii) selection of the country for which the database and study was carried out – in the case of error a warning signal will appear in the gray box; (iii) selection of the Operation Mode, which has the following types available:

- **Energy analysis:** it should be selected when the user does not have enough information about the process or industry in question, and wants to make a quick analysis. This analysis does not take much time to perform, since it requires minimal input data. In this mode of operation, only the sources of energy supply and the machinery used in production or processing are evaluated.
- **Economic analysis:** in this mode of operation the user needs to make a more complete analysis and therefore has more information available. In addition to energy supply sources and machinery, other more specific information on the industry or process related to production costs is also evaluated. Additionally, this mode of operation yields financial results such as NPV and IRR.
- **Evaluation analysis:** this is the most accurate mode of operation. It should be used when the user has sources to build his own database and supply it to the tool. For this purpose, a survey format is provided with the information that the user must collect.

Figure 2. Start of EAAT

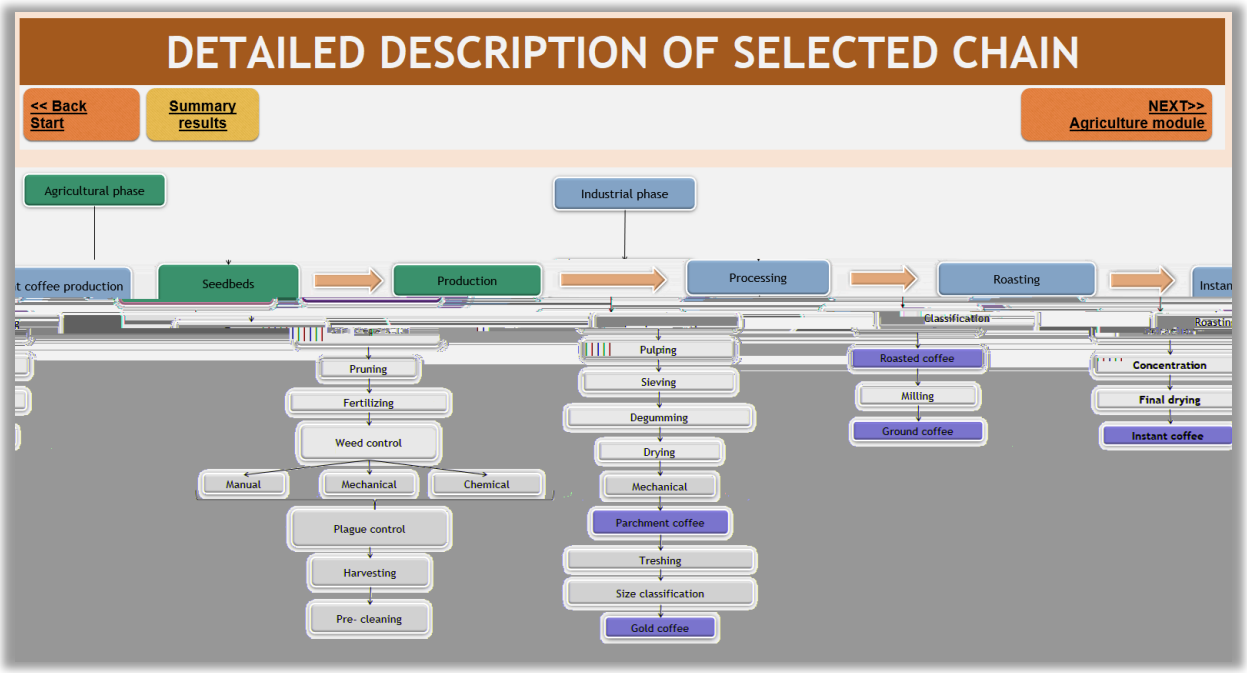


Source: Elaboration based on EAAT results

Detailed description of the chain

After completion of the first section or module, the user can review the 'detailed description of the chain' – a mapping or flowchart showing the production and processing of the final product of the value chain – or continue with the analysis by clicking on the 'next, agriculture module' button. Figure 3 shows the mapping of the coffee chain.

Figure 3. Mapping of the coffee agro-chain.

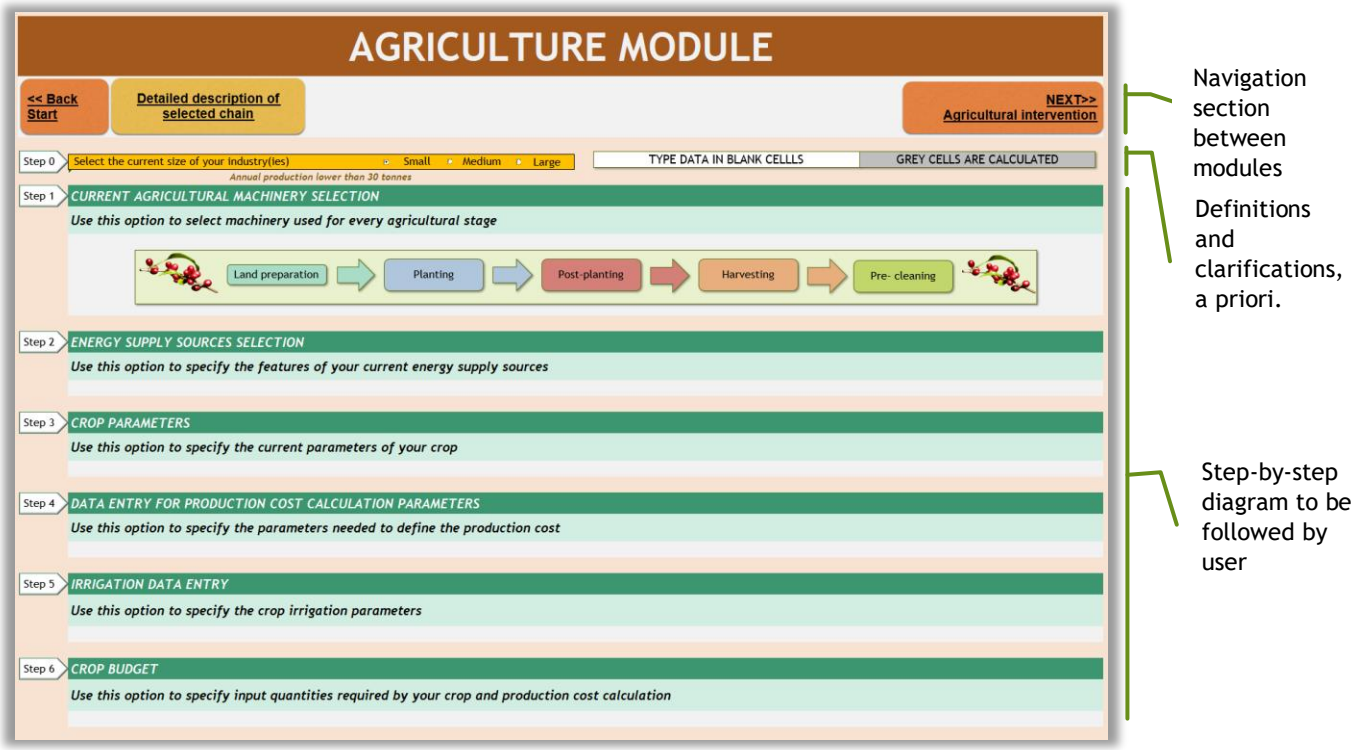


Source: Elaboration based on EAAT results

Agriculture module

After reviewing the agro-chain flowchart, the user will have a clearer idea about the stages for the production and processing of the product of interest. This concept facilitates understanding the next section – the agriculture module. In this module the user will enter and select all information related to the production of his product, i.e., livestock or crops, as in the case of coffee.

Figure 4. Agriculture module.

