BEFS

BIOENERGY AND FOOD SECURITY RAPID APPRAISAL (BEFS RA)

User Manual

CHARCOAL

BEFS Rapid Appraisal

Energy End Use Options Module

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Intermediate or Final Products Sub-Module

Section 3: Charcoal

User Manual

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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 Labor 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.

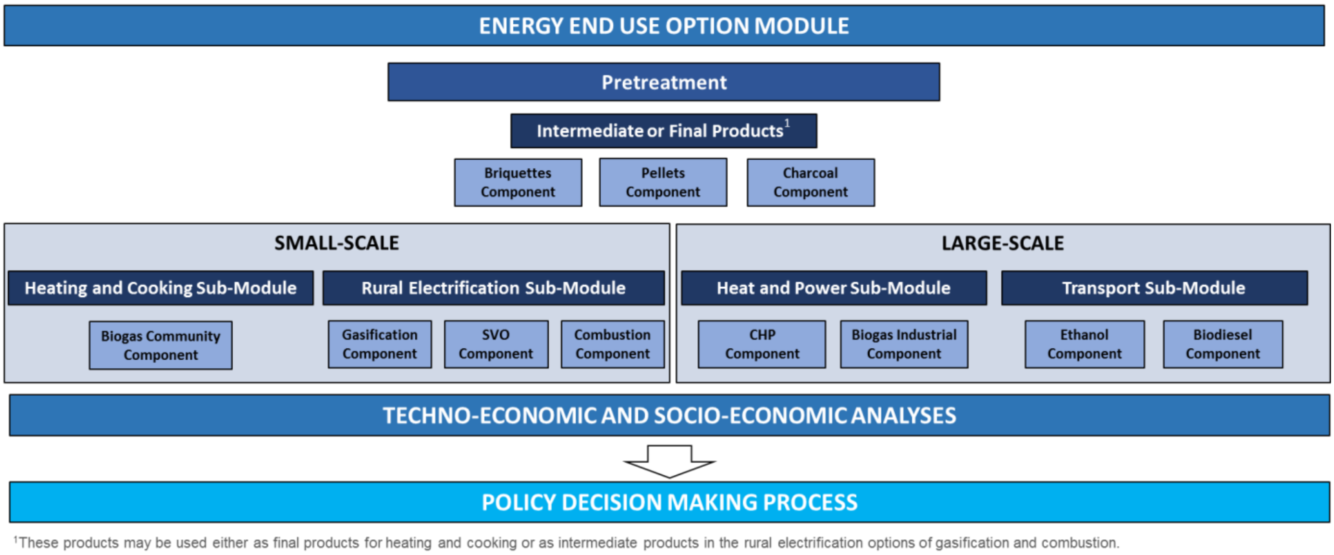


Figure 1: The Structure of the Energy End Use Option Module

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 *Charcoal Component*

The development of efficient and sustainable charcoal value chains requires the identification and promotion of viable options that address sustainable charcoal production and consumption. The introduction of improved designs in charcoal production technologies is one option to improve the production process and reduce pressure on forests. In this context, the *Charcoal Component* is designed to support the user in assessing the cost and benefits of improved charcoal production technologies and compare these to traditional charcoal making. The *Charcoal Component* also provides the user with the option to assess the viability of alternative feedstocks from forest harvest residues and wood products processing residues in charcoal production. The user can evaluate up to seven improved charcoal kilns ranging from small-scale or subsistence to medium and large-scale semi-industrial technologies. The kilns are: oil drum, casamance and improved pit Liberia.

This part of the BEFS RA has been developed based on an extensive literature review on the subject. The boundaries of the improved charcoal system analysed in the BEFS RA are shown in Figure 2. *Note that the tool focuses on assessing improvements in charcoal production. However, in defining a strategy for promoting sustainable charcoal value chains, other aspects such as proper management and planning of a supply source to support sustainable charcoal production and energy-saving through improved charcoal stoves should also be considered.*

[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.

