BIOENERGY AND FOOD SECURITY RAPID APPRAISAL (BEFS RA)

User Manual

PELLETS

BEFS Rapid Appraisal

Energy End Use Options Module

Intermediate or Final Products Sub-Module

Section 2: Pellets

User Manual

Acknowledgements

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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 Labour and Employment, Philippine Coconut Authority, Sugar Regulatory Administration.

BEFS RA User Manual Volumes

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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.

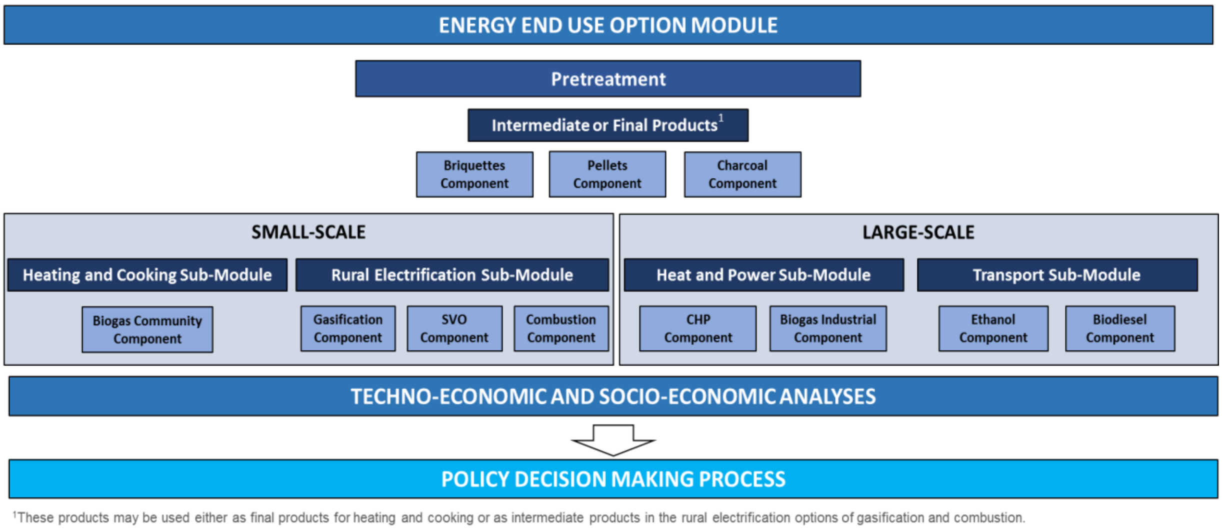


Figure 1: The Structure of the Energy End Use Option Module

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

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

feasibility and socio-economic parameters. In this component, the user has the 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 The *Pellets Component*

The *Pellets Component* is designed to assist the user in evaluating the potential to develop the production of biomass pellets to supply energy for heating and cooking in rural and urban households. The boundary of the pelleting tool analysis is shown in Figure 2.

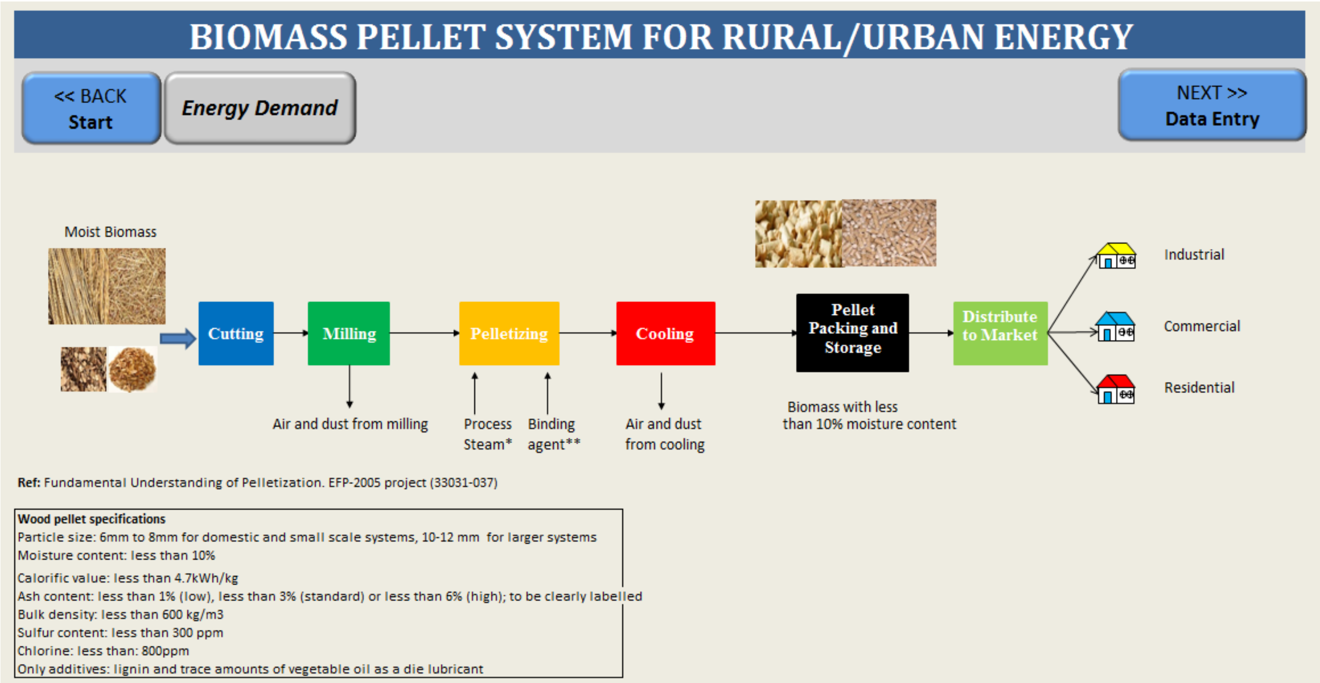


Figure 2: Biomass Pellets System for Rural and Urban Heating and Cooking

After completing the analysis, the user will be able to obtain information to better understand the most viable feedstock that can be used for pelletizing and the potential production scales that can be considered for pellet production in the country. More specifically, the results will provide an indication on: 1) the amount of biomass that is required to supply each of the pre-defined capacities; 2) the cost of production and the investment cost associated with each of the options for pellets production; 3) the number of households that can be supplied with pellets to meet their energy needs for heating and cooking; and 4) the quantity of jobs that can be created (Figure 3). Financial indicators on Net Present Value (NPV) and Internal Rate of Return (IRR) of pellet production are also generated to help the user assess the financial viability of the different production systems.

[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.

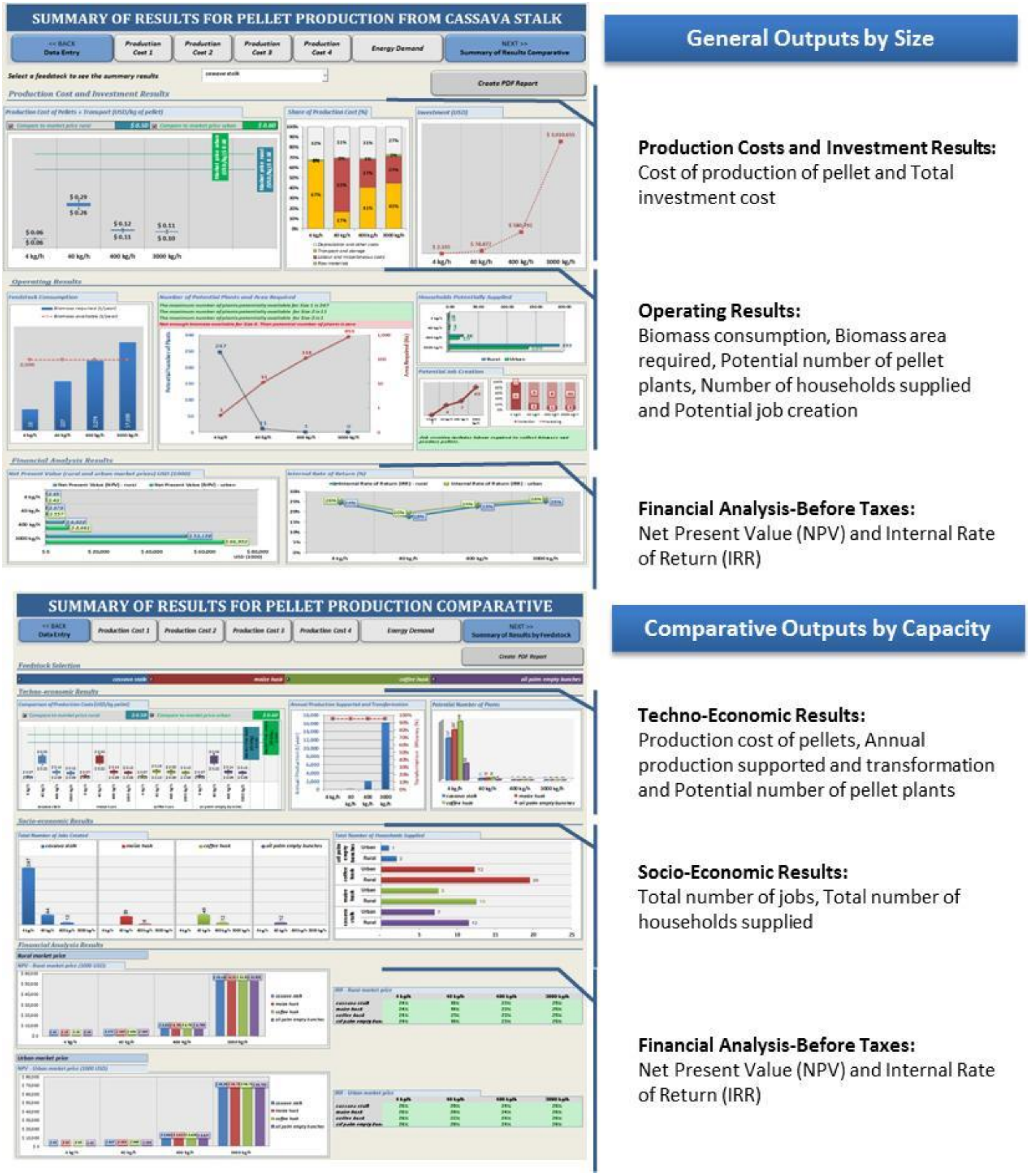


Figure 3: Layout of the Pellets Results Sheets

3 Terms and Definitions used in the *Pellets Component*

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

- **Pelletizing** is a compacting or densification process to increase the low bulk density of biomass to high density (from 150-200 kg/m^3 to 900 to 1300 kg/m^3).
- **Manual pellet technology** is suitable for small-scale production capacity. The technology consists of simple designs that are easy to construct, such as hand-powered screw extruder, lever arm pellet press, car jack pellet press, etc. (Dahlman & Forst, 2001; Hite & Smith, 2011a, 2011b, 2011c, 2012; Lockard, n.d.).
- **Screw press machine** is a processing technology whereby the biomass is extruded continuously by a screw through a taper die (S C Bhattacharya & Kumar, 2005; S.C. Bhattacharya, 2002; Grover & Mishra, 1996; Poudel, Shrestha, & Singh, 2012; SNNPRs Investment Expansion Process, 2012; Tumuluru, Wright, Kenney, & Hess, 2010; Tumuluru, Wright, Kenny, & Hess, 2010).
- **Pre-treatment of biomass:** It is generally agreed that the size of biomass materials should be between 6-8 mm size with 10-20% powdery component (< 4 mesh) and the moisture content should not exceed 10% (Grover & Mishra, 1996). However, due to the diverse range of biomass that can be used for pelletizing and the particular properties associated with each type (e.g. heating value, size, moisture content, and chemical composition), pre-treatment is typically required to ensure that the biomass conditions are suitable for pellet production. In this context, pre-treatment processes may involve drying to remove excess moisture, size reduction (cutting, grinding) and pre-heating biomass (not higher than 300°C) to help loosen fibres in the biomass and to soften its structure which reduces the wear of the screw press (Grover & Mishra, 1996). Pre-heating can also save up electrical energy required in pelletizing. For example, in rice husk at least 10% of energy is saved in conventional electric motor-driven pelletizing machines (S.C. Bhattacharya, 2002). Depending upon the type of biomass, three processes are generally required. These involve the following steps:
    - Sieving - Drying- Preheating - Densification - Cooling - Packing[6]
    - Sieving - Crushing - Preheating - Densification - Cooling - Packing
    - Drying - Crushing - Preheating – Densification - Cooling –Packing
- **Pellet cooling:** The surface temperatures from processing the pellets in the hot screw press can exceed 200°C. The pellet cooling takes place in the conveying belt which moves the pellets from production to storage. The cooling system is based on a perforated steel belt conveyor for which a suitable length is required. The width of this open belt conveyor should be at least 30% greater than the maximum length of the pellets. The conveyor length should be a minimum of 5 metres (Grover & Mishra, 1996). A hood is needed near the outlet of the machine and part of the cooling conveyor to vent toxic fumes and keep the area safe (Grover & Mishra, 1996).
- **Pellet storage and packing:** Pellets are stacked length-wise and protected from water, ideally in a shed (Grover & Mishra, 1996). Packing is required for pellet transportation and selling in the market.
- **The transformation efficiency of a pellet system** relates to the densification conversion process whereby biomass feedstock is converted from a low bulk density (80–100 kg/m^3) to a high bulk density (900 to 1300 kg/m^3) pellet. In general, it has been found that when the biomass feedstock moisture content is 8-10%,

[6] Note: Process A is used with sawdust. Process B is used with agro- and mill residues which are normally dry. These materials are coffee husk, rice husk, groundnut shells, etc. Process C is used for materials like bagasse, coir pith, mustard and other cereal stalks (Grover & Mishra, 1996).

the pellets will have 6-8% moisture (Grover & Mishra, 1996). Therefore, the mass does not change much compared to the volume.