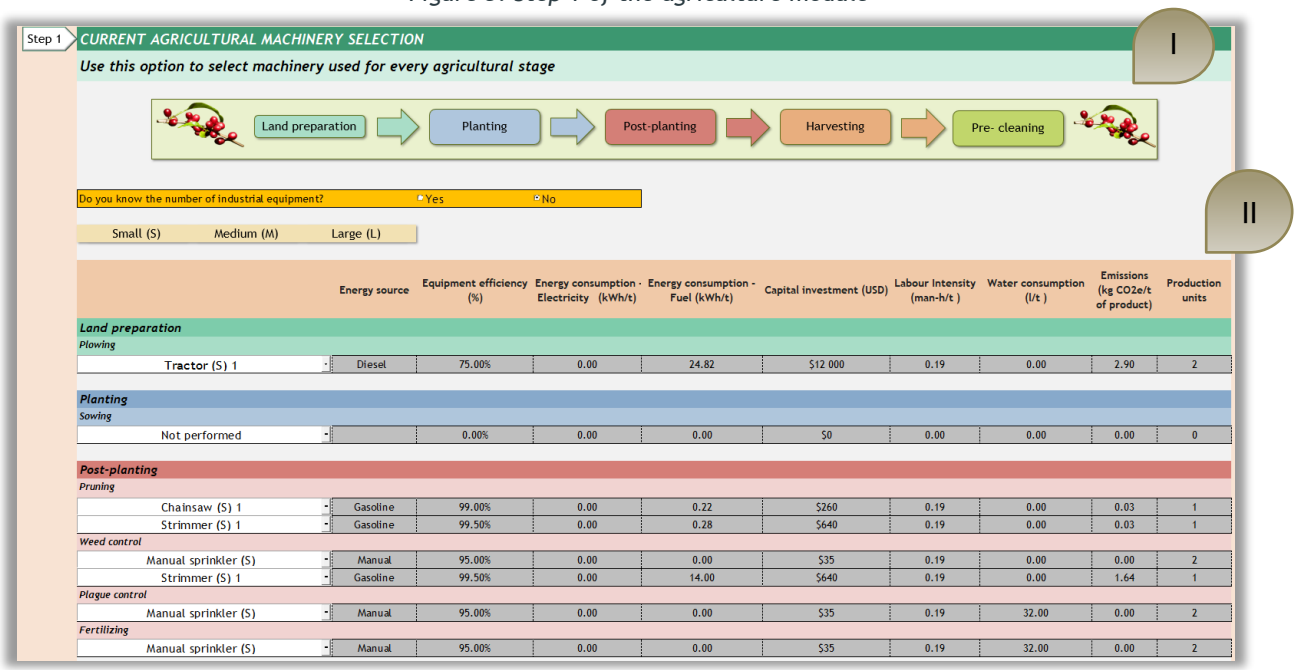


Source: Elaboration based on EAAT results

As can be seen in Figure 4, this module first asks the user to specify the size of their industry. When one of the options (small, medium or large) has been selected, the range in tonnes of the respective size is displayed. Once this has been specified, the user is guided through the six steps described below:

Step 1. Selection of current agricultural machinery: In this step the user must select the type of equipment, technique or technology currently used in each stage of production. For example, in the case of fertilization, if it is done by equipment and what type of equipment or if it is done manually. When the step is activated the first selection to be made is whether the user knows the amount of equipment or not, while a scheme of the stages of the agricultural phase (I) is displayed, as can be seen in Figure 5. If 'yes' is selected, the cells in the column 'production units' (II) are activated for entry. If 'no' is selected, the cells are deactivated and the tool autocalculates the amount of equipment with the information supplied by the user.

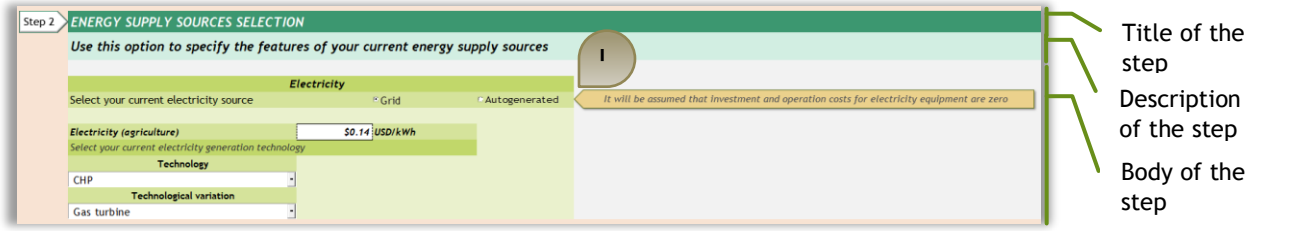
Figure 5. Step 1 of the agriculture module



Source: Elaboration based on EAAT results

Step 2. Selection of energy supply sources: In this step the user must specify whether the electricity used is self-generated or supplied by the central grid (I) as shown in Figure 6. if the first option is selected, assuming that the investment and operating costs are zero and the electricity generation technology option is selected. If the second option is selected the user must enter the cost in US dollars per kWh consumed and also select the electricity generation technology.

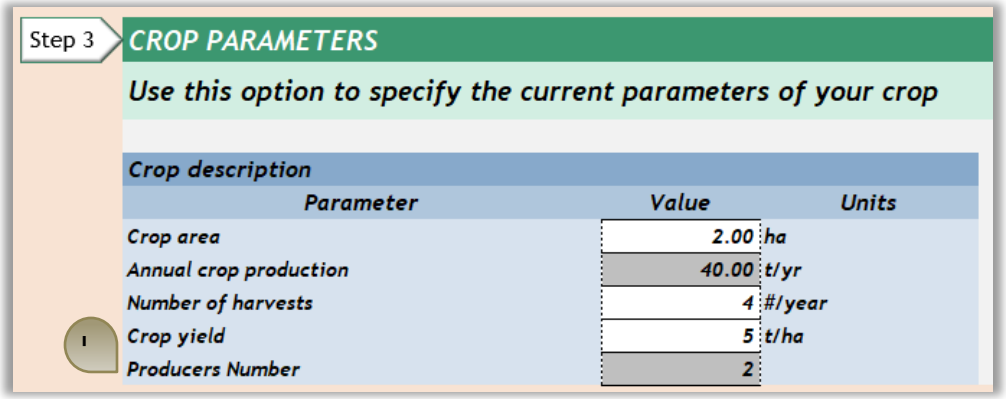
Figure 6. Step 2 of the agriculture module



Source: Elaboration based on EAAT results

Step 3. Crop characteristics: In this step the user must enter minimal information about their crop such as the crop area, number of harvests per year and crop yield per harvest (tonnes of product per hectare). If the production entered here is not consistent with the industry size selected at the beginning of the module, the tool will calculate the number of producers needed to reach the production entered (I) as shown in Figure 7.

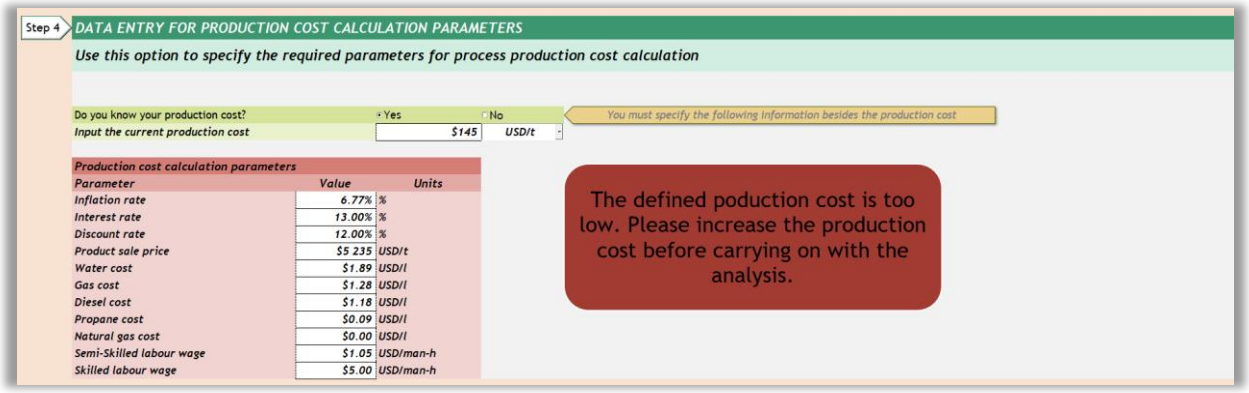
Figure 7. Step 3 of the agriculture module.



Source: Elaboration based on EAAT results

Step 4. Definition of parameters to calculate production costs: This step is of particular importance because, depending on the selections made here, the information that the user must enter is significantly reduced and the following steps are activated or deactivated. The first question in this step is whether the production costs of the process are known. If 'yes' is selected, the production cost in US dollars per year must be entered, together with parameters for the calculation of financial ratios shown in Figure 8. If 'no' is selected, a table is activated that asks for more parameters for the calculation of the cost of production These parameters are shown in Table 3.

Figure 8. Step 4 of the agriculture module.

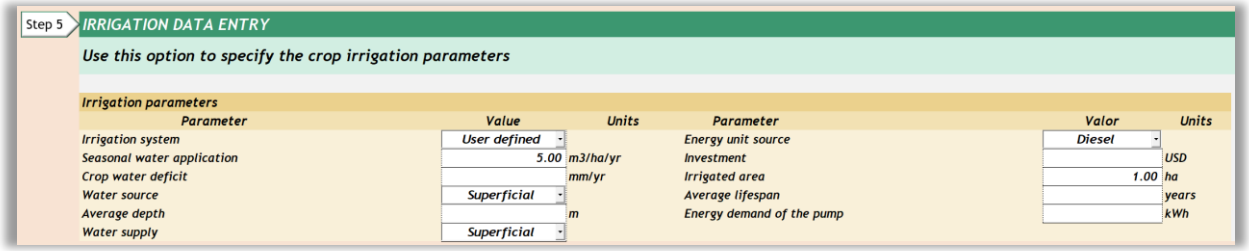


Source: Elaboration based on EAAT results

Steps 5 and 6 are activated only when the production costs that are not known have been selected in Step 4.

Step 5. Irrigation data entry: This step is found only in the agricultural module and in agro-chains that require a crop for production. In this step the user can choose between several irrigation systems and specify indispensable information such as the irrigated area, investments, the water source, or otherwise specify that there is no irrigation system, as shown Figure 9.