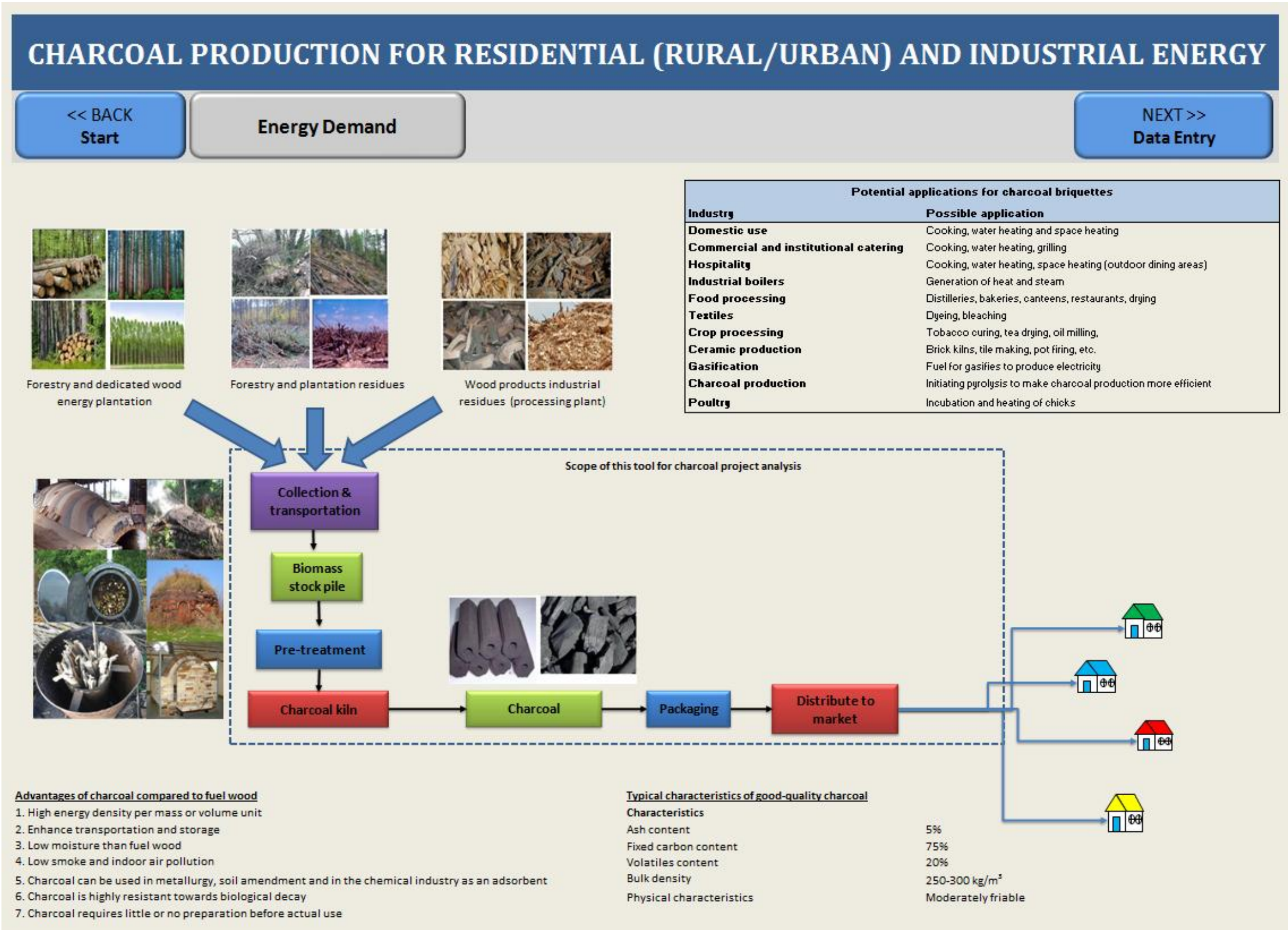


Figure 2: Biomass Charcoal System for Rural and Urban Heating and Cooking

After completing the analysis, the user will have an indication on the biomass used from the various kiln technologies and how these compare to traditional production in the country; the required investment and production cost; the employment generation potential and estimation of the number of households that can be supplied with the given current energy consumption for heating and cooking; and the financial viability associated to each kiln technology as shown in Figure 3. The user will also be able to compare across different biomass types (feedstock) to identify the most appropriate biomass sources based on a number of factors including physical availability, economic and social results.

General Outputs by Feedstock

Sustainable Production and Investment: Distribution of available biomass for specific feedstock, Biomass requirement per plant, Investment per plant and Sustainable number of plants

Socio-Economic Benefits: Total number of jobs and Total consumers supplied with charcoal

Economic and Financial Results: Production cost of charcoal, Net Present Value (NPV) and Profitability Index - under three production levels: ***Small, Medium and Large***

Comparative Outputs by Technology

Sustainable Production and Socio-Economic Benefits: Biomass requirement by feedstock for each selected technology, Comparison of sustainable number of plants for each feedstock, Total consumers supplied with selected technology, Comparison of total job creation potential of selected technology and Traditional comparable scale

Economic and Financial Results: Production cost of charcoal, Net Present Value (NPV) and Profitability Index - under three production levels: ***Small, Medium and Large***.

Figure 3: Layout of the Charcoal Results Sheets

3 Terms and Definitions in the *Charcoal Component*

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

- **Subsistence charcoal** production refers to small-scale producers that operate at a subsistence level and for whom charcoal production provides an opportunity for additional income generation.
- **Semi industrial** charcoal production refers to producers whose main activity is charcoal production.
- **Type of charcoal kilns:**
    - **The 200 litre horizontal oil drum kiln** is easy to construct and appropriate for household charcoal production. It is able to convert even small branches and farm residues to charcoal, and also yields wood vinegar, a by-product with significant farming applications. The capacity per drum is about 60-80 kg of wood yield 12-18 kg of charcoal (Burnette, 2010). The duration of carbonizing time is about 1.3-9.4 hours depending on the wood type and size. Typical efficiency of this kiln is 20% (Burnette, 2010).
    - **Casamance** is an improved earth kiln by which firing is done at the centre and the carbonization front advances towards the periphery. The radially-arranged stringers and the circumferential air space below the apron ensure constant air and gas flows in the mound. The chimney at one side of the mound encourages a very effective reverse, down-draft system. The sagging starts at the centre, leaving the circumferential air chamber intact throughout the burning period of the charge for continued ventilation. The duration of burn (i.e. from time of firing to time of sealing up the kiln for cooling) is eight days on average (Kimaryo & Ngereza, 1989). Typical efficiency of casamance is 25-30% (Kammen & Lew, 2005).
    - **The improved charcoal pit** installation and operation of this kiln involves digging a pit and using a cover made with metal sheets. This kiln produces charcoal more quickly and efficiently than the traditional pit and earth clamp methods. This method should not be used in rocky areas where digging the pit would be both difficult and excessively time consuming (Paddon, 1986). The cover of the kiln is formed using three over- lapping stock-sized mild-steel sheets, sprung into an angle-iron framework surrounding the top edges of the pit. The open ends of the cover are blocked up with mud. Metal tubes are set into the walls of the pit to provide 3 air inlets, 1 smoke outlet, and a steam release vent to assist lighting. Typical efficiency of this kiln is 25-30% (Kammen & Lew, 2005).
    - **Portable steel kiln** or transportable metal kiln is made of metal sheets. It is easily and frequently dismantled and rolled along the forest floor to follow commercial timber extraction, plantation thinning or land clearance operations. This means that the laborious and expensive transportation of wood to a centralized processing site can be avoided (FAO, n.d.-d). Two experienced men are required for operating the kiln. The total production cycle takes 2-3 days. The efficiency of portable steel kiln is 10%-37% (Kammen & Lew, 2005).
    - **Standard beehive** is built entirely of soft-burned, locally made clay/sand bricks and mud mortar. It requires no steel except a few bars of flat steel over doors and as reinforcement at the base of the dome, in the case of the Brazilian furnace. It is robust and is not easily damaged. It cannot be easily harmed by overheating and can stand unprotected in the sun and rain without corrosion or ill effects and have a useful life of 5 to 8 years. Carbonization time of 9 days with a production of 5 tonnes per cycle (FAO, n.d.-b). Typical efficiency of kiln 33% (Kammen & Lew, 2005).