- **Skilled worker** consists of personnel with particular skill or specialized experience, such as machinery operators, supervisors and technicians.
- **Unskilled worker** consists of personnel with no special skill who support operations. Such workers could be helpers or personnel carrying out tasks that can be learned easily, with a few days of training.

4 Scope and Objective of the *Pellets Component*

The aim of the *Pellets Component* is to assess the feasibility to develop biomass pellet production. It provides the user with the technical basis to perform an analysis for the production of pellets at different scales. The results of the analysis can be used to identify the viability of pellet production in terms of the most appropriate feedstock, the financial viability of the different production systems, the optimum production capacity and the socio and economic benefits that can be attained for each production system.

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

Figure 4: Rapid Appraisal Tool for Heating and Cooking - *Pellets Component*

5 Running the *Pellets Component*

The flow of analysis within the *Pellets Component* and the inter-linkages it has with other components is depicted in Figure 5. The user has the choice to select the components of analysis in a different order or even omit some components. It is, however, strongly recommended that the user follows the order and flow of analysis as described below, given that the *Pellets Component* relies on the information generated in the *Natural Resources* module and information can be cross-referenced with other modules to contextualize the results of the analysis. The results of this component are essential for the comprehensiveness of the analysis. When interpreting the results, the user should take into account all relevant factors, particularly aspects related to food security, agricultural trade and the sustainable use of natural resources.

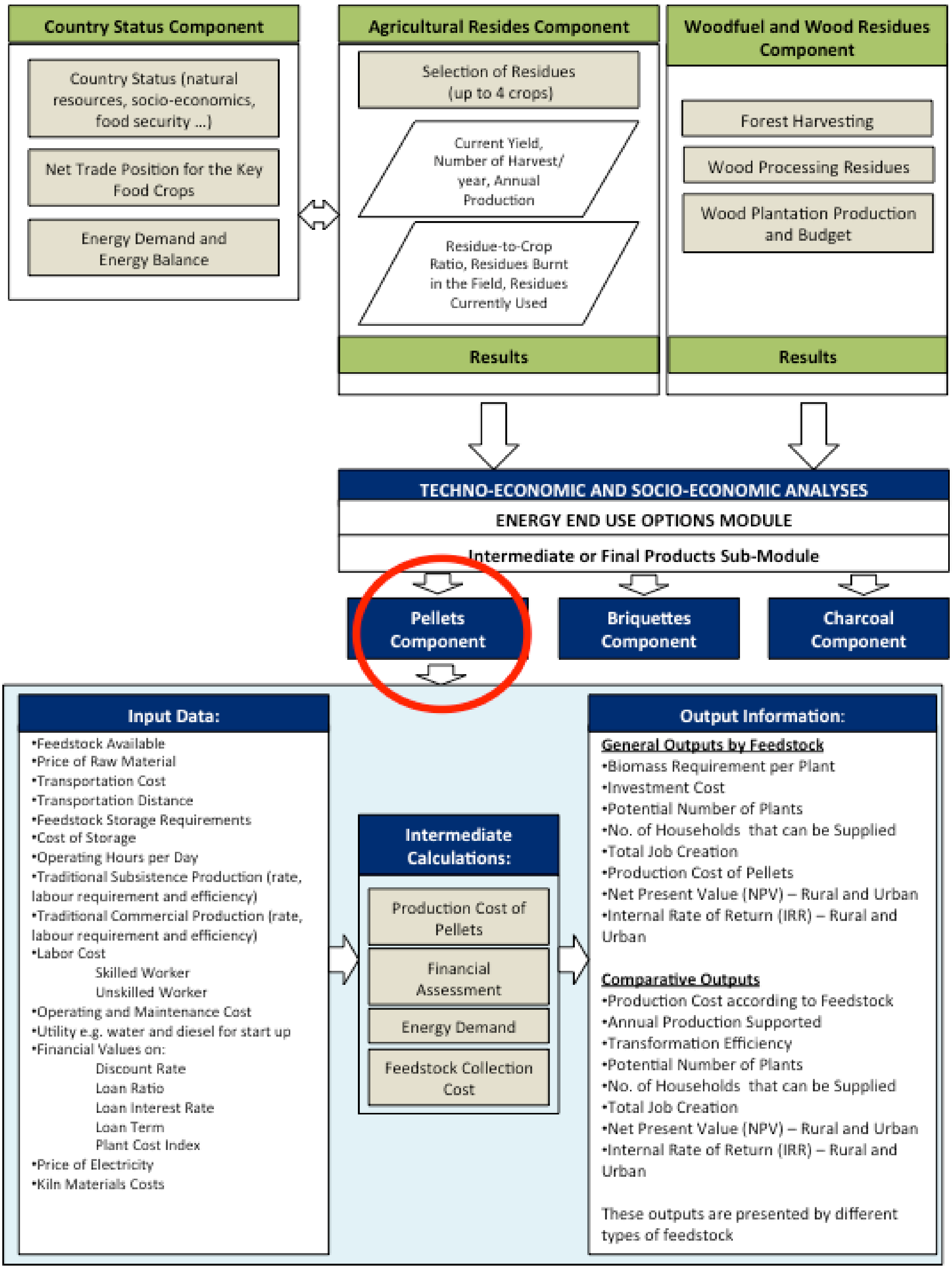


Figure 5: *Pellets Component*: Flow of Analysis and Inter-linkages with BEFS RA Modules and Components

The user navigates step by step through the options and is asked to input the necessary data to obtain final results. When the required data are limited or unavailable, then the default values provided by the tool can be utilised. The navigation buttons are placed on the top and bottom of each sheet, indicating the next step with the button "NEXT>>" and allowing the user to return to a previous section with the "<<BACK" button.

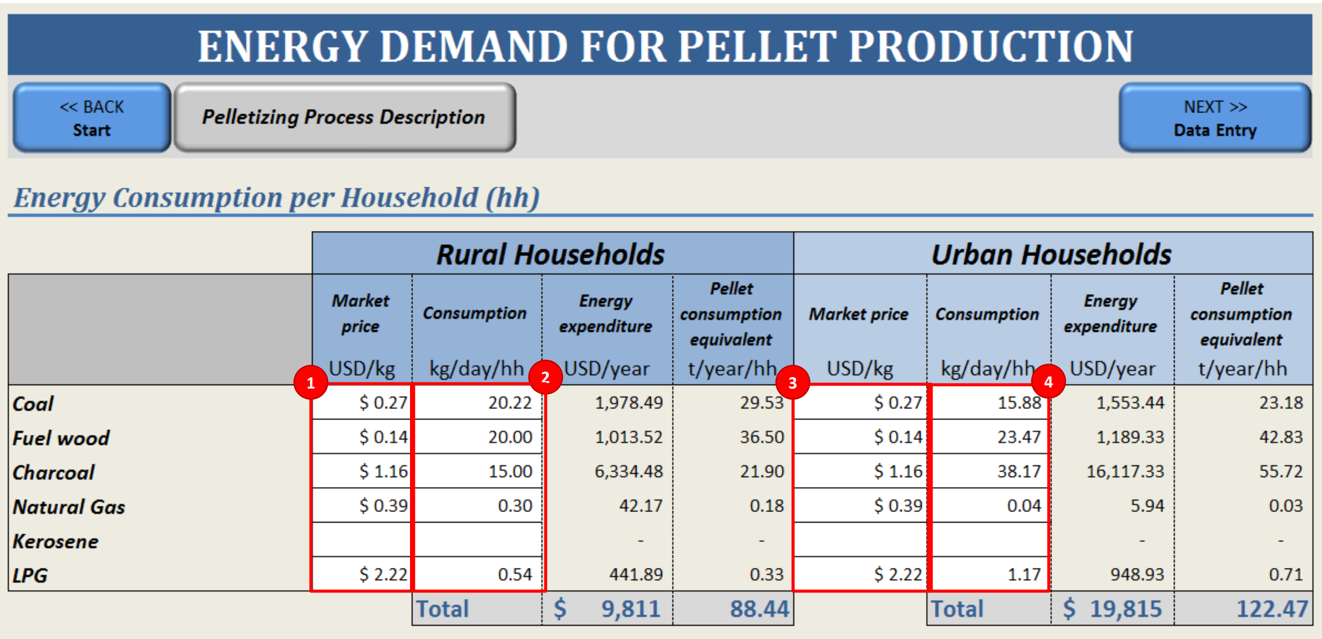
The following sub-chapters describe each step of the analysis, using an example from the ***Agriculture Residues Component*** to produce the pellets. All input parameters are based on a generic situation.

5.1 Step 1: Energy demand

The first step is to enter the market price as well as the current energy consumption of coal, fuel wood, charcoal, natural gas, kerosene, and LPG. This must be done for both rural and urban households. These values are used to estimate the energy expenditure and pellet consumption equivalent of consumers.

To run this analysis, the user has to enter data on:

- Market price of each energy type in rural households (Figure 6, label 1)
- Energy consumption of each energy type in rural households (Figure 6, label 2)
- Market price of each energy type in urban households (Figure 6, label 3)
- Energy consumption of each energy type in urban households (Figure 6, label 4)



	Rural Households				Urban Households			
	Market price USD/kg	Consumption kg/day/hh	Energy expenditure USD/year	Pellet consumption equivalent t/year/hh	Market price USD/kg	Consumption kg/day/hh	Energy expenditure USD/year	Pellet consumption equivalent t/year/hh
Coal	$ 0.27	20.22	1,978.49	29.53	$ 0.27	15.88	1,553.44	23.18
Fuel wood	$ 0.14	20.00	1,013.52	36.50	$ 0.14	23.47	1,189.33	42.83
Charcoal	$ 1.16	15.00	6,334.48	21.90	$ 1.16	38.17	16,117.33	55.72
Natural Gas	$ 0.39	0.30	42.17	0.18	$ 0.39	0.04	5.94	0.03
Kerosene			-	-			-	-
LPG	$ 2.22	0.54	441.89	0.33	$ 2.22	1.17	948.93	0.71
		Total	$ 9,811	88.44		Total	$ 19,815	122.47

Figure 6: Energy Demand in Rural and Urban Areas

For this example, the values shown in Figure 6 were used to carry out the analysis.

5.2 Step 2: Defining the feedstock

Step 2.A Selection of the feedstock

The user will:

1. Select the crop(s) and the residue associated with the crop from the dropdown menu. The list includes 15 key food/cash crops and two types of wood processing residues (Figure 6-Label 1). Up to four residues can be analysed at the same time (Figure 7, label 1).

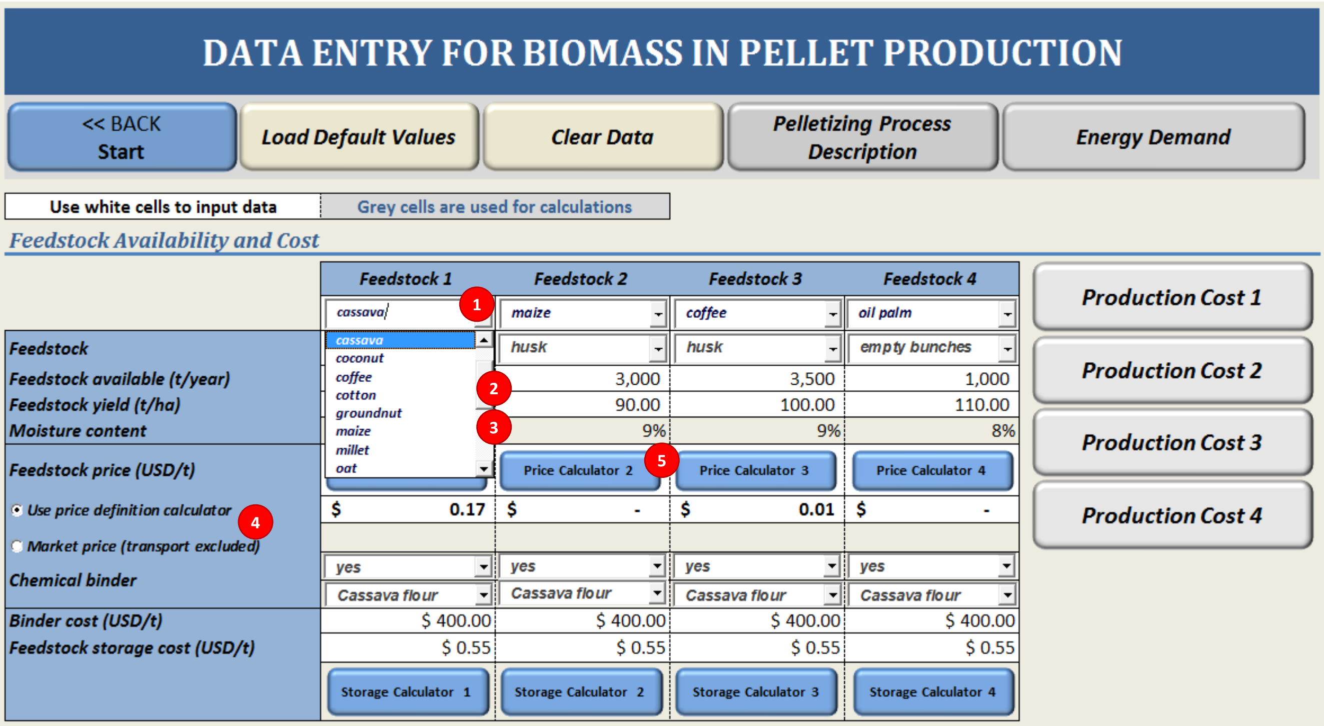


Figure 7: Feedstock Selection

2. Enter data on feedstock available (t/year) and yield (t/ha) of the selected crop residues (Figure 7, label 2). *This information is generated in the Natural Resources Module*.
3. The moisture content (%) or average percentage of moisture content of the selected crop residues is automatically generated from the technical database in the tool (Figure 7, label 3).