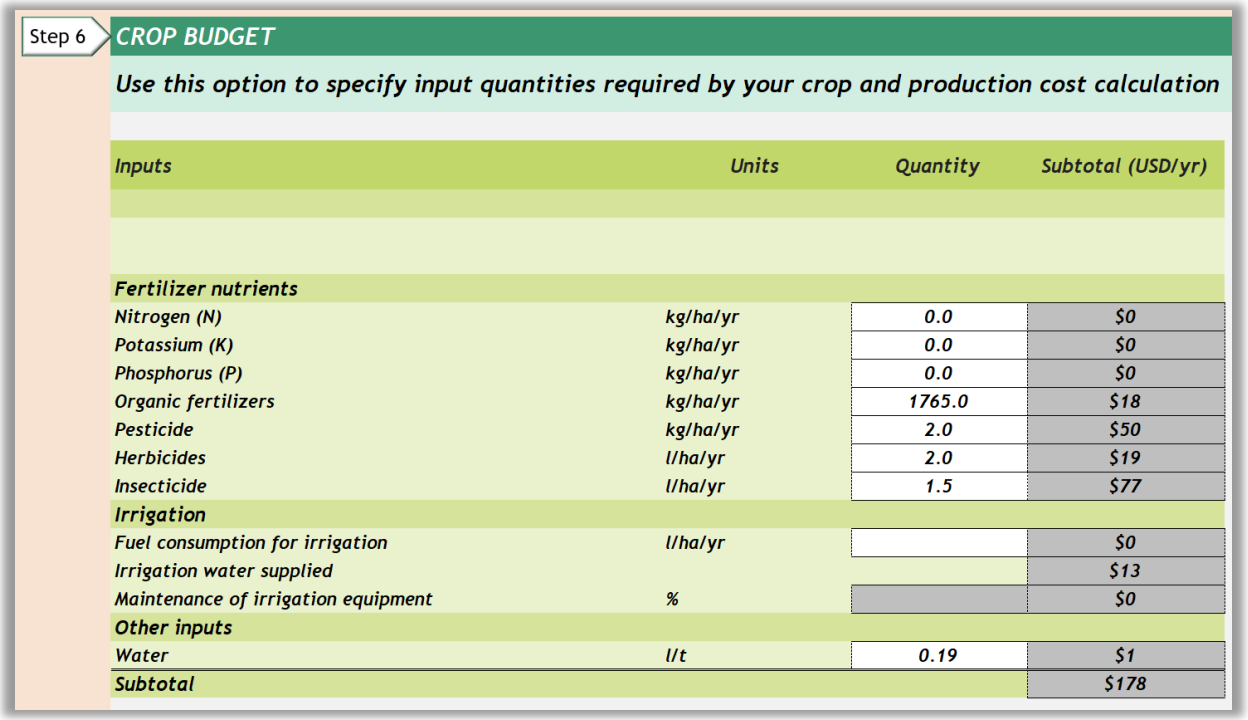
Figure 9. Step 5 of the agriculture module of the coffee chain.



Source: Elaboration based on EAAT results

Step 6. Crop budget: In this step the user must define the quantities of inputs required for the crop, as well as the percentage of other costs such as: (i) maintenance of total production costs; (ii) contingencies of total labour and maintenance; (iii) miscellaneous of total labour cost; and (iv) general and administrative costs of the total sum of the costs of inputs, services, payroll maintenance and contingencies. Given the length of Step 6, only part of it is shown in Figure 10.

Figure 10. Step 6 of the agriculture module of the coffee chain.



Step 6 **CROP BUDGET**

Use this option to specify input quantities required by your crop and production cost calculation

Inputs	Units	Quantity	Subtotal (USD/yr)
Fertilizer nutrients			
Nitrogen (N)	kg/ha/yr	0.0	$0
Potassium (K)	kg/ha/yr	0.0	$0
Phosphorus (P)	kg/ha/yr	0.0	$0
Organic fertilizers	kg/ha/yr	1765.0	$18
Pesticide	kg/ha/yr	2.0	$50
Herbicides	l/ha/yr	2.0	$19
Insecticide	l/ha/yr	1.5	$77
Irrigation			
Fuel consumption for irrigation	l/ha/yr		$0
Irrigation water supplied			$13
Maintenance of irrigation equipment	%		$0
Other inputs			
Water	l/t	0.19	$1
Subtotal			$178

Source: Elaboration based on EAAT results

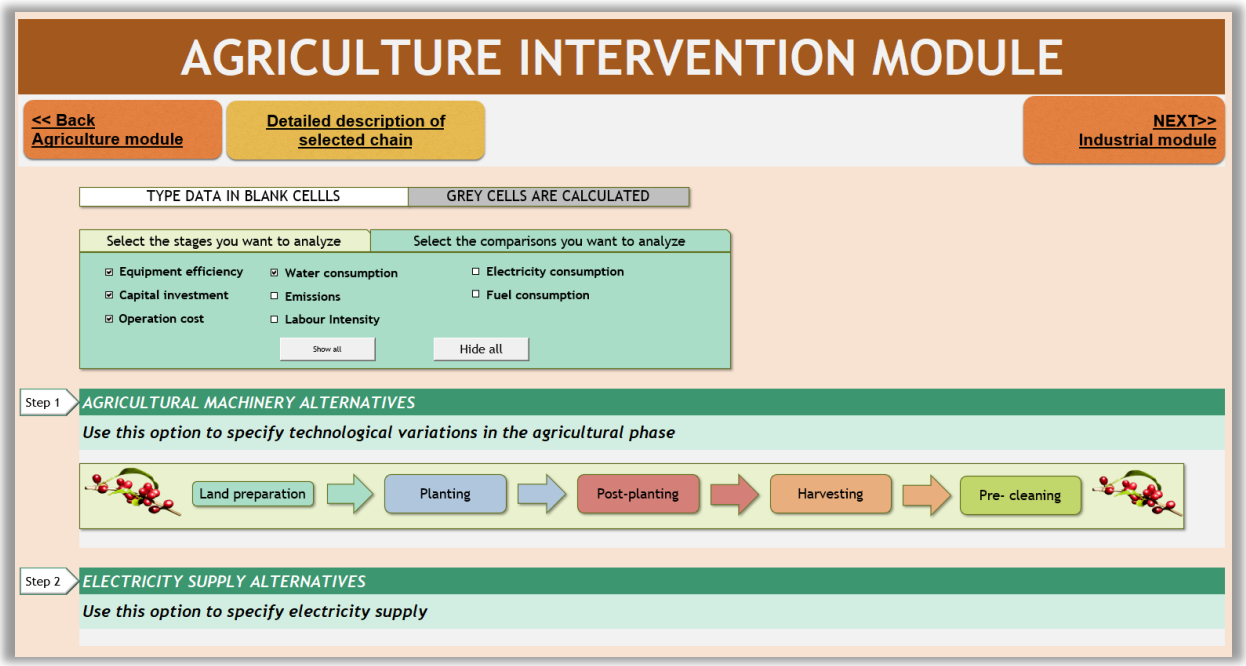
Agricultural Intervention module

This module is intended to show the user what the impact would be on key decision parameters such as: (i) efficiency, emissions, or operating costs of performing each stage with a different technology; or (ii) of using a self-generated or different source of energy supply from the current one. The impact of evaluating these changes is shown in two ways in the tool: one in this module by making immediate graphical comparisons between one piece of equipment (or technique) or the other, and the second in the summary of results. It should be noted that the numerical value of the variables in both scenarios are also shown in this module.

When entering the intervention module and before starting to make comparisons between the current scenario and other options, a menu is displayed where the user can choose which stages to intervene, as well as which variable to compare (see Figure 11). In addition to reducing the visual load, this allows the user to eliminate information that is of no interest to them, and thus display only the information relevant to their evaluation.

After selecting the variables and stages of interest, the user should proceed to Steps 1 and 2, as explained below.

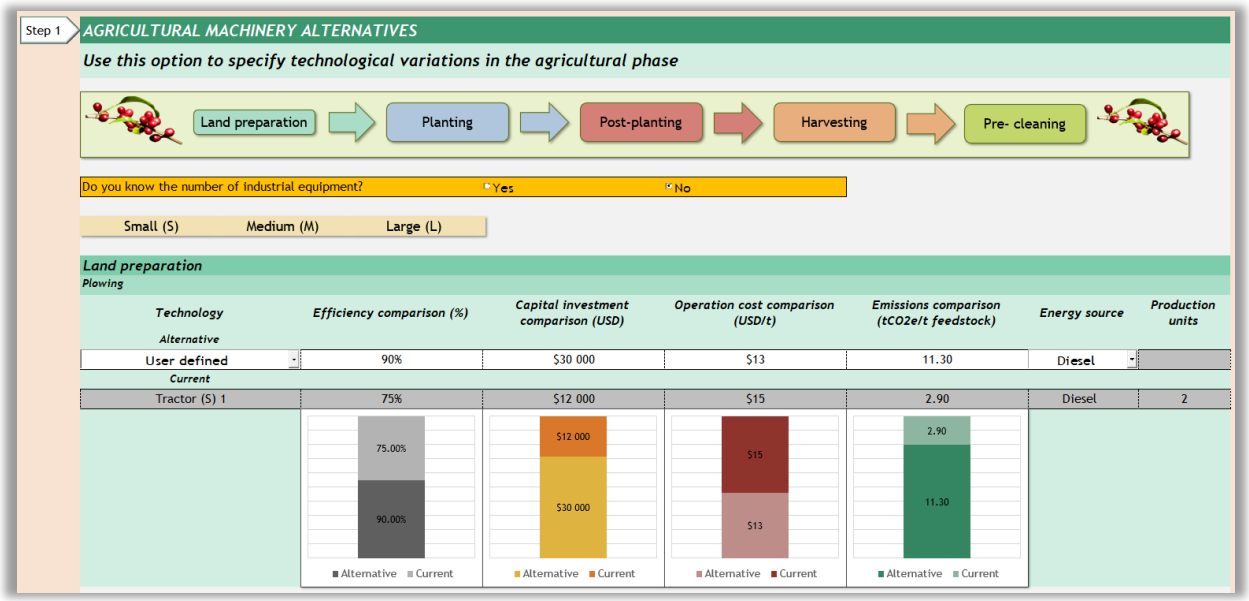
Figure 11. Agricultural intervention module



Source: Elaboration based on EAAT results

Step 1. Agricultural machinery alternatives: In this step, as in the agricultural module, the user is asked whether or not they know the amount of equipment they require with both options in the intervened scenario. After this, a drop-down menu is displayed where the user can choose between the different technologies available, and the equipment selected in the current scenario and its characteristics are simultaneously displayed. The comparison between the decision parameters (e.g., emissions or operating costs) of one equipment or the technology or other, is shown by means of coloured bars (see Figure 12). These bars do not display a normalised value but rather the actual value in their respective units (USD, kg, ha), whereby one can be significantly larger than the other and reach values greater than one hundred.