- **The Missouri kiln** is rectangular and made of concrete fitted with large steel doors. The large doors allow loading and unloading of the kiln with a front-end loader, which considerably reduces the need for labour (FAO, n.d.-b). Typically, the volume of the Missouri kiln is 180 m^3, and production is 17.6 tonnes of charcoal during a 3-week production cycle (EPA, n.d.). The charcoal yield with the Missouri kiln varies between 20%-33% (Kammen & Lew, 2005; Rautiainen, Havimo, & Gruduls, 2012).
- **Somalia mound** generally has capacity ranges between 10 and 35 tonnes of air-dry timber. The kiln is built by stacking the timber upright on the soil floor. The timber is stacked into a circular mound two tiers high at the centre, with the larger pieces making up the lower tier. It is packed as close as possible and the gaps are filled with smaller pieces of wood. When the stacking is complete the timber is covered with metal sheets made from 200-litre empty oil drums. The sheets are placed over the timber stack and overlapped so that the edge of the lower one is underneath the edge of the sheet above it. Soil is placed over the thorny branch wood and metal sheets, forming a covering of approximately 5 cm thick. To light the kiln a worker climbs to the top and removes part of the soil and some of the upper sheets to gain access to the timber charge. The carbonization process takes 4-10 days, depending on the kiln size and condition of the timber(FAO, n.d.-e). Typical efficiency of this kiln is 39-42% (Kammen & Lew, 2005).

4 Scope and Objective of the *Charcoal Component*

The aim of the *Charcoal Component* is to assess: 1) the techno, socio and economic viability of improved charcoal technologies and compare them to traditional charcoal making and 2) the use of alternative biomass feedstock, forest harvest residues and wood processing residues for charcoal production. The tool provides the user with a technical foundation to perform a techno-economic analysis of alternative carbonization options to generate the type of information decision-makers need to address improvements in charcoal production. It particularly raises awareness on current production practices and the opportunities for improving production, as well as providing some indication on the requirements needed to enable producers to deploy more efficient “carbonization” technologies.

The section below describes the flow of analysis and options within this component. The background methodology for the charcoal analysis, assumptions and calculations is described in detail in the Annex.

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

5 Running the *Charcoal Component*

The flow of analysis within the *Charcoal Component* and the inter-linkages it has with other components is depicted in Figure 5. It is essential to note that the *Natural Resources* module generates basic information, and therefore a more detailed analysis regarding the sustainability of biomass production to supply charcoal production is needed. Moreover, when selecting the biomass feedstock and the inputting the quantities available, the user is responsible for ensuring that these values represent sustainable available resources in the country. Likewise, consideration to other issues along the value chain, i.e. cooking stoves, should be considered particularly when interpreting the results.