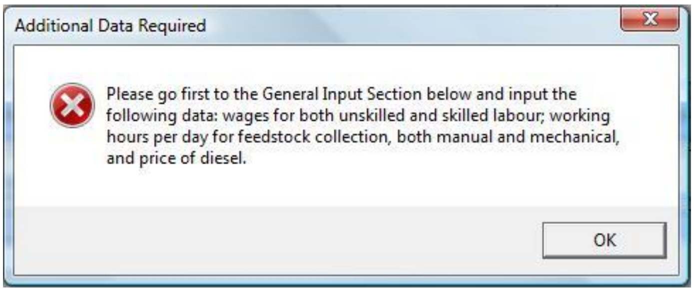
> **For this example, the following were selected: Feedstock 1 "Cassava stalk", Feedstock 2 "Maize husk", Feedstock 3 "Coffee husk" and Feedstock 4 "Oil palm empty bunches" (Figure 7).**

Step 2.B Feedstock price (USD/t)

The user has two options for determining the feedstock price:

A. If there is a current price in the country for this feedstock, the user clicks on the "Market Price (transport excluded)" (Figure 7, label 4) and directly inputs the price of the selected feedstock (USD/t) in the corresponding cell.

B. If there is *no* current price for this feedstock, the user can estimate the feedstock price by clicking on the "Use Price Definition Calculator" and selecting the "Price Calculator" (Figure 7, label 5).



The user will get a "warning" before continuing with the use of the calculator, and the user will need to enter:

1. The wage for both unskilled and skilled labour in "Labour" section in unit of USD per person-hour.
2. The working hours and price of diesel in the corresponding lines under "Feedstock collection".

The "Price Calculator" (Figure 8) assists the user in estimating the potential feedstock price based on the source and collection method of the feedstock.

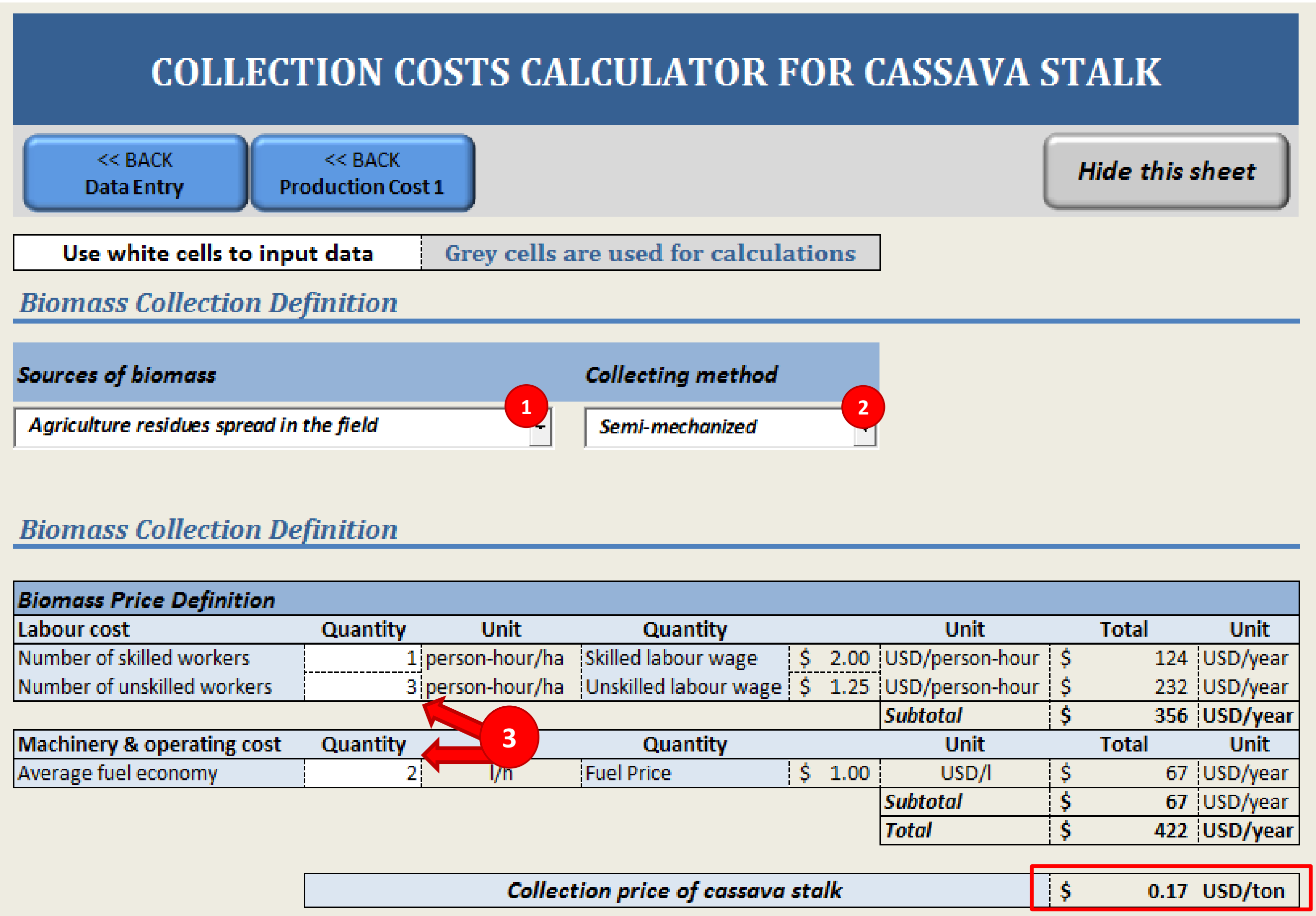


Figure 8: Feedstock price calculation based on the collection method and its source

To run the price calculator, the user will need to:

1. Identify the *biomass source* from one of the following options (Figure 8, label 1):
   - Agriculture residues spread in the field
   - Agriculture residues collected from the field
   - Agriculture residues from food processing plant
   - Forestry

- Forestry and plantation residues
- Residues from wood industry
- Dedicated wood energy plantation

As a reference, Table 1 summarizes the biomass sources that can be used for the production of pellets.

2. Select the *biomass collection method* from the following options (Figure 8, label 2):
   - manual
   - semi-mechanized
   - mechanized

Guidance: The collection method can be identified based on similar practices currently applied in the country.

3. Enter the labour requirements (person-hour per hectare) and the fuel needs (litres per hour) associated with the selected biomass collection method (Figure 8, label 3). To return to the previous section, the user must click on the "<<BACK Data Entry" button.

Note: The type of labour and diesel requirements will depend on the collection method: manual, semi-mechanized and mechanized.

The calculator will automatically generate a feedstock price (Figure 8, red box), and this value is transferred to the "Data Entry Needs" worksheet for further calculation.

4. The user will need to carry out similar steps for each feedstock chosen.

Table 1: Specific Feedstock that can be used in Pellet System

Source	Specific feedstock that can be used
Agricultural field residues	cassava stalk, coconut frond, cotton stalk , *maize stover*, millet straw, *oat* straw, *oil palm* frond, rice straw, rye straw, sorghum straw, soybean straw, sugar cane tops& leaves, wheat straw.
Agriculture residues from industrial processing	cacao pods, coconut husk &shell, coffee shell/husk, *cotton hulls*, groundnut husk, *maize cob & husk, oil palm* empty bunches, olive pruning/pressing residue, rice husk, sugar cane bagasse.
Forestry	leaves, limbs etc.
Forestry and plantation residues	leaves, limbs, stump, roots, etc…
Residues of wood industry	saw dust
Dedicated energy plantations	*Acacia spp., Cunninghamia lanceolata, Eucalyptus spp., Pinus spp., Populus spp.* (poplars) and *Salix spp.* (willows)

For this example, the selected Feedstock 1 "Cassava Stalk" is assumed to be sourced from "agricultural residues spread in the field" and the collection method is "semi-mechanized". The number of person-hours for skilled workers (machine operators) is 1 and for unskilled workers is 3, and the diesel consumption of the machine is 2 litres per hour. Using the information that manual labour works 8 hours per day and machinery works 16 hours with a diesel price of 1 USD per litre, a proxy price of the feedstock is calculated at 0.17 USD per/t (Figure 8).

Before proceeding with the analysis, the user can load the default values for running this part of the component by clicking on "Load Default Values" as shown in Figure 9, label A.

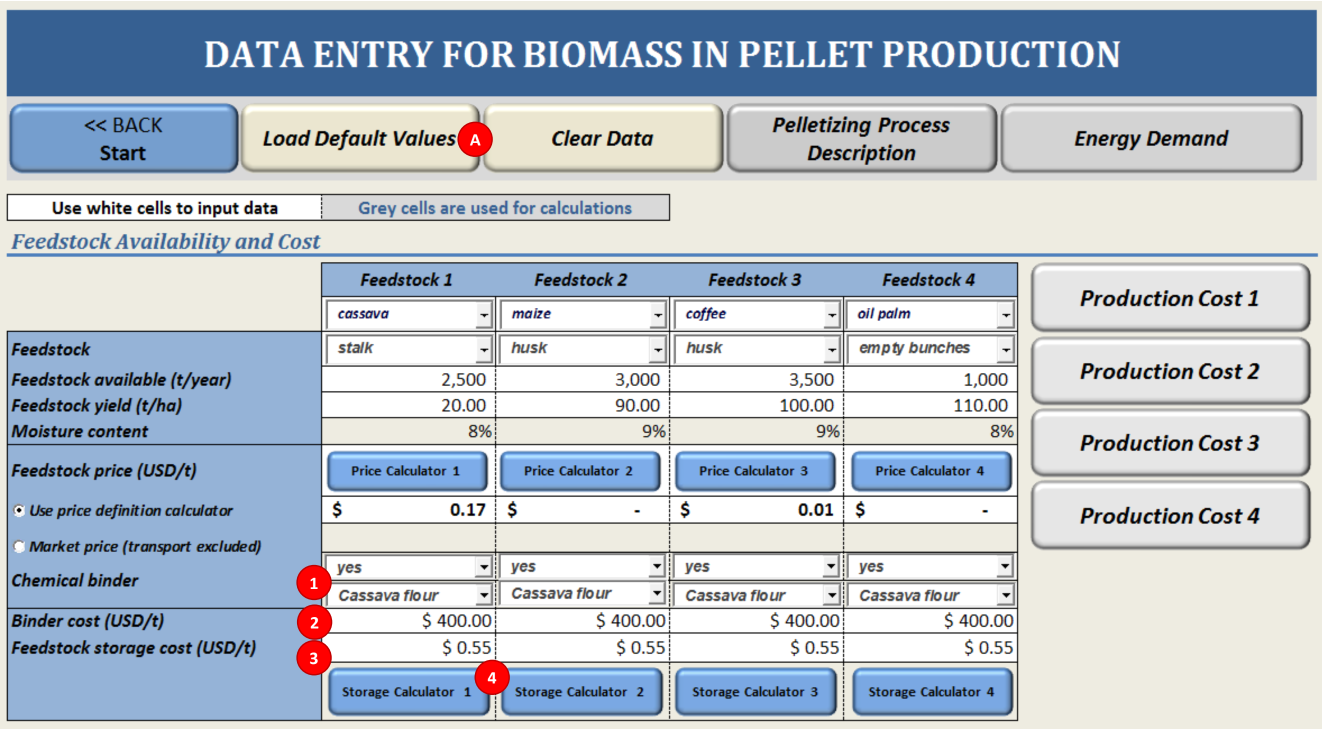


Figure 9: Chemical Binder and Feedstock Storage Cost

Step 2.C Chemical Binder

The user must determine if a chemical binder[7] is used in the pellet production process.

> **Guidance:** According to literature, binder is typically used in manual production. Screw press technologies typically do not require a binder.