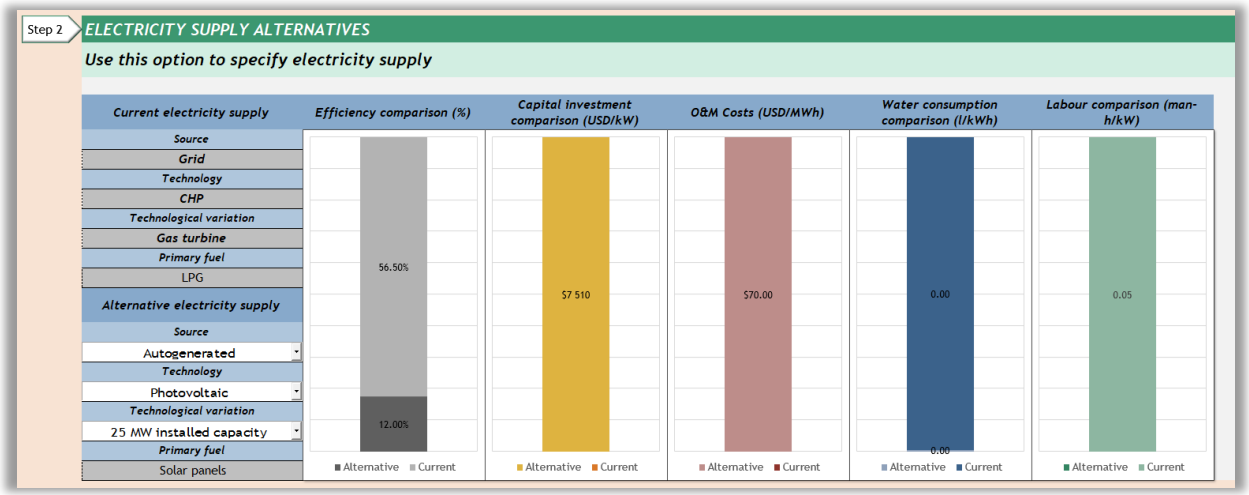
Figure 12. Step 1 of the agricultural intervention module.



Source: Elaboration based on EAAT results

Step 2. Electricity supply alternatives: This step shows the current electricity source with its respective decision parameters represented graphically, and the available alternatives for electricity supply. Similarly, an immediate graphical comparison of the technologies in both scenarios is shown (see Figure 13). In addition, as can be observed in the comparison of investments and operating costs, when the electricity source is 'central grid' the costs have a value of zero, since the user does not have to buy the equipment or operate it, but only receives the service.

Figure 13.Step 2 of the agricultural intervention module.

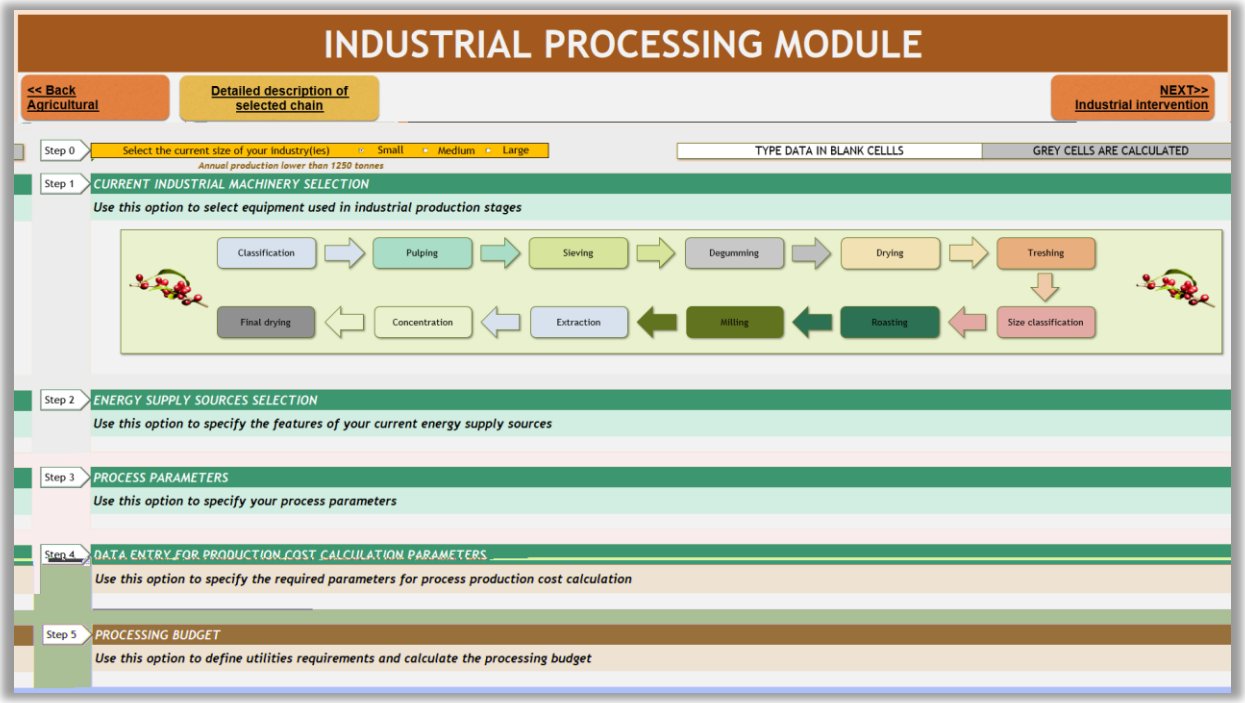


Source: Elaboration based on EAAT results

Industrial module

This module has a scheme of steps very similar to the agricultural module (see Figure 14). The only differences are that the budget is not in Step 6 but in Step 5, in the case of agro-chains with crops such as coffee, furthermore, there is no mention of agricultural but only industrial machinery, in addition to the names of some parameters. Another important difference is that in this phase there are two more forms of energy, heating, and cooling. For this reason, Step 2 not only asks to specify the characteristics of the sources of electrical energy supply, but also of heating and cooling.

Figure 14. Industrial processing module



Source: Elaboration based on EAAT results

Step 1. Selection of current industrial machinery: This step has the same analysis scheme as Step 1 of the agricultural module. The only difference is that it has two more parameters: energy for heating and energy for cooling. To learn more about this step go to Step 1 of the agriculture module.

Step 2: Selection of energy supply sources: This step has the same analysis scheme as Step 2 of the agricultural module. The only difference is that it has two more parameters: energy for heating and energy for cooling. To learn more about this step go to Step 2 of the agriculture module.

Step 3. Process characteristics: In this step, important process parameters such as throughput, hours of operation per year and annual production should be defined. If the production entered here is not consistent with the industry size selected at the beginning of

the module, the tool will calculate the number of producers needed to reach the production entered.