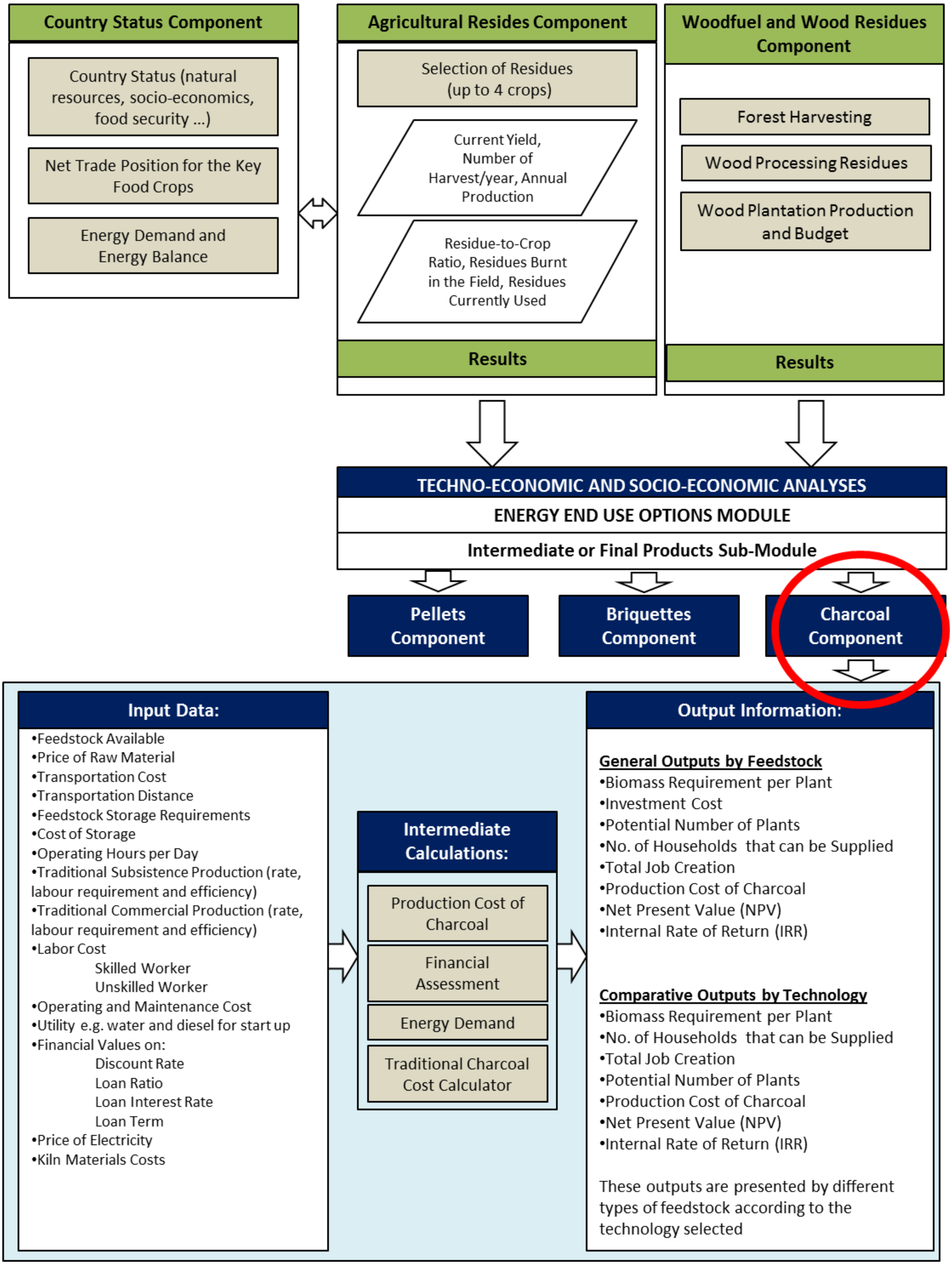


Figure 5: *Charcoal Component:* Flow of Analysis and Inter-linkages with BEFS RA Modules and Components

The user navigates step by step through the options and is asked to input the necessary data to obtain the 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.

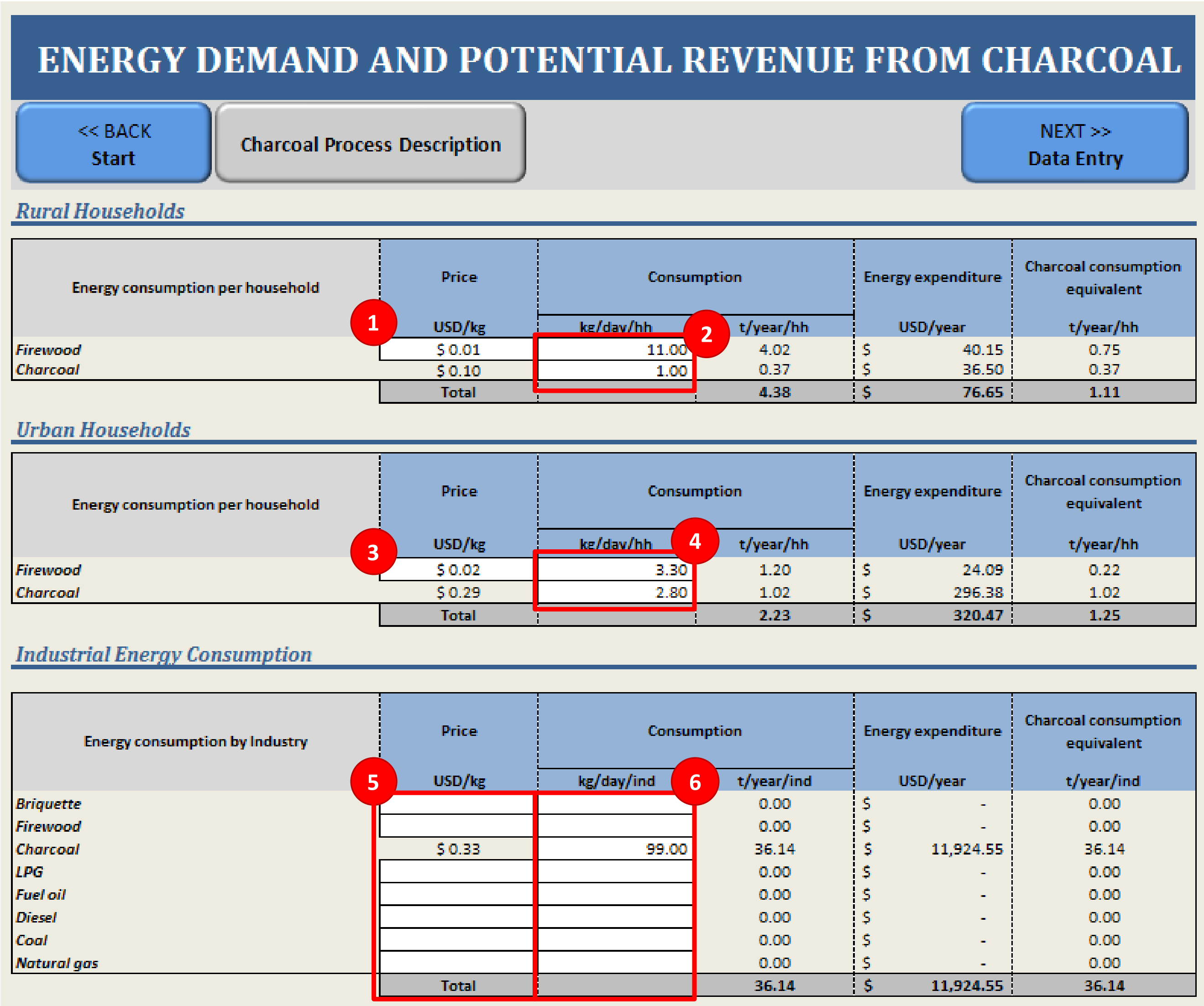
The following sub-chapters describe each step of the analysis, using **firewood and residues from the wood processing industry** as an example. All input parameters are based on a generic situation.