If the user selects *"yes",* the user will need to:

1. Select the type of binder from the following options (Figure 9, label 1):
   - Cassava flour
   - Maize flour
   - Wheat flour
2. Enter the binder cost (USD/tonne) for all feedstock (Figure 9, label 2).

Step 2.D: Feedstock storage cost (USD/t)

Step 2.D.1 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/tonne). If this information is not available, then the user should go to the next step.

Step 2.D.2 The user can determine *a proxy* for this value. The user will need to do the following:

1. Identify a type of feedstock storage likely associated with the conditions in their country from the options presented in Table 2.
2. For the selected storage option, look up the global building cost provided in Table 2.

[7]Guidance reference: Ferguson, 2012; GVEP International, 2010; Kaliyan & Morey, 2010; Tumuluru, Wright, Kenney, et al., 2010; Kaliyan & Morey, 2010; Tumuluru, Wright, Kenney, et al., 2010.

3. Enter the proxy value (USD/tonne) in the respective cell for each feedstock.

Note that this value will be used as a proxy for the storage cost for both the feedstock, i.e. raw material, and the product, i.e. pellet.

Table 2: Estimated Cost of Storage

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)

For this example, all feedstock are stored on crushed rock and unprotected. Therefore, the cost of storage is 1 USD/tonne. (User inputs the cost in the corresponding cells as shown in Figure 9, label 3).

Step 2.D.3 In order to calculate the storage capacity needs, the user needs to click on the "Storage Calculator" (Figure 9, label 4)**.** This will take the user to the Biomass Storage Calculator (Figure 10). In this worksheet, the user will need to:

1. Select the harvesting month(s) of the crop (Figure 10, 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 10, label 2).
3. Click on "Calculate" (Figure 10, 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 10, label 4).
4. Click "OK", to return to the Data Entry Needs sheet (Figure 10, label 5).
5. Repeat the same steps for all feedstock.

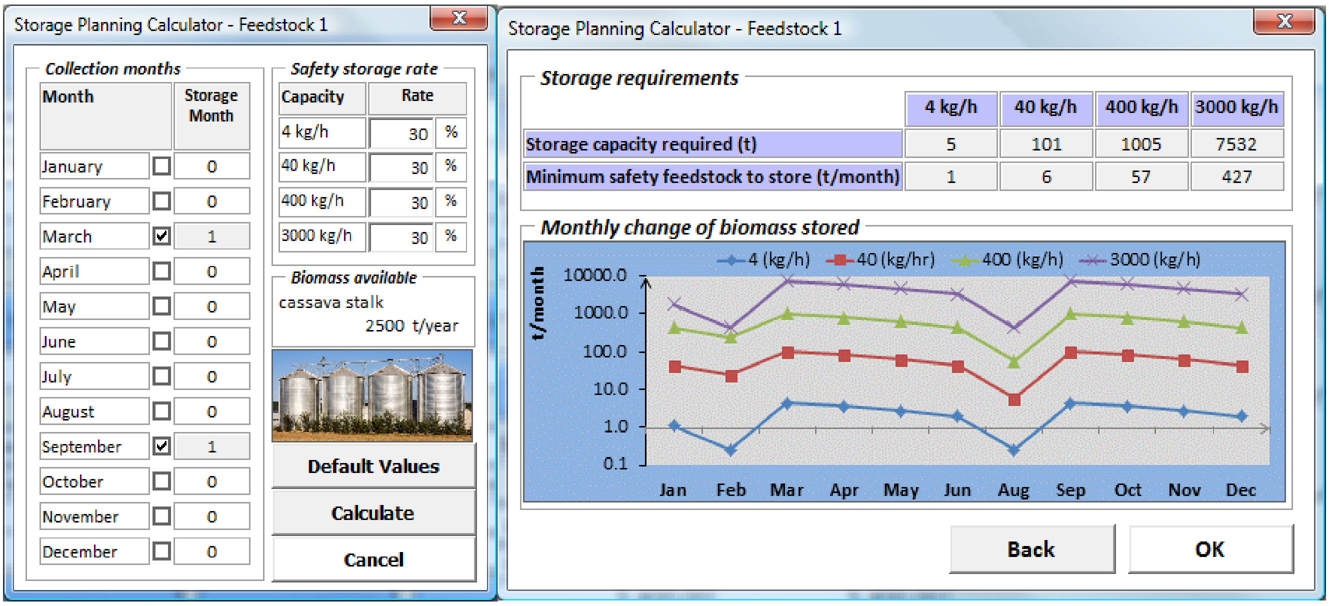
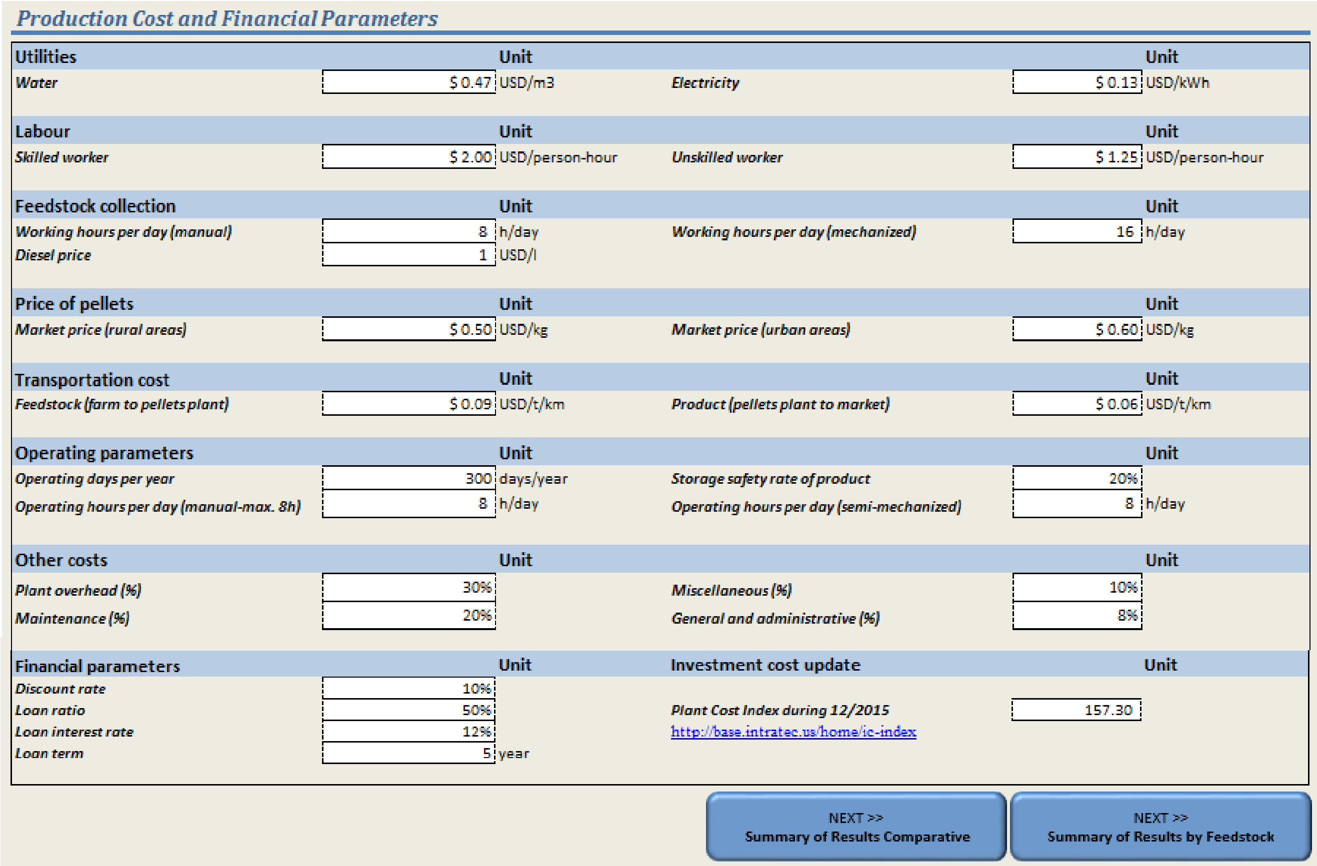


Figure 10: Feedstock Storage Calculator

For this example, Feedstock 1 "Cassava Stalk" is harvested in March and September. As a result, the storage capacity required is 5 tonnes for 4 kg/h production capacity. The minimum safety feedstock to store is 1 tonne per month.

5.3 Step 3: Production cost and financial parameters

General inputs required to run the operations are shown in Figure 11. The user will need to provide data on:



Production Cost and Financial Parameters

Utilities		**Unit**			**Unit**
Water	$ 0.47	USD/m3	*Electricity*	$ 0.13	USD/kWh
Labour		**Unit**			**Unit**
Skilled worker	$ 2.00	USD/person-hour	*Unskilled worker*	$ 1.25	USD/person-hour
Feedstock collection		**Unit**			**Unit**
Working hours per day (manual)	8	h/day	*Working hours per day (mechanized)*	16	h/day
Diesel price	1	USD/l			
Price of pellets		**Unit**			**Unit**
Market price (rural areas)	$ 0.50	USD/kg	*Market price (urban areas)*	$ 0.60	USD/kg
Transportation cost		**Unit**			**Unit**
Feedstock (farm to pellets plant)	$ 0.09	USD/t/km	*Product (pellets plant to market)*	$ 0.06	USD/t/km
Operating parameters		**Unit**			**Unit**
Operating days per year	300	days/year	*Storage safety rate of product*	20%	
Operating hours per day (manual-max. 8h)	8	h/day	*Operating hours per day (semi-mechanized)*	8	h/day
Other costs		**Unit**			**Unit**
Plant overhead (%)	30%		*Miscellaneous (%)*	10%	
Maintenance (%)	20%		*General and administrative (%)*	8%	
Financial parameters		**Unit**	**Investment cost update**		**Unit**
Discount rate	10%				
Loan ratio	50%		*Plant Cost Index during 12/2015*	157.30	
Loan interest rate	12%		http://base.intratec.us/home/ic-index		
Loan term	5	year			

NEXT >> Summary of Results Comparative

NEXT >> Summary of Results by Feedstock

Figure 11: General Inputs

1. **Utilities cost**: the price of water (USD/m^3) and electricity (USD/kWh).
2. **Labour cost (USD/person-hour)**: the labour rate for unskilled and skilled workers (USD per employee per hour). These parameters are required to calculate the feedstock price (as explained in Step 2.B) and the labour cost of the pelletizing production process.
3. **Feedstock collection:** these parameters are required to calculate the feedstock price as explained in Step 2.B. The user enters the hours of labour required for manual labour, hours of labour required for running the machinery and the price of diesel.
4. **Price of pellets (USD/kg):** The user will also need to provide the current market price for pellets in both rural and urban areas. If this information is not available, then the price of charcoal can be used as proxy. This data is used to analyse the total potential revenue of the pellet system for each pre-defined production capacity.
5. **Transportation cost of feedstock (USD/t/km):** cost of transportation of feedstock from the collection point to the pellet plant. The user will need to:
   - Identify the current methods of transportation of moving agriculture commodities within the country.
   - Define the current transportation prices associated with the transportation method identified above in unit of USD per tonne per km.

Guidance: This can be based on unprocessed agricultural goods.

Guidance: If the method of transportation is by person or bike, then it is recommended that the user estimates the cost by using the cost of labour per hour, working time, the amount of material that can be transported and the approximate kilometres that can be travelled under the selected method as given in the following equation:

$$\text{Transportation cost (USD/tonne/km)} = \frac{\text{Hourly wages (USD/hour/person)} \times \text{Working time (hours)}}{\text{Transportation distance (km)} \times \text{Feedstock transport (tonne/person)}}$$

Alternatively, the user can include this cost in the collection cost of feedstock by adding this to the number of workers in **Step 2.B** (estimate price of feedstock) and then inputting zero costs for the transportation of feedstock from the collection point to the plant.

6. **Transportation cost of pellets (USD/t/km):** cost of transportation of pellet from plant to market. The user will need to:
   - Identify the current methods of transportation of moving agriculture commodities within the country.
   - Define the current transportation prices associated with the transportation method identified above in unit of USD per tonne per km.

Guidance: This can be based on processed agricultural goods.

7. **Operation parameters of the pellet system:** The user enters the operating hours per day and operating days per year of the pellet system. These parameters are used to estimate the annual pellet production (tonnes per year).

Guidance: For manual pellet production, the maximum operating hours per day should be 8 hours.

8. **Other Costs (%):** The user enters the percentage of:
   - Plant overhead,
   - Maintenance,
   - General and administrative and
   - Safety storage rate of pellet products.

These parameters are used to estimate the production costs of pellet.

Guidance: The user determines the pellet safety stock rate to ensure sufficient supply of pellet in the market.

9. **Financial parameters**: The user identifies the values for the following financial parameters:
   - Discount rate (%),
   - Loan ratio (%),
   - Loan interest rate (%),
   - Loan term (years) and
   - Plant Cost Index.

The plant cost index data for equipment cost is obtained from technical literature and based on past technical and economic conditions. Therefore, the Intratec Chemical Plant Construction Index (IC), a dimensionless index used as a proxy to update the capital cost of a chemical plant, which accounts for price changes due to inflation/deflation and economic conditions, is applied to the BEFS RA tool. This index is freely updated and available on (http://base.intratec.us/home/ic-index).