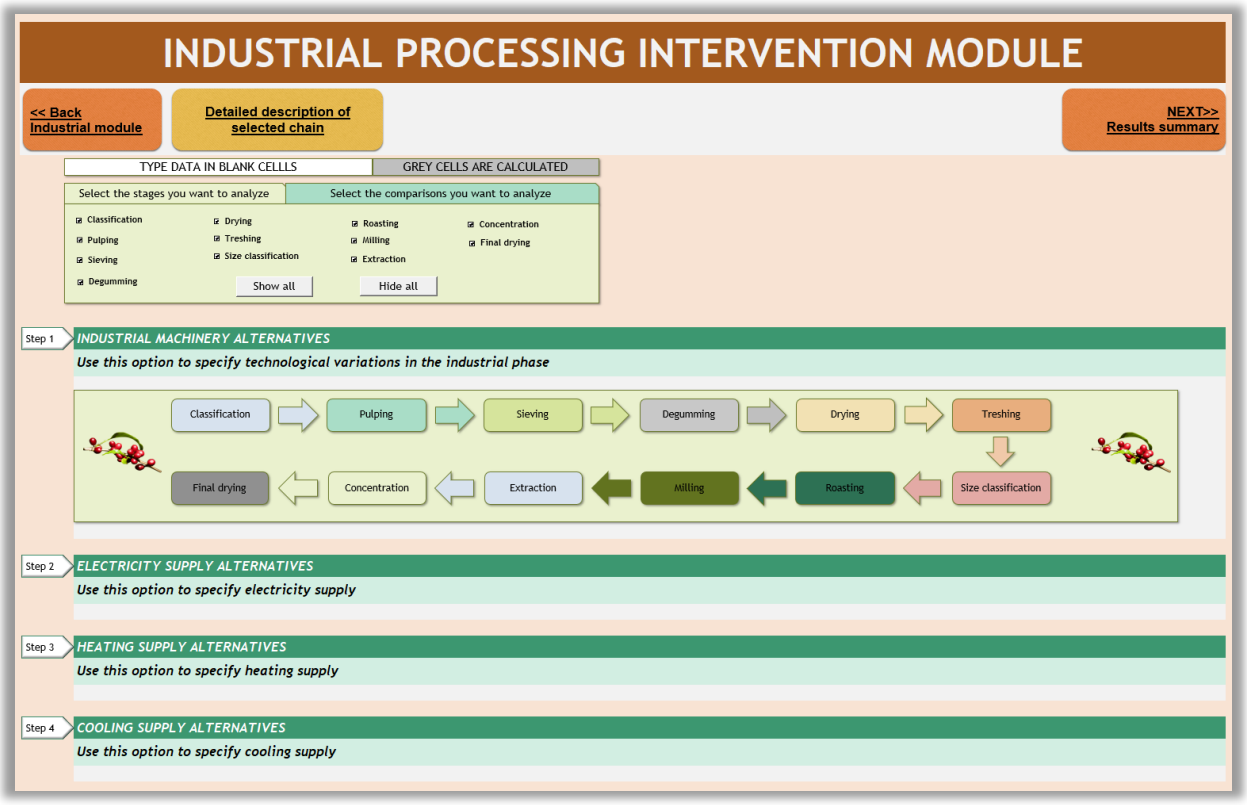
Step 4. Definition of parameters for the calculation of production costs: This step has the same analysis scheme as Step 4 of the agricultural module. The only difference is that in the case of selecting that the production costs are not know, the raw material cost is requested and can be entered by the user (market price) or can be calculated by the tool with the production cost of the agriculture module.

Step 5. Processing budget: This step has the same analysis scheme as Step 6 of the agricultural module (Step 6 for agro-chains with crops such as coffee, Step 5 for chains with livestock). To learn more, see Step 6 of the agriculture module.

Industrial intervention module

This module has a scheme of steps similar to the agricultural intervention module (see Figure 15). The difference lies in the two additional steps related to the provision of heating and cooling. To learn more about the operation and navigation of this module and its steps, please go to the agricultural intervention module.

Figure 15. Industrial intervention module.

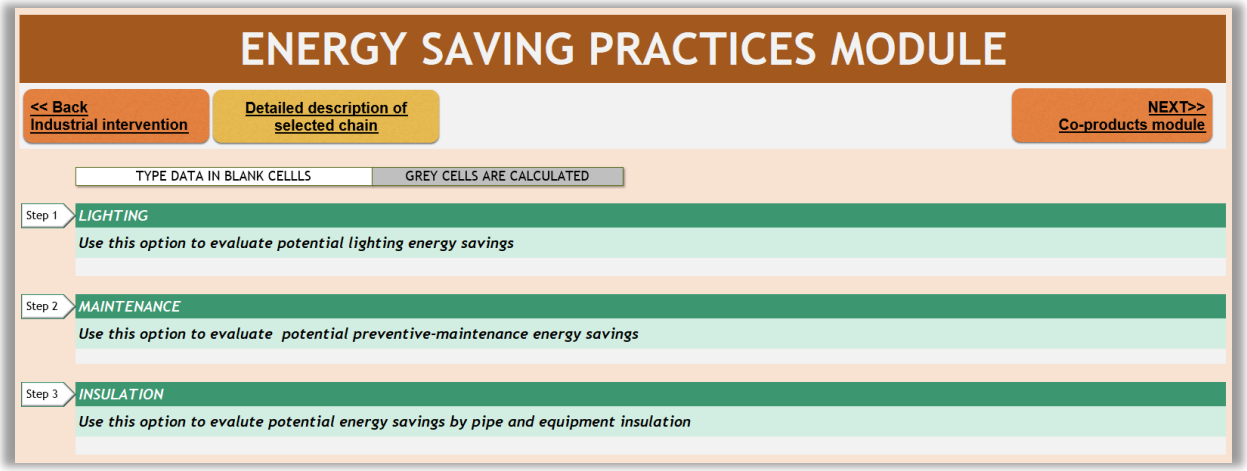


Source: Elaboration based on EAAT results

Energy saving practices module

This module was created to cover the energy consumption that is not generated due to the process directly (machinery) but to factors inherent to the process, but that represent an important amount of the total energy and economic consumption. The factors considered are divided in to 3 steps: lighting, maintenance, and insulation (Figure 16).

Figure 16. Energy saving practices module

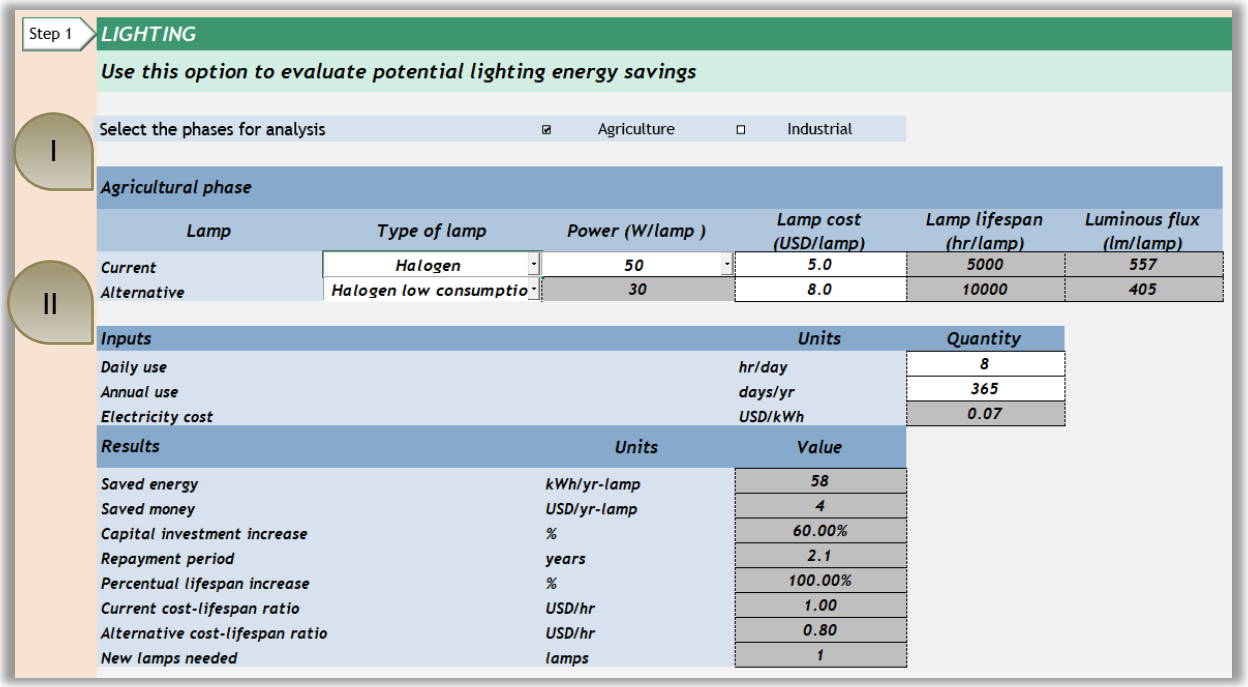


Source: Elaboration based on EAAT results.

Step 1: Lighting: This step evaluates the potential savings that the user has if he changes the type of lamps used in their plant. It is possible to choose between analysing only the agricultural or industrial phase, or evaluating both (I) (see

Figure 17). The current lamp type wattage and cost (II) must first be selected (II). Then, the alternative lamp type must be specified from those available in the selection menu and its cost (II). Additionally, the daily hours of use and the days per year that the lighting system is used must be entered (III). With this information the tool calculates and provides results about the energy saved annually per lamp in kWh, the amount of money saved in US dollars, the percentage increase in the investment, the number of new lamps needed to replace the old one, and other key decision parameters such as the cost-lifetime ratio. The lower it is, the lower the investment cost per hours of lamp life.

Figure 17. Step 1 of the energy saving practices module.