5.1 Step 1: Energy demand

The first step is to enter the market price of firewood and charcoal as well as current energy consumption. This must be done per household for rural and urban areas and for industries. These values are used to estimate the energy expenditure and charcoal consumption equivalent of consumers.

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

- Market price for each energy type in rural areas (Figure 6, label 1)
- Consumption for each energy type in rural households (Figure 6, label 2)
- Market price for each energy type in urban areas (Figure 6, label 3)
- Consumption for each energy type in urban households (Figure 6, label 4)
- Market price for each energy type for industries (Figure 6, label 5)
- Consumption for each energy type for industries (Figure 6, label 6)



Rural Households

Energy consumption per household	Price	Consumption		Energy expenditure	Charcoal consumption equivalent
	USD/kg	kg/day/hh	t/year/hh	USD/year	t/year/hh
Firewood	$ 0.01	11.00	4.02	$ 40.15	0.75
Charcoal	$ 0.10	1.00	0.37	$ 36.50	0.37
	Total		4.38	$ 76.65	1.11

Urban Households

Energy consumption per household	Price	Consumption		Energy expenditure	Charcoal consumption equivalent
	USD/kg	kg/day/hh	t/year/hh	USD/year	t/year/hh
Firewood	$ 0.02	3.30	1.20	$ 24.09	0.22
Charcoal	$ 0.29	2.80	1.02	$ 296.38	1.02
	Total		2.23	$ 320.47	1.25

Industrial Energy Consumption

Energy consumption by Industry	Price	Consumption		Energy expenditure	Charcoal consumption equivalent
	USD/kg	kg/day/ind	t/year/ind	USD/year	t/year/ind
Briquette			0.00	$ -	0.00
Firewood			0.00	$ -	0.00
Charcoal	$ 0.33	99.00	36.14	$ 11,924.55	36.14
LPG			0.00	$ -	0.00
Fuel oil			0.00	$ -	0.00
Diesel			0.00	$ -	0.00
Coal			0.00	$ -	0.00
Natural gas			0.00	$ -	0.00
	Total		36.14	$ 11,924.55	36.14

Figure 6: Energy Demand

5.2 Step 2: Defining the feedstock

Step 2.A Selection of feedstock

> **Note:** The user will need to know where the feedstock is coming from and consider its sustainability.

The user will:

1. Select the biomass to be considered as feedstock from the dropdown list. The options include briquettes, firewood, forest harvesting residues and wood processing residues. Up to three feedstocks can be analysed at the same time (Figure 7, label 1).
2. Enter the quantity of biomass sustainably available (t/year) (Figure 7, label 2).
3. Enter the biomass density of each feedstock selected (t/m^3) (Figure 7, label 3).

Table 1: Examples of Feedstock that can be Used in the Charcoal System

Feedstock	Source	Specific feedstock that can be used
Firewood	Forestry	Extraction from natural forest or
	Non-forest	Trees from outside the forest
	Dedicated energy plantations	*Acacia spp., Cunninghamia lanceolata, Eucalyptus spp., Pinus spp., Populus spp.* (poplars) and *Salix spp.* (willows)
Residues	Forestry and plantation residues	Limbs, stump, roots, etc.
	Residues from wood industry	Wood chips and barks, etc.
Briquettes	Briquettes industry	Pre-processing of small wooden pieces to make them suitable for charcoal production