For this example, the values shown in Figure 11 were used to carry out the analysis.

5.4 Step 4 (Optional): Calculation of the production cost of pellets

Note: This section also shows the budgets for calculating the processing costs. These calculations are done automatically using the information entered by the user in the previous steps and can be reviewed if needed (see section 7.1 for more details).

After completing all of the data entries required in **Steps 1 to 3**, the user clicks on the "Production Cost" button in the Data Entry Sheet (Figure 12, red box).

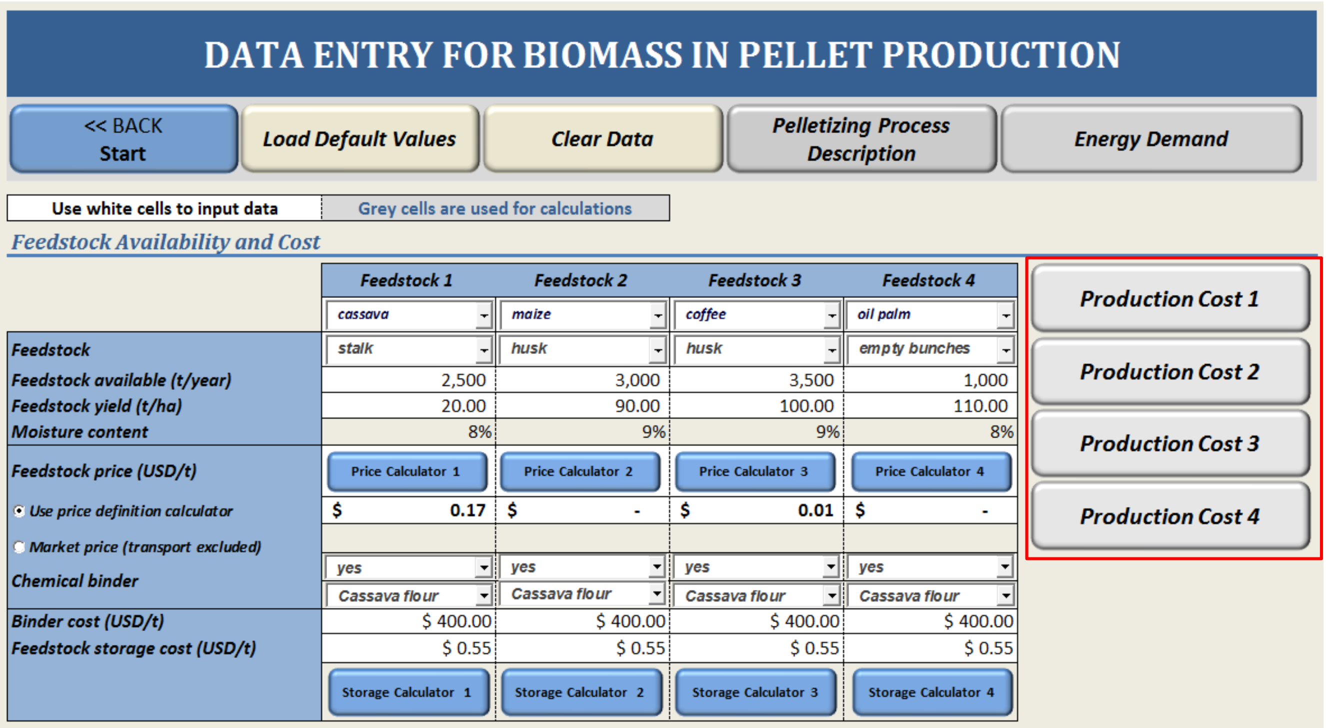


Figure 12: Production Cost Calculation

This will take the user to the budget processing section for the selected feedstock (Figure 13).

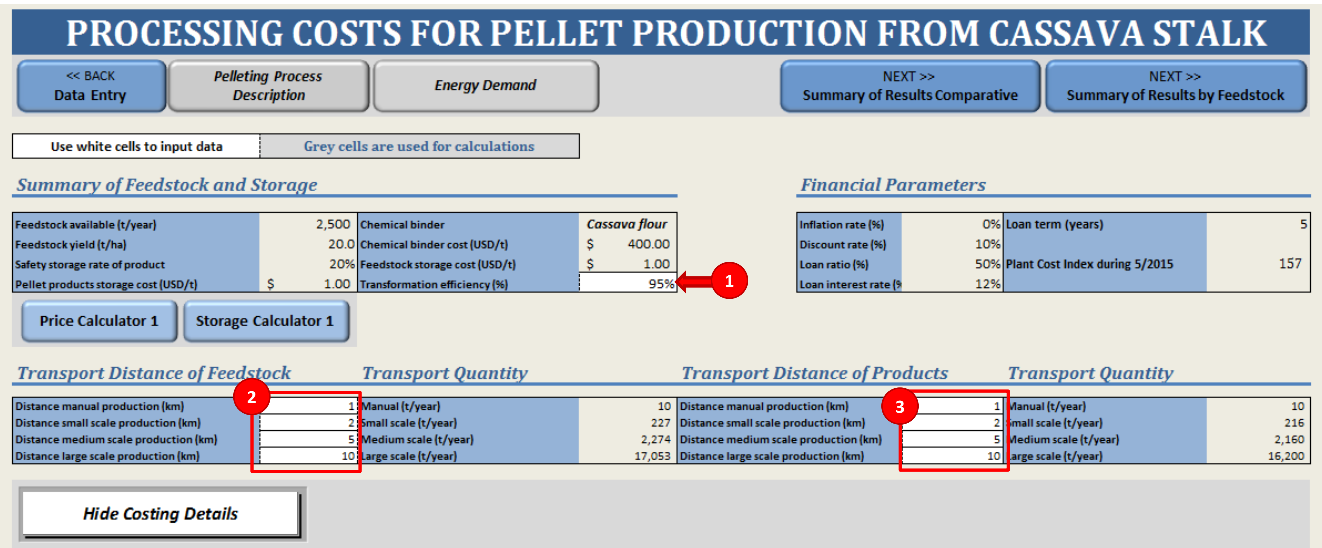


Figure 13: Processing Costs of Pellets

In this worksheet, the user will need to enter additional data in the white cells, specifically on:

1. **Transformation efficiency:** the typical transformation efficiency is *assumed to be 95% mass basis*. The user, however, can enter different transformation efficiency values to assess the effect that this efficiency can have on the amount of feedstock consumption and production cost of pellets (Figure 13, label 1).

2. **The transportation distance of feedstock to pellet plant:** The user identifies an estimated transportation distance that will be required to transport the feedstock in kilometres for each pellet production capacity (Figure 13, label 2).

Guidance: The transportation distance depends on the availability of biomass in a particular area and the amount of biomass required for each production capacity. The manual and small-scale plants use less biomass compared to the medium and large-scale ones. Therefore, the distance of transportation could be shorter. If the availability of biomass in that area is high and sufficient enough to supply for all production scales of the pellet plants, then the users can input the same transportation distance of feedstock for all production scales.

3. **The transportation distance of pellet products to market:** The user identifies an estimated transportation distance that will be required to transport the pellets to market in kilometres for each pellet production capacity (Figure 13, label 3). *Note: If the availability of pellets in an area is high and sufficient enough to supply for all production scales of the pellet plants, then the user can input the same transportation distance for all scales of production.*

Guidance: The large-scale plant can supply pellets to many markets that are further away, and may require longer transportation distances compared to other scales.

For this example, the default values are utilised to carry out the analysis (Figure 13).

6 Assumptions and Limitations of the *Pellets Component*

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 limitations of the *Pellets Component* are:

1. Manual pellet production is set at 4 kg per hour.
2. Mechanized screw press is set at 40,400 and 3,000 kg per hour.
3. Optimum moisture content of the raw material is 8-9%.
4. Particle size must be 6-8 mm.
5. The chemical binders include only cassava flour, maize flour or wheat flour.
6. The cost of the external heating system is excluded.
7. The cost of pre-treatment is excluded.
8. Business lifetime is 20 years for financial analysis.

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

7 The Results of the *Pellets Component*

7.1 Overview of the production cost calculations (optional)

After the user inputs all required data (Steps 1 to 3), then the user has the option to review the detailed production cost as shown in Figure 14. There are four main sections in this worksheet as explained below.

- **PART 1** (Figure 14, label 1) shows the distribution of production cost along the following categories: inputs, labour, transportation of feedstock, storage, investment, plant overhead, general and administrative cost, loan interest, and income tax. The total production costs (USD/year) of the four pellet production capacities (4, 40, 400 and 3,000 kg per hour) are also summarized.
- **PART 2** (Figure 14, label 2) shows the unit cost of pellet (USD/kg of pellet) for each of the production capacities.
- **PART 3** (Figure 14, label 3) summarizes the loan details, e.g. loan amount, loan interest, annual loan payment, etc., for financial analysis.
- **PART 4** (Figure 14, label 4) the "Financial Analysis" buttons will open the worksheet with the detail on the financial analysis for each production capacity for both rural and urban markets.

Production Cost Details 1

Rural Markets 4

Financial Analysis (Manual) | Financial Analysis (2 ton/h) | Financial Analysis (6 ton/h) | Financial Analysis (15 ton/h)

Urban Markets

Financial Analysis (Manual) | Financial Analysis (2 ton/h) | Financial Analysis (6 ton/h) | Financial Analysis (15 ton/h)

			Capacities (kg of pellet per hour)							
			4 Manual		40 Mechanized screw press		400 Mechanized screw press		3,000 Mechanized screw press	
			Operating hours per year	2,400	Operating hours per year	5,400	Operating hours per year	5,400	Operating hours per year	5,400
Annual pellet production (t/year)			**10**		**216**		**2,160**		**16,200**	
Inputs	**Unit**	**Unit Price (USD/Unit)**	**Quantity (Unit/year)**	**Total (USD/year)**	**Quantity (Unit/year)**	**Total (USD/year)**	**Quantity (Unit/year)**	**Total (USD/year)**	**Quantity (Unit/year)**	**Total (USD/year)**
Feedstock	t	$ 0.17	10	$ 2	227	$ 38	2,274	$ 384	17,053	$ 2,881
Chemical binder	t	$ 400.00	1.0	$ 384	21.6	$ 8,640	216	$ 86,400	1,620	$ 648,000
Water	m^3	$ 0.47	2.3	$ 1.08	51.8	$ 24	518	$ 244	3,888	$ 1,827
Electricity	KWh	$ 0.13		$ -	9,817	$ 1,276	98,172	$ 12,762	736,290	$ 95,718
Subtotal			$	*387*	$	*9,979*	$	*99,790*	$	*748,426*
Labour and miscellaneous costs	**Unit**	**Unit Price (USD/person-hour)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**
Skilled worker	# employee	$ 2.00	-	$ -	2	$ 21,600	5	$ 54,000	33	$ 356,400
Unskilled worker	# employee	$ 1.25	-	$ -	1	$ 6,750	1	$ 6,750	8	$ 54,000
Miscellaneous costs			10%	$ -	10%	$ 2,835.00	10%	$ 6,075	10%	$ 41,040
Subtotal			$ -	$ -	$ 31,185	$ 31,185	$ 66,825	$ 66,825	$ 451,440	$ 451,440
Transportation	**Unit**	**Unit Price (USD/t/km)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**
Feedstock (farm to pellet plant)	km	$ 0.09	1	$ 1	2	$ 41	5	$ 1,023	10	$ 15,347
Pellet products (pellet plant to market)	km	$ 0.06	1	$ 1	2	$ 26	5	$ 648	10	$ 9,720
Subtotal			$	*1*	$	*67*	$	*1,671*	$	*25,067*
Storage	**Unit**	**Unit Price**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**
Feedstock	USD/t	$ 0.55	5	$ 3	101	$ 56	1,005	$ 553	7,532	$ 4,143
Pellet products	USD/t	$ 0.55	2	$ 1	43	$ 24	432	$ 238	3,240	$ 1,782
Subtotal			$	*4*	$	*79*	$	*790*	$	*5,925*
Investment	**Unit**	**Years**	**Total (USD)**	**Depreciation (USD/year)**	**Total (USD)**	**Depreciation (USD/year)**	**Total (USD)**	**Depreciation (USD/year)**	**Total (USD)**	**Depreciation (USD/year)**
Equipments	USD	20	$ 885	$ 44	$ 58,212	$ 2,911	$ 402,668	$ 20,133	$ 1,833,672	$ 91,684
Building	USD	20	$ -	$ -	$ 2,188	$ 109	$ 15,205	$ 760	$ 68,935	$ 3,447
Installation	USD	20	$ 1,279	$ 64	$ 18,476	$ 924	$ 162,919	$ 8,146	$ 1,108,049	$ 55,402
Total investments			*$ 2,165*		*$ 78,877*		*$ 580,792*		*$ 3,010,655*	
			Total Depreciation	*$ 108*	Total Depreciation	*$ 3,944*	Total Depreciation	*$ 29,040*	Total Depreciation	*150,533*
Maintenance cost		20%		$ 22		$ 789		$ 5,808		$ 30,107
Subtotal			$	*130*	$	*4,733*	$	*34,848*	$	*180,639*
Other costs	**Unit**	**Rate (%)**		**Total (USD/year)**		**Total (USD/year)**		**Total (USD/year)**		**Total (USD/year)**
Plant overhead	USD	30%		$ 6		$ 8,742		$ 19,967		$ 132,152
General and administrative cost	USD	8%		$ 33		$ 4,056		$ 15,391		$ 108,970
Loan interest	USD	12%		$ 18		$ 660		$ 4,859		$ 25,189
Subtotal			$	*58*	$	*13,457*	$	*40,218*	$	*266,311*
Total costs			**Total (USD/year)**	**Share (%)**	**Total (USD/year)**	**Share (%)**	**Total (USD/year)**	**Share (%)**	**Total (USD/year)**	**Share (%)**
Total operating costs			*$ 391*	*68%*	*$ 41,286*	*69%*	*$ 168,839*	*69%*	*$ 1,229,076*	*73%*
Total fixed costs			*$ 130*	*22%*	*$ 4,733*	*8%*	*$ 34,848*	*14%*	*$ 180,639*	*11%*
Total other costs			*$ 58*	*10%*	*$ 13,457*	*23%*	*$ 40,218*	*16%*	*$ 266,311*	*16%*
Total production costs			***$ 579***		***$ 59,476***		***$ 243,904***		***$ 1,676,026***	