Step 1 **LIGHTING**

Use this option to evaluate potential lighting energy savings

I

Select the phases for analysis ☑ Agriculture ☐ Industrial

Agricultural phase

Lamp	Type of lamp	Power (W/lamp)	Lamp cost (USD/lamp)	Lamp lifespan (hr/lamp)	Luminous flux (lm/lamp)
Current	Halogen	50	5.0	5000	557
Alternative	Halogen low consumptio	30	8.0	10000	405

II

Inputs	Units	Quantity
Daily use	hr/day	8
Annual use	days/yr	365
Electricity cost	USD/kWh	0.07

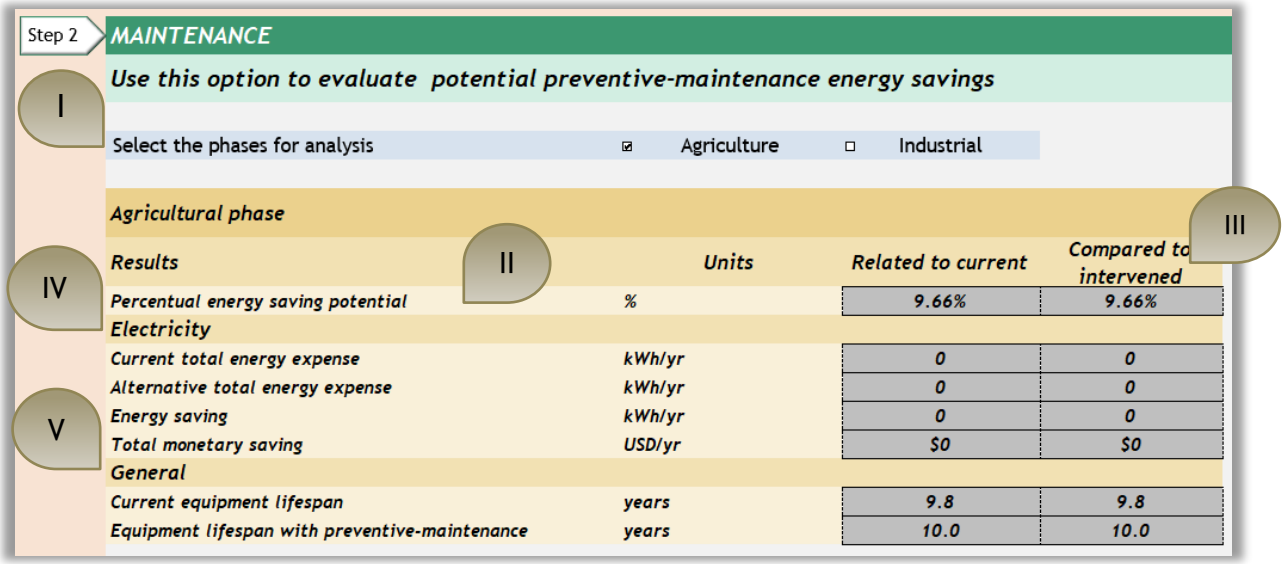
Results	Units	Value
Saved energy	kWh/yr-lamp	58
Saved money	USD/yr-lamp	4
Capital investment increase	%	60.00%
Repayment period	years	2.1
Percentual lifespan increase	%	100.00%
Current cost-lifespan ratio	USD/hr	1.00
Alternative cost-lifespan ratio	USD/hr	0.80
New lamps needed	lamps	1

Source: Elaboration based on EAAT results.

Step 2. Maintenance: The objective of this step is to allow the user to evaluate the potential energy savings and the effect on equipment lifetime that implementing a preventive maintenance (PM) plan can generate or improve, if already in place. For this step, it is also possible to choose between analysing the agricultural phase, the industrial phase or both (I).

Figure 18 shows the maintenance step for the agricultural phase. The first important factor is the potential percentage energy savings (II), which describes what percentage of the total energy consumed in each step can be saved by implementing a PM plan. If this percentage is equal to zero, it means that the user already has an optimal PM plan implemented in its process. This factor is calculated for both the current and intervened process (III). Subsequently, the possible savings for electricity (which is the only type of energy other than fuels taken into account in the agricultural phase) are shown. The current electricity energy expenditure and the potential expenditure, if the PM plan were to be implemented, are then shown. Also, the annual electricity savings that would be achieved and finally the monetary savings achieved are shown, taking into account the electricity price that was specified or calculated in the agricultural module. In addition, a section with general calculations (IV) is shown. There, the current useful life of equipment is defined (depending on the current investment in a PM plan), after which the useful life that would be obtained by setting the optimal investment for PM is shown.

Figure 18. Step 2 of energy saving practices in the agriculture phase



Source: Elaboration based on EAAT results

Figure 19**Error! Reference source not found.** shows the maintenance step for the industrial phase. The only difference with respect to the agricultural phase is that in this section the savings applied to heating and cooling are also analysed; furthermore, the total monetary savings as the sum of savings for electricity, heating and cooling are calculated. It should be noted that all of these savings are calculated using electricity, heating and cooling prices specified or calculated in the industrial module. Again, if the percentage specified in the potential percentage energy savings parameter equals zero, it is understood that the user already has an optimal PM plan.

Figure 19. Step 2 of energy saving practices module in the industrial phase.

Industrial phase			
Results	**Units**	**Related to current**	**Compared to intervened**
Percentual energy saving potential	%	14.98%	14.98%
Electricity			
Current total energy expense	kWh/yr	15 524 545	15 524 545
Alternative total energy expense	kWh/yr	13 199 632	13 199 632
Energy saving	kWh/yr	2 324 913	2 324 913
Monetary saving	USD/yr	$77 739	$77 739
Heating			
Current total energy expense	kWh/yr	0	0
Alternative total energy expense	kWh/yr	0	0
Energy saving	kWh/yr	0	0
Monetary saving	USD/yr	0	0
Cooling			
Current total energy expense	kWh/yr	0	0
Alternative total energy expense	kWh/yr	0	0
Energy saving	kWh/yr	0	0
Monetary saving	USD/yr	0	0
General			
Current equipment lifespan	years	8.0	8.0
Equipment lifespan with preventive-maintenance	years	10.0	10.0
Total monetary saving	USD/yr	$77 739	$77 739

I

II

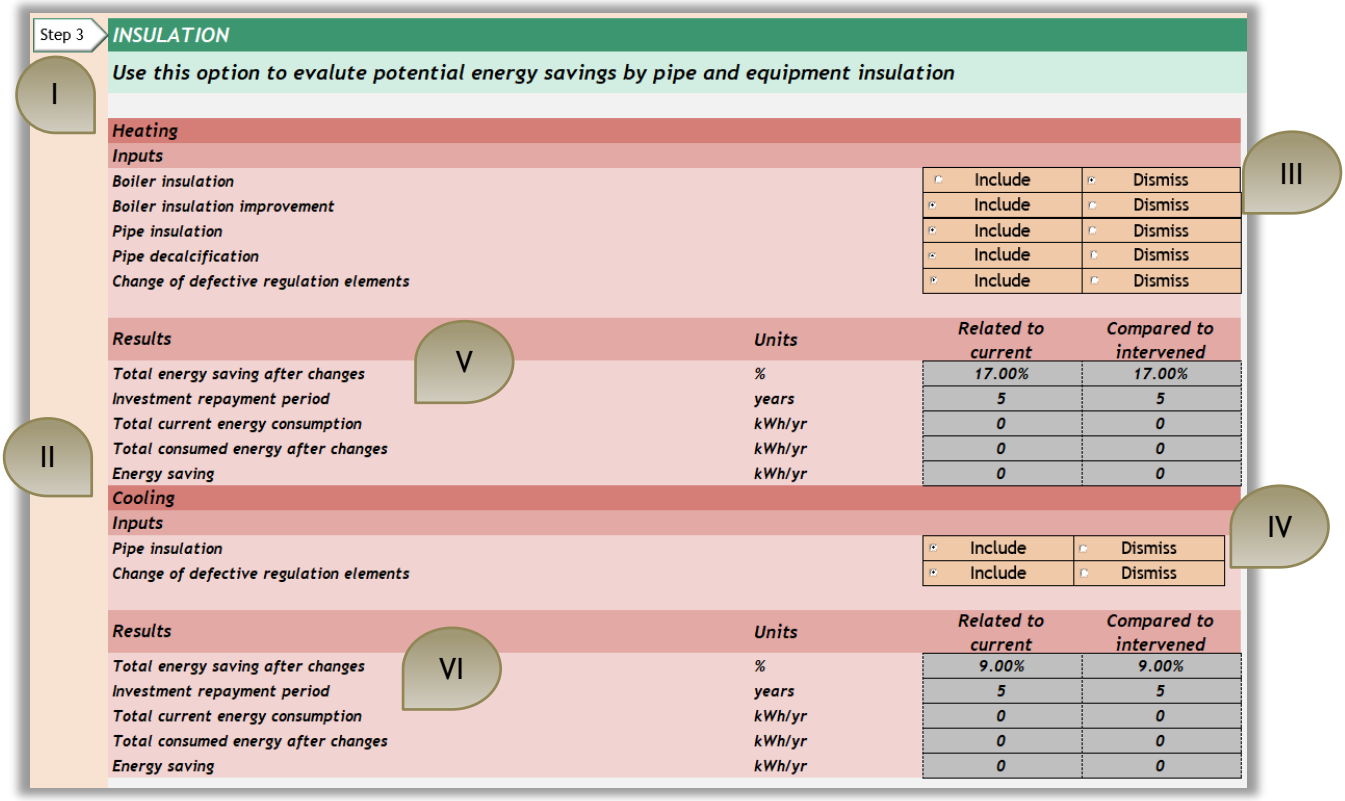
III

Source: Elaboration based on EAAT results

Step 3. Insulation: The isolation step is defined specifically for the industrial phase, since it only applies to processes with heating (I) cooling (II) and energy supply discarded for the agricultural phase.