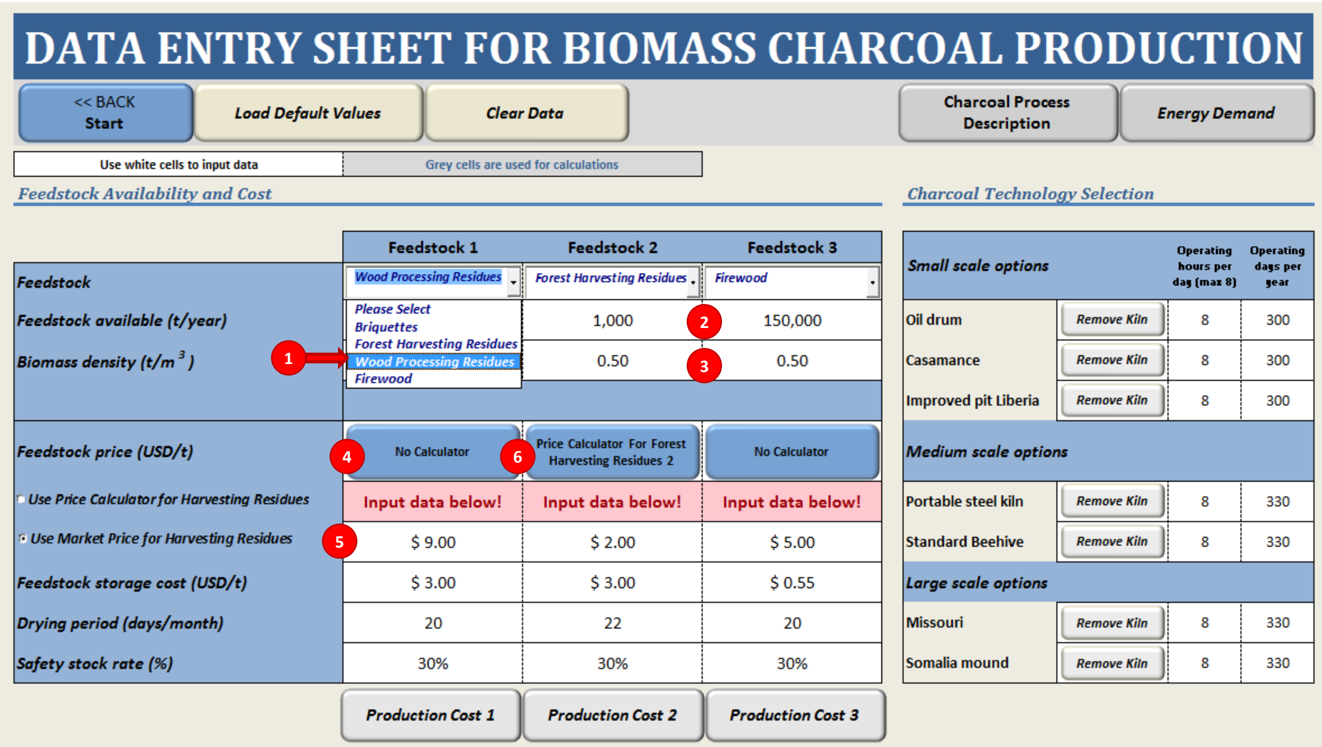
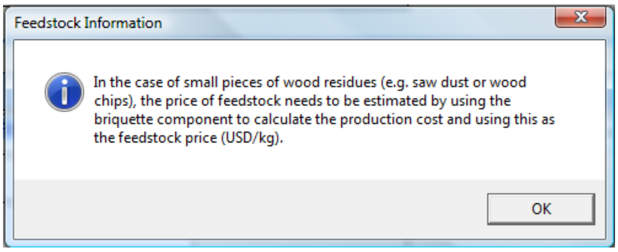


Figure 7: Feedstock Selection

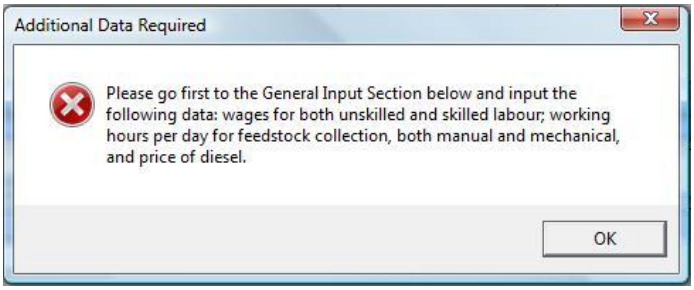
For this example, the selected Feedstocks are: Feedstock 1 "Wood Processing Residues", Feedstock 2 "Forest Harvesting Residues" and Feedstock 3 "Firewood" as shown in Figure 7.



Step 2.B Feedstock price (USD/t)

1. If the user selects firewood, or wood processing residues, a price for this feedstock will need to be entered. The text “No Calculator” will appear in the corresponding button (Figure 7, label 4).
2. In the case of small pieces of wood residues (e.g. saw dust or wood chips), the price of feedstock needs to be estimated by using the briquette component to calculate the production cost and using this as the feedstock price (USD/kg).

3. If forest harvesting residues is selected, the user has two options:
   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 5) 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 Calculator” and selecting the “Price calculator for Forest Harvesting Residues” (Figure 7, label 6).

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 the **“Labour”** section in the unit of USD per person-hour.
2. The working hours and price of diesel in the corresponding lines under **“Feedstock collection”.**

The “Price calculator for Forest Harvesting Residues” (Figure 8) assists the user in estimating the potential feedstock price based on the collection method in the forest.