	Capacities (ton of pellet per hour)			
	4	216	2,160	16,200
Unit cost of pellet (USD/kg of pellet) 2	$ 0.060	$ 0.275	$ 0.113	$ 0.103

3 Average loan interest	Unit	Loan ratio (%)	Total investment (USD)	Loan amount (USD)	Total investment (USD)	Loan amount (USD)	Total investment (USD)	Loan amount (USD)	Total investment (USD)	Loan amount (USD)
Loan amount	USD	50%	$ 2,164.58	$ 1,082.29	$ 78,876.63	$ 39,438.31	$ 580,792.40	$ 290,396.20	$ 3,010,655.38	$ 1,505,327.69
Loan interest rate	%			12%		12%		12%		12%
Loan payment	USD/month			-$ 24.07		-$ 877.28		-$ 6,459.70		-$ 33,485.18
Annual loan payment	USD/year			-$ 288.90		-$ 10,527.40		-$ 77,516.44		-$ 401,822.20
Loan terms	year			5		5		5		5
Total loan payment	USD			-$ 1,444.50		-$ 52,637.01		-$ 387,582.19		-$ 2,009,110.98
Loan interest	USD			-$ 362.21		-$ 13,198.70		-$ 97,185.98		-$ 503,783.29
Average loan interest	USD/year			-$ 18.11		-$ 659.93		-$ 4,859.30		-$ 25,189.16

Figure 14: Detail of Production Costs of Pellets by Production Capacity

For the example of Cassava Stalk, the total production cost of manual (4 kg/h) is 579 USD per year. The unit cost of pellet is 0.060 USD/kg. The average loan interest is 18 USD/year.
For other pre-defined capacities refer to Figure 14.

7.2 The summary of results by feedstock

Results for the *Pellets Component* are divided along three main categories: Production Cost and Investments; Plant Operating; and Financial Analysis.

1. The user first selects the feedstock from the dropdown menu that he/she wants to review (Figure 15, label 1). The results for that specific feedstock will be generated.
2. The production cost and investments results are presented as follows:
   - Cost of production and transportation of pellets (USD/kg) (Figure 15, label 2). The user can compare the production cost to the market price (rural or urban) by selecting either or both options.
   - Total investment cost (USD) of the pellet system by production capacity (Figure 15, label 3).

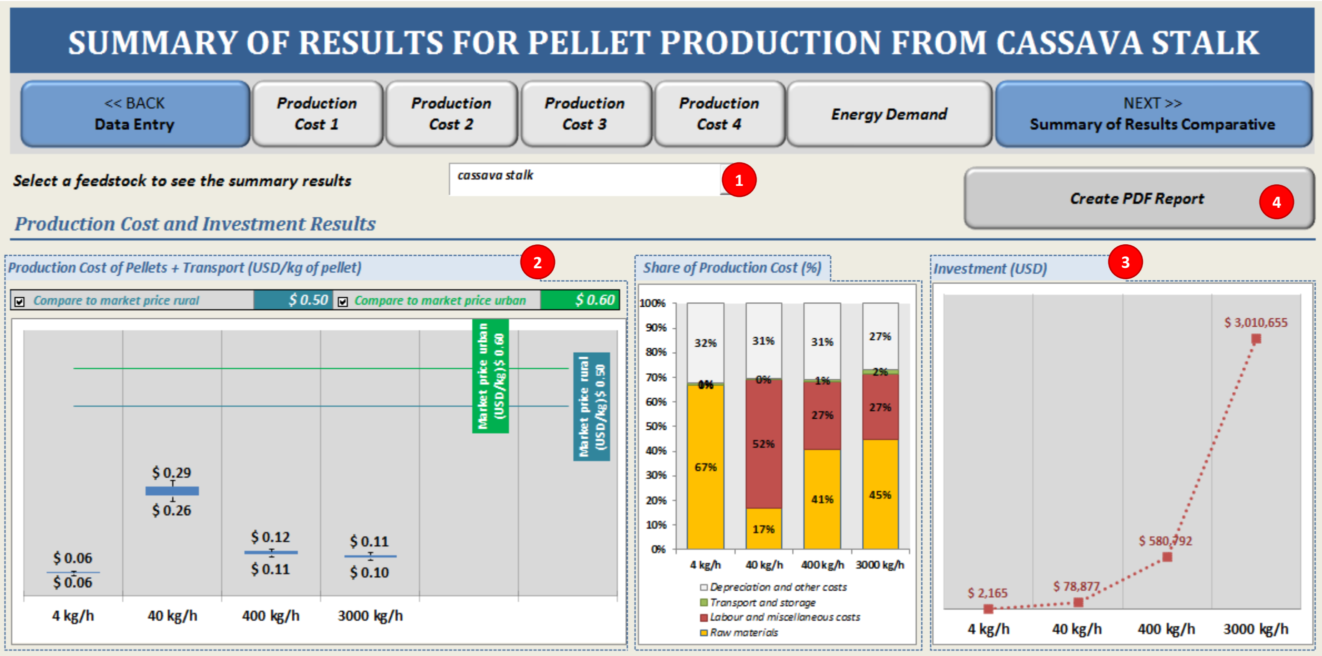


Figure 15: Production Cost and Investment Results

For this example, Feedstock 1 "Cassava Stalk", the total production cost included the transportation cost of both manual production at 4 kg/h (Size 1) and mechanized production at 3,000 kg/h (Size 4), which was 0.06 USD/kg and 0.10-0.11 USD/kg, respectively. These unit costs are lower than the rural market price of 0.5 USD/kg and the urban market price of 0.6 USD/kg. Therefore, both plants are attractive investments that are feasible. The total investment cost of Size 1 and Size 4 are 2,165 USD and 3,010,655 USD, respectively (Figure 15).

3. The technical and operating results are presented as follows:
   - Biomass required to run the selected capacity (tonnes per year) (Figure 16, label 1).
   - Number of pellet plants that can be developed for each capacity based on biomass availability (Figure 16, label 2).
   - Biomass area requirement to produce pellets (hectare) (Figure 16, label 3).
   - Number of households that can be supplied by the system (Figure 16, label 4).
   - Total job creation by the implementation of the pre-defined pellet systems (Figure 16, label 5).

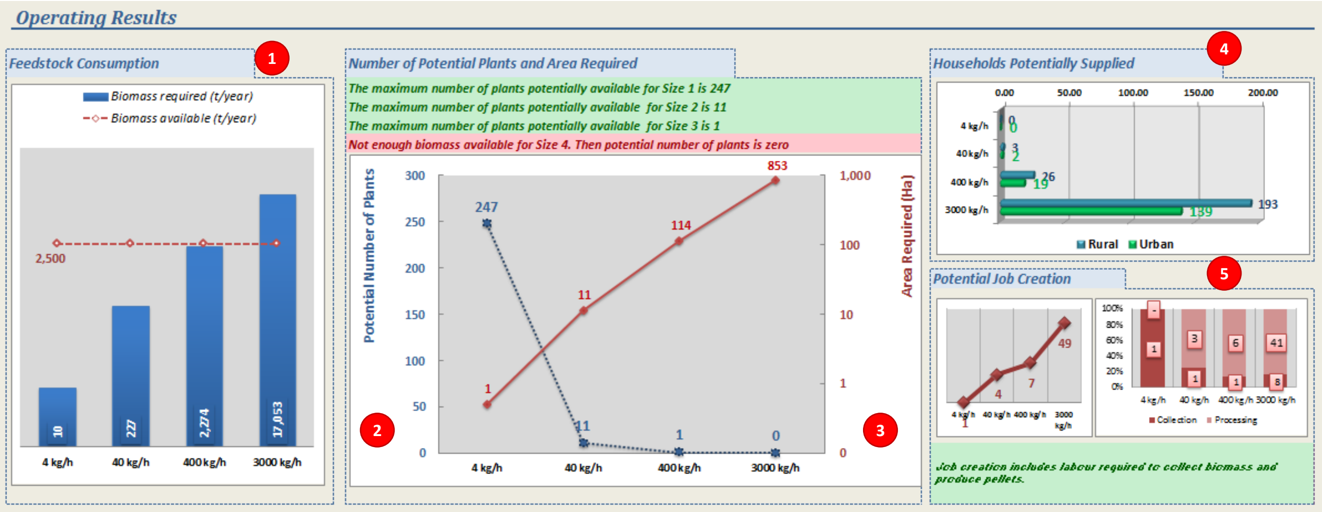


Figure 16: Operating Results

In the example Feedstock 1 "Cassava Stalk", the feedstock available is 2,500 tonnes per year, which is sufficient enough to supply for Size 1, Size 2 and Size 3 production capacities. But, it is not sufficient enough to supply for the Size 4 capacity. In accordance with the feedstock availability, there can be 11 potential pellet plants at 40 kg/h capacity (Size 1) which require 11 hectares of area of feedstock. In turn, this would supply pellets to 3 households in rural areas or 2 households in urban areas. Moreover, the potential job creation from a pellet plant of 40 kg/h capacity (Size 2) is 1 job for feedstock collection and 3 jobs for the pellet processing plant (Figure 16).

4. The financial analysis (before tax return) results are presented as follows:
   - Net Present Value (NPV) (Figure 17, label 1)
   - Internal Rate of Return (IRR) (Figure 17, label 2)

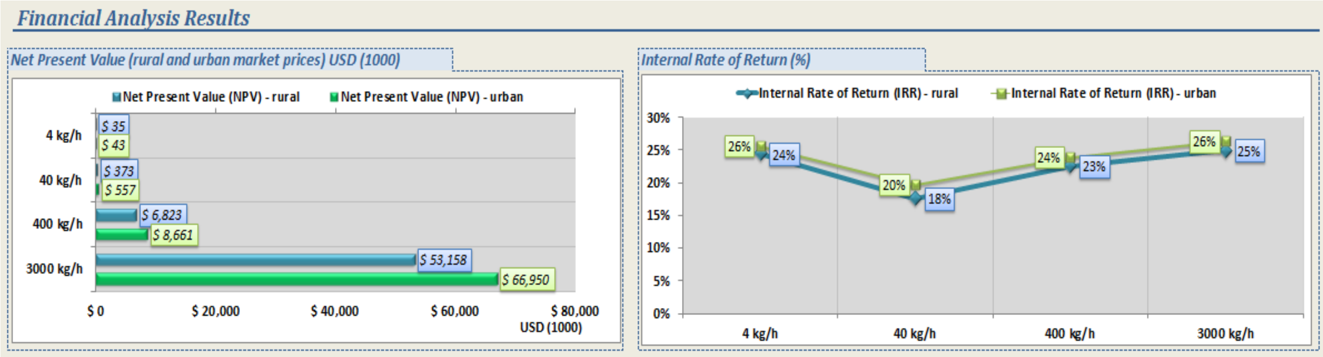


Figure 17: Financial Analysis Results

For this example, Feedstock 1 "Cassava Stalk", the NPV and IRR are positive for both rural and urban markets in all pellet plant sizes (Figure 17).

The user can save and print the results in PDF format by using "Create a PDF report" and following the instructions (Figure 15, label 4).

The results aim to answer the following questions:
- What is the production cost and investment cost of pellets?
- How much biomass is required to supply each of the pre-defined capacities?
- How many households can be supplied with energy for heating and cooking?
- How many jobs can be created by developing this production system?
- What are the Net Present Value (NPV) and Internal Rate of Return (IRR) of pellet production?

For this example, the information generated indicates that the possible sizes of pellet plants based on the availability of cassava stalk are Sizes 1 to 3 (as shown in Figure 16).

7.3 The summary of comparative results

In this section, the user can compare the results across the various feedstock that were evaluated.