In this section several improvements have been proposed that can be included in processes requiring heating (III) or cooling (IV). The user must choose which of these options to include in their analysis and evaluate the effect on each process – current and intervened. The results section (V and VI) of Figure 20 show the total energy savings with heating or cooling that can be obtained by applying changes. Subsequently, the amortization period corresponding to the changes made is displayed, in addition to the total energy currently consumed and after the changes. Finally, the total energy savings obtained for each heating and cooling is shown.

Figure 20. Step 3 of energy saving practices module.

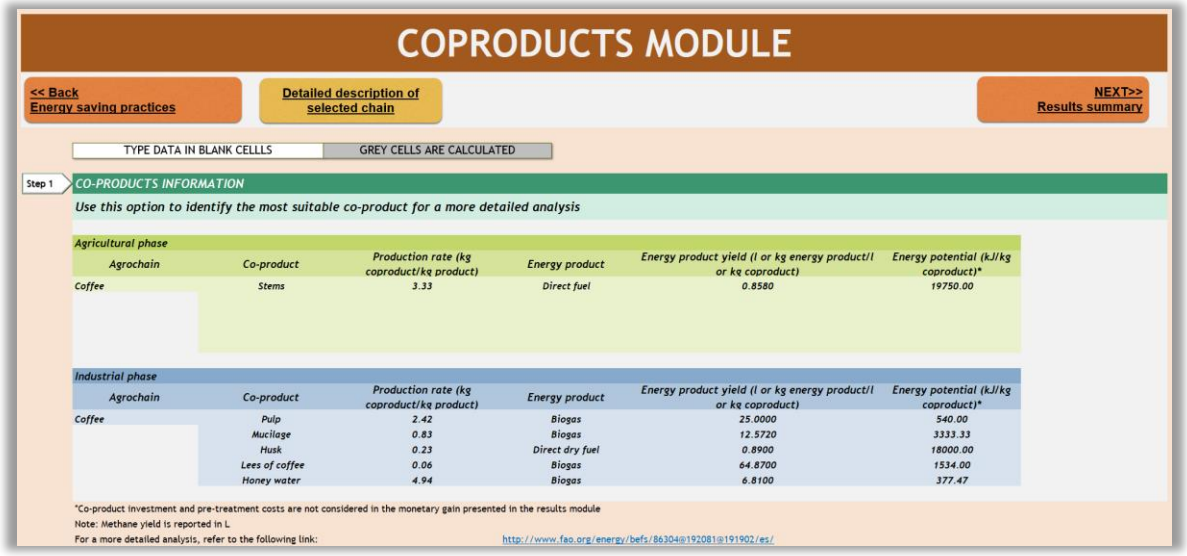


Source: Elaboration based on EAAT results

Co-products module

In this module the user does not have to enter any data, since the results are calculated with values entered in the previous modules. The module is divided into two sections: the agricultural phase and the industrial phase (see Figure 21). Both sections show the same variables: production rate, energy product, COD (if applicable), energy product yield and potential.

Figure 21. Co-products module.



COPRODUCTS MODULE

<< Back
Energy saving practices

Detailed description of selected chain

NEXT>>
Results summary

TYPE DATA IN BLANK CELLLS | GREY CELLS ARE CALCULATED

Step 1 CO-PRODUCTS INFORMATION

Use this option to identify the most suitable co-product for a more detailed analysis

Agricultural phase

Agrochain	Co-product	Production rate (kg coproduct/kg product)	Energy product	Energy product yield (l or kg energy product/l or kg coproduct)	Energy potential (kJ/kg coproduct)*
Coffee	Stems	3.33	Direct fuel	0.8580	19750.00

Industrial phase

Agrochain	Co-product	Production rate (kg coproduct/kg product)	Energy product	Energy product yield (l or kg energy product/l or kg coproduct)	Energy potential (kJ/kg coproduct)*
Coffee	Pulp	2.42	Biogas	25.0000	540.00
	Mucilage	0.83	Biogas	12.5720	3333.33
	Husk	0.23	Direct dry fuel	0.8900	18000.00
	Lees of coffee	0.06	Biogas	64.8700	1534.00
	Honey water	4.94	Biogas	6.8100	377.47

*Co-product investment and pre-treatment costs are not considered in the monetary gain presented in the results module
Note: Methane yield is reported in L
For a more detailed analysis, refer to the following link: http://www.fao.org/energy/befs/86304@192081@191902/es/

Source: Elaboration based on EAAT results

RESULTS GENERATED BY THE TOOL

The results section is one of the most important section on the tool. A summary of the results calculated with information entered by the user is provided. The results summary is divided into 4 types of results: energy, economic, socio-economic and environmental and the operation summary, as shown in Figure 22, where each section is expanded upon.

Figure 22. Outline of the tool's results sections.

Source: Elaborated by the authors.

Economic results

The economic results are divided into five more sections: (i) financial indicators; (ii) return on investment; (iii) capital investment; (iv) unit production costs and their distribution (see Figure 23).

The financial results show the NPV, IRR, profit margin and payback period for both phases (industrial and agricultural).

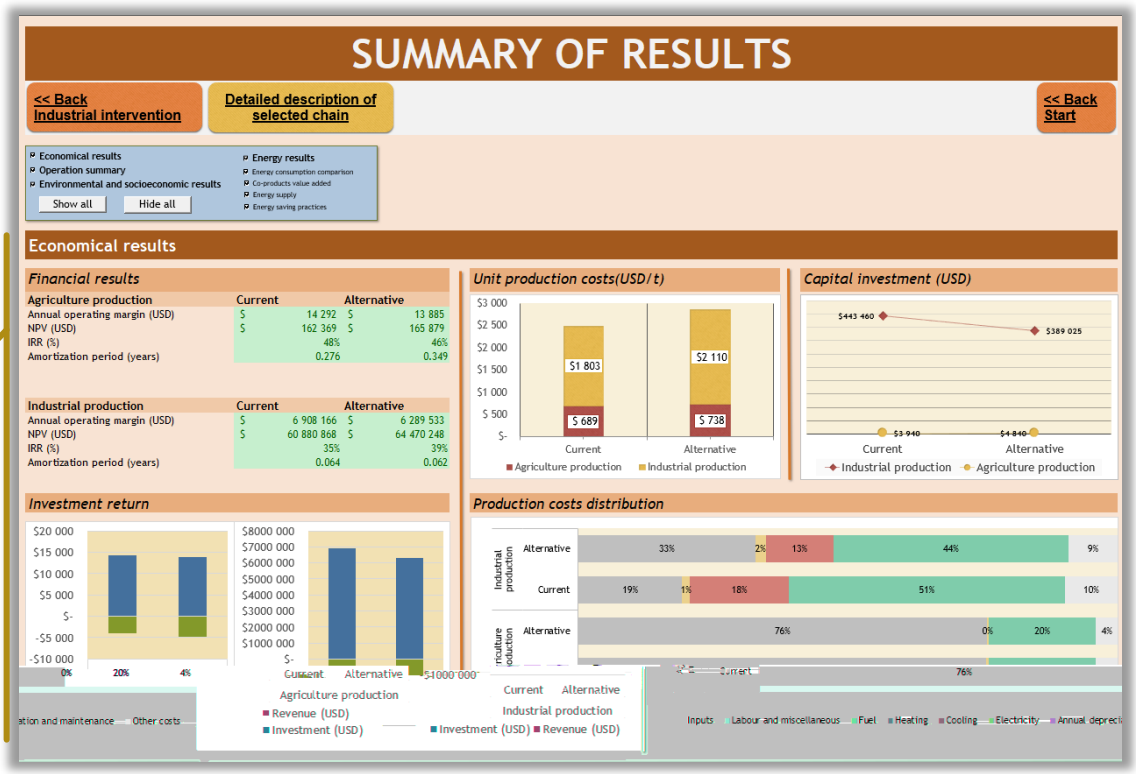
The NPV indicates that a project should be invested in when the value is positive, since it represents an improvement in the investor's cashflow, or availability of resources (Mondino and Pendas, 2007). It is important to note that when the NPV is equal to zero, the net initial investment and the minimum rate of return are recovered.

The IRR must be greater than the capital cost, that is, what it costs to finance the investment project (Morales Castro and Morales Castro, 2002). When the IRR is lower than the capital cost rate, the project is not viable.

The amortization period indicates the number of years it takes to pay off the debt or loan generated during the initial investment of the project, so that at the end of this period the value of the project is paid in full. If the value of this period is sizeable it will take a long time to pay off the debt, which is not a promising indication for the project.

In the 'Distribution of Production Costs' section of the economic results, it is possible to see from a graphical standpoint which variables most affect the cost, both in the current scenario and in the intervened scenario. In the 'Return on Investment' section, a graph is displayed with the comparison of the US dollars spent for investments and US dollars generated in profits. All economic results are shown for the industrial and agricultural phases separately.

Figure 23. Economic results.



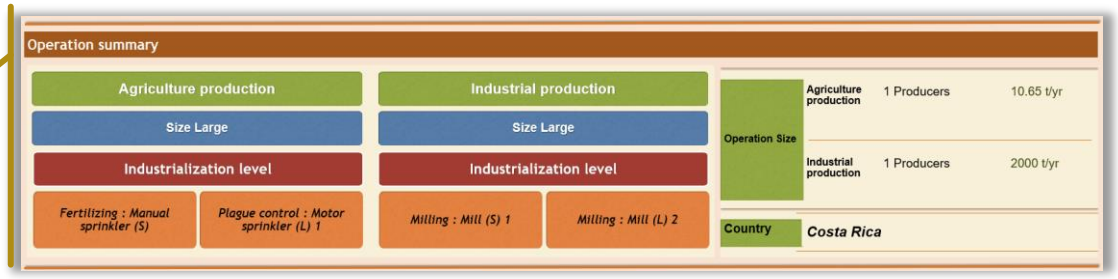
Economical results: Financial indicators (NPV, IRR, amortization period), production costs, capital investment, investment return.