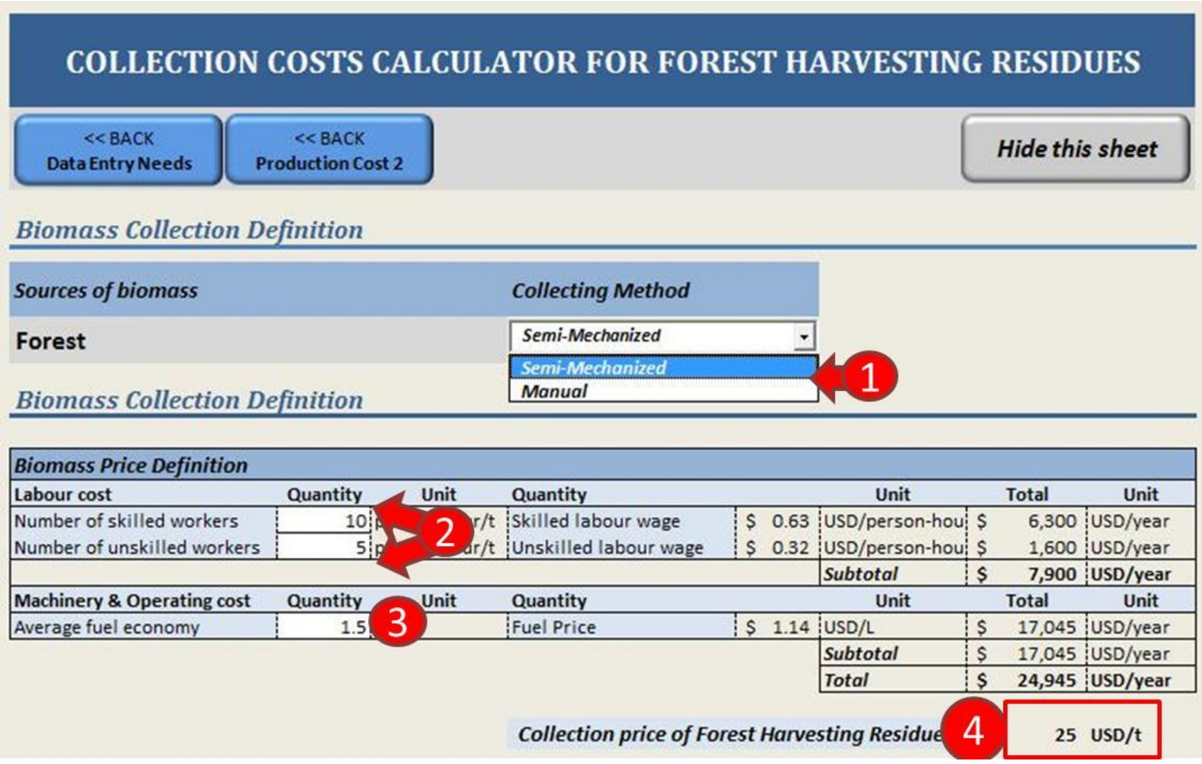


Figure 8: Feedstock Price Calculation based on the Collection Method and Source

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

1. Select the *biomass collection method* from the following options (Figure 8, label 1):
   - manual
   - semi-mechanized

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

2. Enter the labour requirements (person-hour/t) (Figure 8, label 2) and the fuel needs (litres per hectare) (Figure 8, label 3) associated with the selected biomass collection method. To return to the previous section, the user must click on the “<<BACK Data Entry Needs” button.

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

The calculator will automatically generate a feedstock price (Figure 8, label 4), and this value is transferred to the “Data Entry Needs” worksheet for further calculation.

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

For this example, the selected Feedstock 2 “Forest Harvesting Residues” is assumed to come from forest activities and the collection method is “semi-mechanized”. The number of person-hours for unskilled workers is 10, the number of man-hours for skilled workers is 5, and the diesel consumption of the machine is 1.5 litres per hectare. As a result, the proxy price of the feedstock is calculated at 25 USD per ton (Figure 8).

Step 2.C Feedstock storage cost (USD/t)

Step 2.C.1 The user can enter *the existing prices* of storage of agricultural/forestry 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.C.2 The user can determine a *proxy* for this value. The user will need to do the following:

1. Identify a type of 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.
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. charcoal.

Table 2: Estimate Cost of Storage

Estimate 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 feedstocks are stored outside in unprotected ground at an estimated cost of 3 USD/tonne. (User inputs the cost in the corresponding cells as shown in Figure 9, label 7).

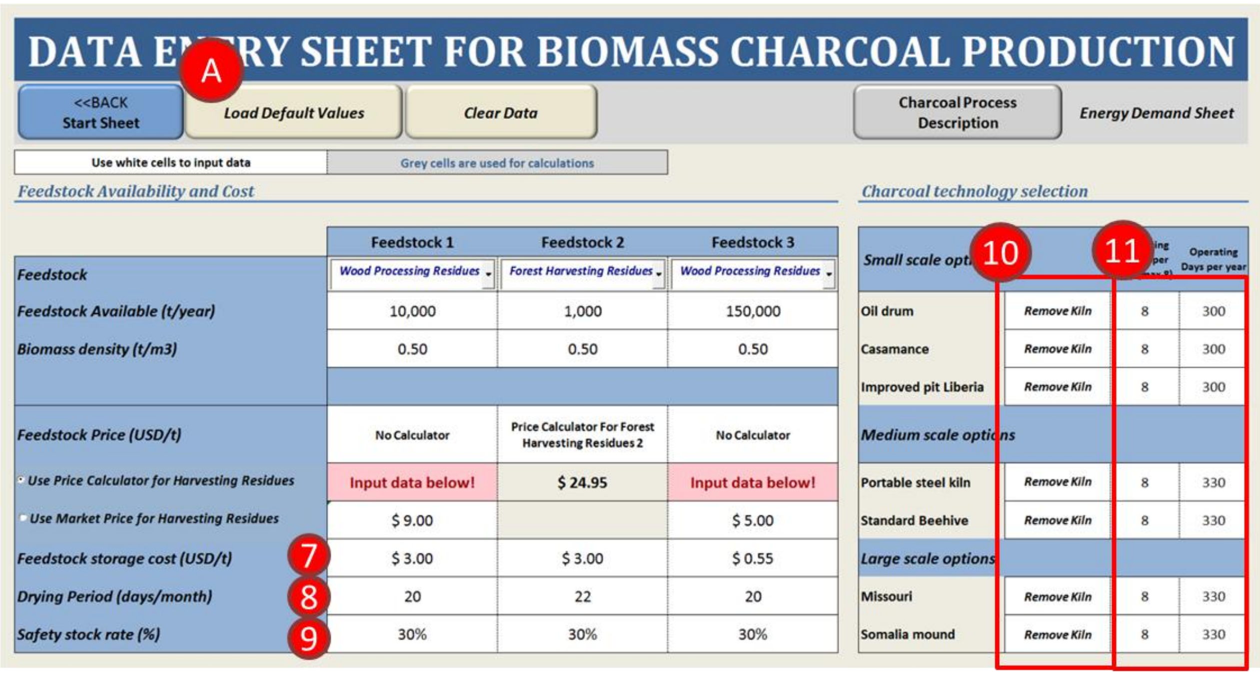


Figure 9: Feedstock Storage Cost, Drying Period, Safety Stock Rate and Kiln Technology