1. The user first selects the feedstock, by clicking on it, that he/she wants to review. The results for that specific feedstock will be generated.
2. Comparison results are presented on:
   - Production costs according to feedstock (USD/kg) (Figure 18, label 1)
   - Number of pellet plants by production capacity (Figure 18, label 2)
   - Number of jobs creation by production capacity (Figure 18, label 3)

3. To assess the financial analysis, the user can select rural or urban markets or both. Depending on this selection, a comparison of the financial results (before taxes) is generated for:
   - NPV in rural areas (Figure 18, label 4)
   - NPV in urban areas (Figure 18, label 5)
   - IRR in rural areas (Figure 18, label 6)
   - IRR in urban areas (Figure 18, label 7)

> **Guidance**: These results can help identify the type of feedstock and production scale that is most viable should be promoted for pellet production.

The user can save and print the results in PDF format by using "Create a PDF report" and following the instructions (Figure 18, label A).

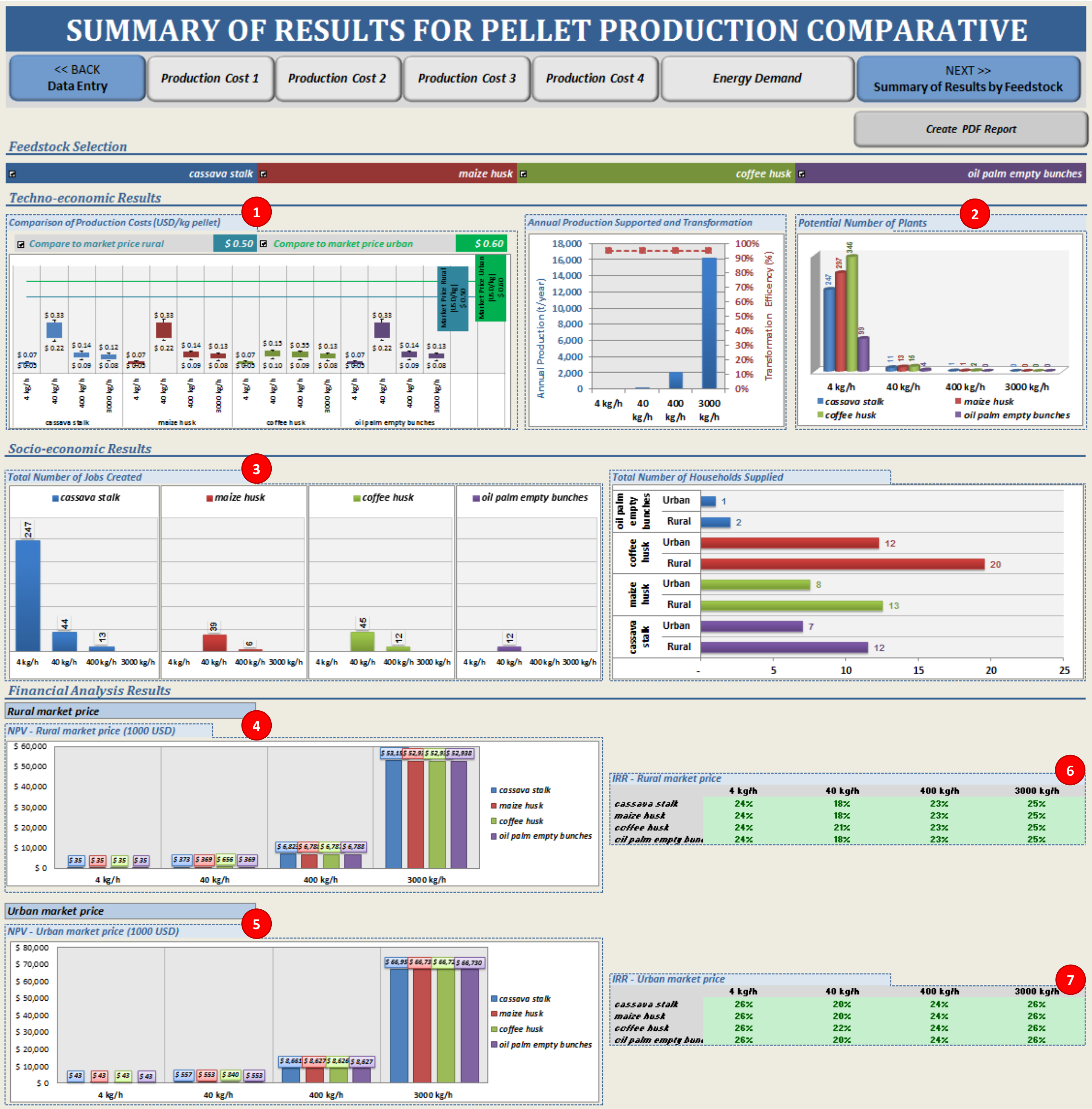


Figure 18: Layout of Comparative Results

For this example, the production cost of all four feedstock are all lower than the rural and urban market prices. In addition, all of the feedstock have positive NPV and IRR for both rural and urban markets. However, there is not enough of any biomass available for Size 4 (3000 kg/h) (Figure 18).

It can be concluded that:
All feedstock are feasible and available for pellet production at Sizes 1-3 only. Therefore, policy makers can promote all four feedstock for pellet production in rural and urban areas.

8 Annex

8.1 Methodology and outputs

This section describes the methodologies integrated in the *Pellets Component*. It also includes a description of the equations which support the analysis. The equations 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 Cost calculation of required inputs

The detailed calculation used in the production cost of pellet for the pre-defined capacities: 4 kg/h, 40 kg/h, 400 kg/h and 3000 kg/h. Total inputs cost consist of the feedstock/biomass cost, chemical binder cost, water, and electricity consumption. The equations for calculation are presented in Table 3.

Table 3: Inputs Cost Equations

Item	Equation and Assumption	Remark
Pellet Products (BP) (tonnes per year)	BP = Capacity (kg/hr) x Operating hours per year Where: The pre-defined capacities are: ○ Manual scale 4 kg/h ○ Mechanized small scale 40 kg/h ○ Mechanized medium scale 400 kg/h ○ Mechanized large scale 3000 kg/h Operating hours per year = Operating days per year x Operating hours per day	The maximum operating days per year of manual pellet production are 300 days and 8 hours per day.
Quantity of Feedstock (tonnes per year)	QF = BP/transformation efficiency Where: QF is Quantity of feedstock (tonne per year) BP is Pellet products (tonne per year)	The transformation efficiency default value is 95%, but the user can input other values directly.
Chemical Binder (tonnes per year)	CB = BP/BS Where: CB is Quantity of chemical binder (tonne per year) BP is Pellet products (tonne per year) BS is Specific consumption of binder (kg of pellet/kg)	The specific consumption of binder is 1 kg of binder per 10 kg of pellet (Ferguson, 2012)
Water Consumption (m^3 per year)	WC = BP *1000/WS Where: WC is Water consumption (m^3 per year) BP is Pellet products (Tonne per year) WS is Specific water consumption (kg per m^3)	The default value of WS is 4,667(SNNPRs Investment Expansion Process, 2012).
Electricity Consumption (kWh per year)	EC = BP*ES Where: EC is Electricity consumption (kWh per year) BP is Pellet products (tonne per year) ES is Specific electricity consumption (kWh per tonne)	The default value of ES is 93.4 (Tumuluru, Wright, Kenney, et al., 2010).
Total Inputs Cost (USD per year)	TIC = (QF x Cf) + (CB x Cb) + (WC x Cw) + (EC x Ce) Where: TIC is Total inputs cost (USD per year) QF is Quantity of feedstock (tonne per year) CB is Quantity of chemical binder (tonne per year) WC is Water consumption (m^3 per year) EC is Electricity consumption (kWh per year) Cf is unit cost of feedstock (USD per tonne) Cb is unit cost of chemical binder (USD per tonne) Cw is unit cost of water (USD per m^3) Ce is unit cost of electricity (USD per kWh)	

8.1.2 Cost calculation of required labour

The equations and assumptions for calculating the labour and miscellaneous cost based on the pellet production capacity are shown in Table 4.

Table 4: Labour and Miscellaneous Cost Equations

Item	Equation and Assumption	Remark
Number of unskilled workers	Manual scale is 0 persons (owner is worker) Mechanized small scale is 6 persons Mechanized medium scale is 64 persons Mechanized large scale is 15 persons	(Ferguson, 2012; Poudel et al., 2012; SNNPRs Investment Expansion Process, 2012; Young & Khennas, 2003)
Number of skilled workers	Manual scale is 0 persons (owner is worker) Mechanized small scale is 2 persons Mechanized medium scale is 12 persons Mechanized large scale is 20 persons	The assumptions are made based on the number of unskilled labourers as related to production capacity (SNNPRs Investment Expansion Process, 2012).
Unit cost of unskilled worker (USD/person/hour)	Input data by user in "Data Entry Needs"	
Unit cost of skilled worker (USD/person/hour)	Input data by user in "Data Entry Needs"	
Operating hours per year	Operating hours per year = Operating days per year x Operating hours per day	
Total unskilled worker cost (USD per year)	Unit cost of unskilled worker x number of unskilled workers x operating hours per year	
Total skilled worker cost (USD per year)	Unit cost of skilled worker x number of skilled workers x operating hours per year	
Miscellaneous cost* (USD per year)	25% x (Total unskilled worker cost + Total skilled worker cost)	
Total labour cost (USD per year)	Total Unskilled worker cost + Total skilled worker cost + Miscellaneous cost	

*Note: A miscellaneous cost consists of labour benefits, health & life insurance, operating supplies and/or laboratory charges.

8.1.3 Cost calculation of required transportation

The calculation equations for the transportation cost are shown in Table 5.

Table 5: Transportation of Feedstock and Pellet Products Cost Equations

Item	Equation and Assumption	Remark
Transportation of feedstock (collecting point to plant) (USD per year)	Unit transportation cost x Transportation distance x QF Input by user in “Data Entry Needs” (USD/tonne/km) Input by user in “COST_RES#” (km)	QF is calculated in Table 3
Transportation of pellet (plant to market) (USD per year)	Unit transportation cost x Transportation distance x BP Input by user in “Data Entry Needs” (USD/tonne/km) Input by user in “COST_RES#” (km)	BP is calculated in Table 3

8.1.4 Cost calculation of storage

The calculation equations of storage cost are as shown in Table 6.

Table 6: Storage Cost Equations

Item	Equation and Assumption	Remark
Storage cost of feedstock (USD per year)	Unit storage cost x Storage Capacity	The storage cost is input by the user in the processing budget section (USD/tonne).
Storage capacity (tonnes/year)	The storage capacity is calculated by the storage calculator	Result of storage calculator
Storage cost of pellet products (USD per year)	Unit storage cost x Storage Capacity	Pellet product storage input by User (USD/tonne)
Storage capacity of pellet products (tonnes/year)	Pellet stock rate x BP	BP is calculated in Table 3

8.1.5 Fixed cost calculation

Fixed costs consist of equipment cost, building cost and installation cost. This step presents the calculation equations of fixed costs and its depreciation cost as shown in Table 7.

Table 7: Fixed Cost Equations

Item	Equation and Assumption	Remark
Equipment cost (EC) (USD)	EC (base year) = Unit equipment cost x BP x 20 years EC at current period = EC (base year) x [Plant Cost Index (current period)/Plant Cost Index (base year)]	Unit equipment cost in Table 14 BP is calculated in Table 3 Plant cost index (current period) input by the user
Building cost (BC) (USD)	BC (base year) = Unit Building cost x BP x 20 years BC at current period = BC (base year) x [Plant Cost Index (current period) / Plant Cost Index (base year)]	Unit Building cost in Table 14 BP is calculated in Table 3 Plant cost index (current period) input by the user
Installation cost (IC) (USD)	IC (base year) = Unit Installation cost x BP x 20 years IC at current period = IC (base year) x [Plant Cost Index (current period) / Plant Cost Index (base year)]	Unit Installation cost in Table 14 BP is calculated in Table 3 Plant cost index (current period) input by the user
Total investment (USD)	Equipment cost + Building cost + Installation cost	Business lifetime is 20 years
Equipment depreciation (USD per year)	Equipment cost divided by business life time	Straight line method of depreciation calculation
Building depreciation (USD per year)	Building cost divided by business life time	Straight line method of depreciation calculation
Installation depreciation (USD per year)	Installation cost divided by business life time	Straight line method of depreciation calculation
Total depreciation (USD per year)	Equipment Depreciation + Building Depreciation + Installation Depreciation	Straight line method of depreciation calculation
Maintenance cost (USD per year)	Percentage of maintenance x Total depreciation	Share of maintenance input by the user
Total of Fixed cost (USD per year)	Total depreciation + Maintenance cost	

Note: The plant cost index is used to update equipment, building and installation costs to the current period.
Please visit this website for further information: http://en.wikipedia.org/wiki/Chemical_plant_cost_indexes.
The assumption in this tool is that plant cost index can be applied to any plant type and size. It is providing an acceptable proxy to update the investment costs.

8.1.6 Calculation of other costs

The plant overhead is defined as a charge to the production for services, facilities and payroll overhead. The general and administrative costs comprise of rents, insurances, managerial, administrative and executive salaries. The equations for calculating the plant overhead, general and administrative cost, average loan interest payment and income tax are as shown in Table 8.