Source: Elaboration based on EAAT results

Summary of operations

The section of the summary of results shows the main characteristics of the agricultural and industrial phases. It is important to show here the level of industrialization of each phase, the size of the operation and the country of analysis (see Figure 24).

Figure 24. Operation summary



Operation summary: Sizes of agriculture and industrial stages, country, industrialization level.

Source: Elaboration based on EAAT results

Energy results

This section is one of the most important sections of the tool, due to its energetic character and for this reason, it is one of the most extensive. It is divided into four subsections: (i) comparison of energy consumption; (ii) added value of co-products; (iii) energy supply; and liv) best energy practices, as explained in Figure 24.

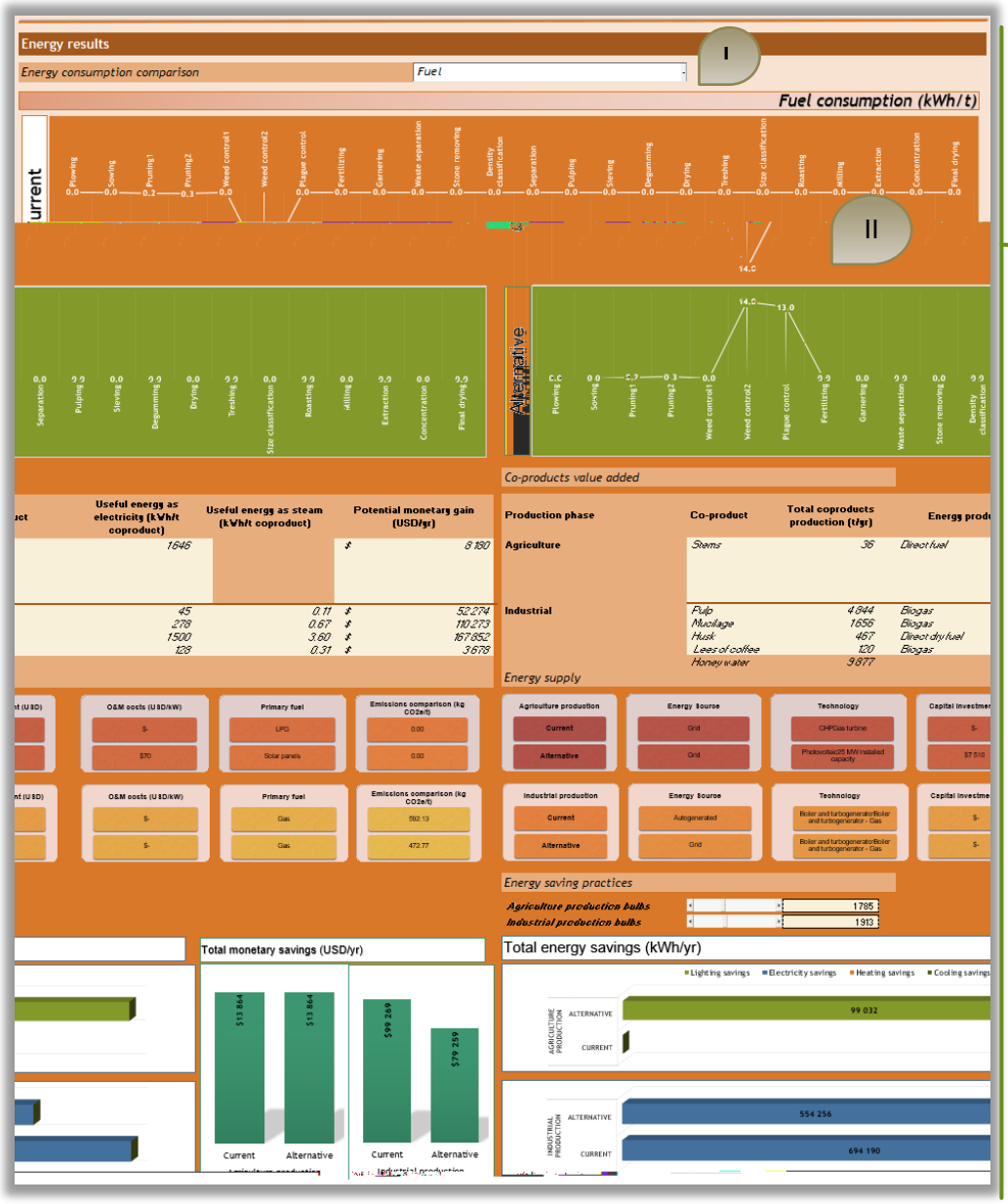
Comparison of energy consumption: This section displays four different forms of energy: (i) electricity; (ii) fuels; (iii) heating; and (iv) cooling (I). These results are a key factor for the user as it describes the stages representing the energy bottlenecks of production and processing of the product. As in the previous results, the values are displayed for both the current scenario and the evaluation or intervened scenario. In the current scenario, the energy consumption peaks are shown downwards, to facilitate a comparison with the intervened scenario (II).

Added value of co-products: In this section the user can see the energy potential that some co-products of the agro-chains have, both in the agricultural and industrial phase. The amount of co-product per year, the useful energy as steam and electricity and the potential profit are shown.

Energy supply: This section presents a summary of the energy supply for each phase in the current and intervention scenarios. It shows the energy source, technology, capital investment, operation and maintenance costs, and primary fuel and emissions for each phase and scenario.

Best energy practices: This section provides the most important results of energy saving practices. A dynamics bar has been designed for each phase that increases or decreases the number of light bulbs in the plant or farm. After this selection, two graphs are shown that represent annual savings in both energy and money by changing the light bulbs for the ones selected in the energy saving practices module.

Figure 24. Energy results.



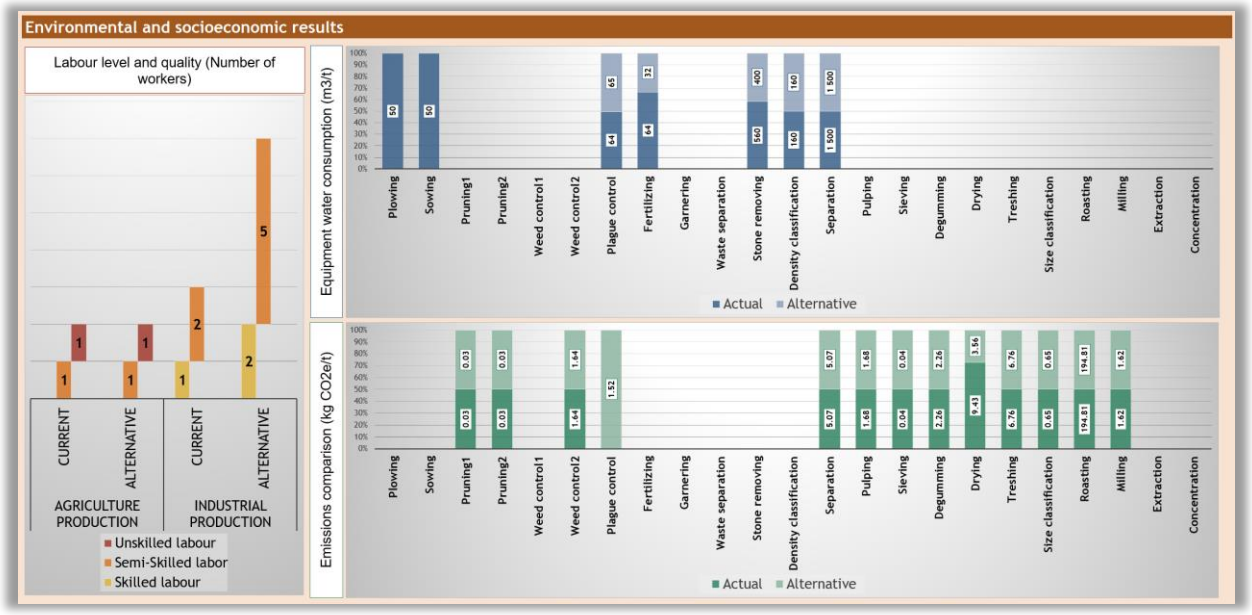
Energy results:
Selection of type of energy (fuel, electricity, heating, cooling), consumption per operation, added value of co-products, energy supply, energy saving practices by best energy practices (dynamic with number of bulbs selection bar).

Source: Elaboration based on EAAT results

Socio-economic and environmental results

This section of the results has three different subsections: (i) levels and quality of employment; (ii) water consumption by equipment; and (iii) emissions generated by stage (see Figure 25). The first section shows employment in the primary and industrial stages for unskilled, semi-skilled and skilled labour. The second and third sections show water consumption and emissions per stage for the current and intervention scenarios. If a bar does not appear in the stage, this means that there is no water consumption or emissions are not being generated during this stage.

Figure 25. Socio-economic and environmental results.



Source: Elaboration based on EAAT results

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