Table 8: Other Costs Equations

Item	Equation and Assumption	Remark
Plant Overhead (USD per year)	Percentage of plant overhead x (Total labour cost + Maintenance cost)	Percentage of plant overhead is input by the user. The default value is 5%.
General and Administrative Cost (USD per year)	Percentage of general and administrative cost x (Total inputs cost + Total labour cost + Maintenance cost + Plant overhead)	Percentage of plant overhead is input by the user. The default value is 5%.
Average Loan interest payment (USD per year)	Loan amount = Loan ratio (%) x Total investment cost Loan payment (USD/month) = PMT([Loan interest rate/12],[12x Loan term], Loan amount) Annual loan payment = Loan payment (USD/month) x 12 months Total loan payment = Annual loan payment x Loan terms Loan interest payment = Total Loan payment - Loan amount Average loan interest payment = Loan interest payment divided by business lifetime	PMT is a financial function in Microsoft Excel for calculating the payment for a loan based on constant payments and a constant interest rate.

8.1.7 Total production cost and unit cost of pellet calculation

The calculation equations of the total operating costs, total fixed costs, other total costs, total annual production cost of pellets and unit production cost per kg are shown in Table 9.

Table 9: Total Production Cost Equations

Item	Equation and Assumption	Remark
Total Operating Costs (USD per year)	annual inputs cost + annual labour cost + annual transportation cost + annual storage cost	
Total Fixed Costs (USD per year)	depreciation fixed cost +annual maintenance cost	
Total Other Costs (USD per year)	annual plant overhead + annual general &administration cost + annual loan payment	
Total Production Cost (USD per year)	Total Operating Costs + Total Fixed Costs + Total Other Costs	
Production cost per kg	Total Production Cost divided by pellet production	Pellet production is calculated in Table 3

8.1.8 Pellet demand calculation

This step details the calculation equations carried out to determine the energy demand in pellet equivalents. Note that the conversion factors have taken into consideration the energy efficiency gains of the end use (i.e. stove).

Table 10 presents the calorific value and the assumptions used in stove efficiency to calculate the useful energy of pellets when compared to other fuels. For example, burning pellets in a 50% efficiency stove yields 7.7 MJ/kg of useful energy to the end use (Table 10 - line 1, column 3). Comparing the useful pellet energy with low efficiency fuelwood stove (Efficiency 20%), indicates that the use of fuelwood yields only 16% of the useful energy of pellets. That is 6.11 kg of fuelwood are needed to provide the useful energy equal to 1 kg of pellet (Table 10 – line 2, column 4). Similar assessments for charcoal, kerosene and LPG are presented below:

Table 10: Comparison of Pellets with Other Fuels

	Calorific Value (CV) MJ/kg	Stove efficiency %	Useful energy MJ/kg	Conversion factor (CF) kg of Fuel*
Pellets	15.4	50%	7.7	1.00
Fuelwood	6.3	20%	1.3	6.11
Charcoal	27.0	25%	6.8	1.14
Kerosene	44.0	55%	24.2	0.32
LPG	49.0	60%	29.4	0.26

Note: *compared to energy of pellet 1 kg
Source: Young & Khennas, 2003

The conversion factor to calculate the pellet consumption equivalent is therefore the values of 6.11 kg of fuelwood, 1.14kg of charcoal, 0.32kg of kerosene and 0.26kg of LPG compared to the energy of 1 kg of pellet (Table 10).

The equations for calculating the pellet demand equivalent are presented in Table 11.

Table 11: Pellet Demand Equations

Item	Equation and Assumption	Remark
Annual Fuel $_i$ consumption (Tonnes per year)	AFi = Fuel $_i$ x 365 /1000 Where: AFi = Annual fuel i consumption Fuel $_i$ = fuel i consumption (kg/day) i = Pellet, fuel wood, charcoal, kerosene and LPG	Fuel $_i$ (kg/day) is input by the user
Annual pellet consumption equivalent (tonnes per year)	ABe = ∑(AFi/CFi) Where: ABe = Annual pellet equivalent AFi = Annual fuel i consumption CFi = Conversion factor of fuel i i = Pellet, fuel wood, charcoal, kerosene and LPG	Table 10 CF of pellet = 1 kg/ kg_{pellet} CF of fuel wood =6.11 kg/kg_{pellet} CF of charcoal = 1.14 kg/kg_{pellet} CF of kerosene = 0.32kg/kg_{pellet} CF of LPG = 0.26 kg/kg_{pellet} (Young & Khennas, 2003)
Energy expenditure of fuel i (USD per year)	EEi = Unit price fuel i x AFi x 1000 Where: EEi = Energy expenditure of fuel i Unit price fuel i (USD/kg)	Unit price fuel i (USD/kg) is input by the user

	AFi = Annual fuel i consumption i = Pellet, fuel wood, charcoal, kerosene and LPG	
Competitive price of pellet (USD per kg)	CPb = (∑EEi)/ ABe Where: CPb = Competitive price of pellet EEi = Energy expenditure of fuel i ABe = Annual pellet equivalent i = Pellet, fuel wood, charcoal, kerosene and LPG	

8.1.9 Project revenue calculation

The equations for calculating the project revenue are presented in Table 12.

Table 12: Project Revenue Equations

Item	Equation and assumption	Remark
Potential revenue (USD per year)	Pellet products x Market Price of pellet x 1000	Pellet products (tonnes per year) in Table 3, Market price of pellet (USD/kg) is input by the user

8.1.10 Pelletizing technologies

Table 13: Pelletizing Technologies Comparisons

Pelletizing Technologies	**Screw Press**	**Piston Press**	**Roller Press**	**Pellet Mill**	**Agglomerator**	**Manual**
Production capacity (kg/hr)	150 kg/hr	200 - 2,500 kg/hr	900-1,500 kg/hr	200 - 8,000 kg/hr	No information	6 kg/hr
Optimum moisture content of the raw material	8–9%	10–15%	10–15%	10–15%	No information	up to 80%
Particle size	Smaller	Larger	Larger	Smaller	Smaller-powder	Smaller-fibre
Wear of contact parts	High	Low	High	High	Low	Low
Output from machine	Continuous	In strokes	Continuous	Continuous	Continuous	In strokes
Specific energy consumption (kWh/t)	36.8-150	37.4-77	29.91-83.1	16.4-74.5	No information	No electricity
Through puts (t/hr)	0.5	2.5	5.0-10.0	5	No information	No information
Density of pellet	1-1.4 g/cm^3	1-1.2 g/cm^3	0.6-0.7 g/cm^3	0.7-0.8 g/cm^3	0.4-0.5 g/cm^3	No information
Maintenance	Low	High	Low	Low	Low	Low
Combustion performance of pellets	**Very good**	Moderate	Moderate	Very good	No information	Moderate
Carbonization of charcoal	Makes good charcoal	Not possible	Not possible	Not possible	Not possible	Yes
Suitability in gasifiers	**Suitable**	**Suitable**	**Suitable**	**Suitable**	**Suitable**	No information
Suitability for co-firing	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Suitability for biochemical conversion	Not suitable	Suitable	Suitable	Suitable	No information	No information
Homogeneity of densified biomass	Homogenous	Not homogenous	Not homogenous	Homogenous	Homogenous	Homogenous
Cost (USD)	1,350	20,000-30,000	14,000-19,000	No information	No information	150

Source: Tumuluru, Wright, Kenny, et al., 2010

8.1.11 Database for financial analysis

The database for the financial analysis of pellet production is presented in Table 14.

Table 14: Investment Cost of the Pellet System

Capacity of Pellet Production	**Unit**	**Tonne of Pellet (production per year)**			
		<20	**<200**	**<2000**	**<20,000**
Investment Cost of Equipment	USD	1,000	5,000	50,000-100,000	2,200,000
Lifetime of Equipments	Years	5	10	15	20
Estimate Equipment Cost (per t of pellet)	USD per tonne	10	3	3.3	6
Equipment		1 or 2 manual machines, e.g. lever extruder/ manual screw extruder Single Drum Kilns Sun-drying	Motorized machines that are fabricated locally, e.g. Electric screw extruder Sun-drying/solar driers	Motorized machines that are imported, e.g. Roller press/ large(flywheel) piston Sun-drying / Flash drier	Large-scale industrial machinery, imported, e.g. 8 t/h hydraulic pellet press Accelerated drying
Building and Land		Often in entrepreneurs house and garden, e.g. biomass storage, pellet storage, pelletizing plant	Can do at entrepreneurs residence or in a large garden, e.g. biomass storage, pellet storage, pelletizing plant	Dedicated factory needed. Approximate 2 acres of land, e.g. biomass storage, pellet storage, pelletizing plant	Large centralized factory, e.g. biomass storage, pellet storage, pelletizing plant, office building
	Assumption	Estimate at 20% of Total investment cost	Estimate at 20% of Total investment cost	Estimate at 44% of Total investment cost	Estimate at 44% of Total investment cost
	USD per tonne	2.50	0.63	2.62	4.32
Installation Cost	Assumption	Estimate at 10% of equipment cost	Estimate at 10% of equipment cost	Estimate at 10% of equipment cost	Estimate at 10% of equipment cost
	USD per tonne	1.00	0.25	0.33	0.55
Estimated Total Investment Cost	**USD per tonne per year**	**13.50**	**3.38**	**6.29**	**10.37**

Source: Ferguson, 2012; Young & Khennas, 2003

8.2 Data requirements for running the tool

Table 15 includes data requirements for running the *Pellets Component*. A suggested data source is provided.

Table 15: Data Requirements for Running the Tool

Data	Definition and Sources
Biomass and its residue	The user selects the biomass/crops and its residue for detailed analysis.
Price of feedstock	If the price of feedstock is not available, then the user will need information on hourly wages for skilled and unskilled workers (USD per employee per hour) and fuel consumption of machinery typically used in agricultural or forestry operations to calculate a proxy for this value.
Price of water	The user enters the current price of water (USD/m3).
Price of electricity	The user enters the current price of electricity (USD/kWh).
Price of diesel	The user enters the current price of diesel (USD/litre).
Feedstock storage cost (USD per tonne)	The user identifies the cost for storing the feedstock. The user can enter the current prices on storage for agricultural products in the country. If this information is not available in the country, then the user can estimate this based on the selection of the type of storage available in the country. Then, he/she can use the estimated global cost for building this type of storage, which is provided in the tool. Moreover, the size of the storage site or container is estimated using the biomass storage calculator.
Feedstock safety stock rate (%)	The user defines the values entered in each biomass storage calculator. These values define the percentage of biomass that should be reserved to operate the plant during shortage periods.
Pellet storage building cost (USD per tonne)	The user identifies the cost for storing the pellets. The user can enter the current prices on storage for agricultural products in the country. If this information is not available in the country, then the user can estimate this based on the selection of the type of storage available in the country. Then, he/she can use the estimated global cost for building this type of storage, which is provided in the tool.
Safety stock ratio of pellet products (%)	The user determines the pellet stock rate to ensure sufficient supply of pellets in the market.
Labour cost	Unskilled and skilled workers in unit of USD per employee per hour.
Working hours of feedstock collection	Working hours of feedstock collection for manual and mechanized methods.
The cost of transportation of feedstock (field/collecting point to plant) in unit of USD per tonne per km.	The user enters the cost of transportation in unit of USD per tonne per km. The user can use the current methods of transportation to move

	agriculture commodities within the country. If transportation is done on foot or by bike, the user can include this cost in the collection cost of feedstock. Alternatively, the user estimate the cost by using the cost of labour per hour, working time, the amount of material that can be transported and the approximate kilometres that can be travelled under the selected method.
The transportation distance of feedstock to pellet plant in kilometres by production capacity.	It is determined based on the availability of biomass in a particular area in relation to the amount required to operate each of the production capacity.
The cost of transportation of pellet products from plant to market in unit of USD per tonne per km.	The user enters the cost of transportation in unit of USD per tonne per km. The user can use the current methods of transportation to move agriculture commodities within the country. If transportation is done on foot or bike, it is recommended that the user estimates the cost by using the cost of labour per hour, working time, the amount of material that can be transported and the approximate kilometres that can be travelled under the selected method.
The transportation distance of pellet products to market in kilometres by production capacity.	The user identifies an estimated transportation distance that will be required to transport the pellet to market in kilometres according to the pellet production capacity.
Transformation efficiency by different types of feedstock	It relates to the densification conversion process whereby biomass feedstock is converted from a low bulk density (80–100 kg/m^3) to a high bulk density (900 to 1300 kg/m^3) pellet.
Operating parameters for pellet system	Such as operating days per year, operating hours per day of manual and mechanized pellet production.
Current market price of pellet	Market price of pellet (USD/kg) in rural and urban areas.
Costing parameters	Percentage of plant overhead cost, general and administrative cost and maintenance cost.
Financial parameters	○ Inflation rate (%) ○ Discount rate (%) ○ Loan ratio (%) ○ Loan interest rate (%) ○ Loan term (years), ○ Plant cost index http://base.intratec.us/home/ic-index
The types and quantities of typical fuels used for heating and cooking	Fuels are charcoal, fuel wood, kerosene and LPG that used for heating and cooking in urban and rural households (kg per day per household).
Price of fuels used for heating and cooking	The current price of fuels such as charcoal, fuel wood, kerosene and LPG in unit of USD/kg.

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