Step 2.C.3 Drying period (days/month)

Freshly cut wood has high moisture content of up to 50% (wet basis), which needs to be dried-up to a moisture content of 18%-20% prior to carbonization. The user will need to define the drying period (Figure 9, label 8) for each type of feedstock. The drying period depends on the initial moisture content and size of the wood.

Guidance: Not less than 4-5 weeks air drying time is recommended for 1.00 m - 1.30 m length with a minimum diameter 0.05 m (FAO, n.d.-c). Wood billet size 0.45 m - 0.60 m long and up to 0.20 m in diameter requires at least 3 weeks of drying (Paddon & Harker, 1980).

Step 2.C.4 Security stock rate (%)

The user must identify the security stock rate (Figure 9, label 8) needed to ensure the sufficient feedstock supply, taking into account the uncertainty of biomass production yield due to seasonal availability, flood, drought, and other factors. This security stock rate is used to estimate the storage capacity.

Note: This same security storage rate is used for products, except for small-scale kilns, e.g. oil drum, casamance and improved pit Liberia, where a value of 10% was assumed by default.

Step 2.D Charcoal technology selection

The user has the option to select one or several improved kilns to evaluate from a list of seven improved kiln technologies: Oil drum, Casamance, Improved pit Liberia, Portable steel kiln, Standard Beehive, Missouri and Somalia mound. To select the kiln technology, the user clicks on the "Add Kiln" button to add that kiln to the comparative analysis or clicks on the "Remove Kiln" button to delete it (Figure 9, label 10).

For this example, the values shown in Figure 9 are used to carry out the analysis.

5.3 Step 3: Traditional existing charcoal production in the country

The following applies to the information required for the current technology and features:

1. First, the user has two options when selecting the data source (Figure 10, label 1):
    - If information on the current charcoal production in the country is readily available, the user enters it in the respective cells (clicks "Own Values").
    - If this information is not available, the user can run the price calculator (clicks "Price Calculators").
2. Secondly, the user has to select the scale of operation by clicking on the appropriate square (Figure 10, label 2). The options are:
    - Small-scale/subsistence
    - Medium/large semi-industrial
    - Or both

3. If the user has selected to input his/her own information (Step 1), then those values need to be entered in the appropriate cells (Figure 10, label 3).
4. Alternatively, if the user decides to use the price calculators, then he/she needs to provide information on traditional charcoal production in the country by clicking on the appropriate buttons (Figure 10, label 4). The required information to run the calculator is: average production efficiency, average production cost and average investment costs (e.g. equipment cost, building cost, installation cost, plant overhead and administrative costs).

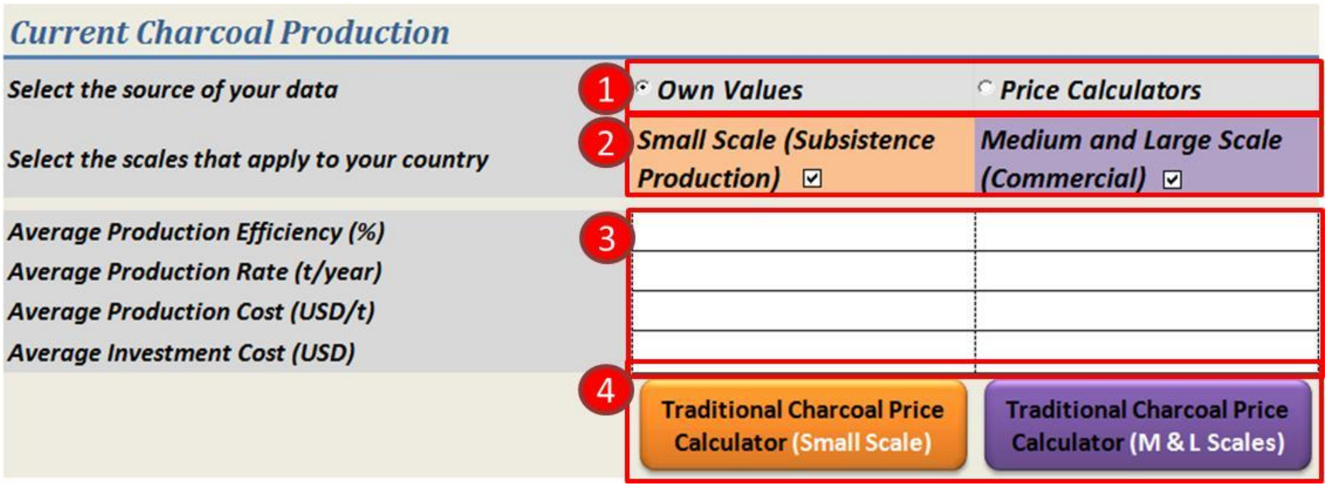
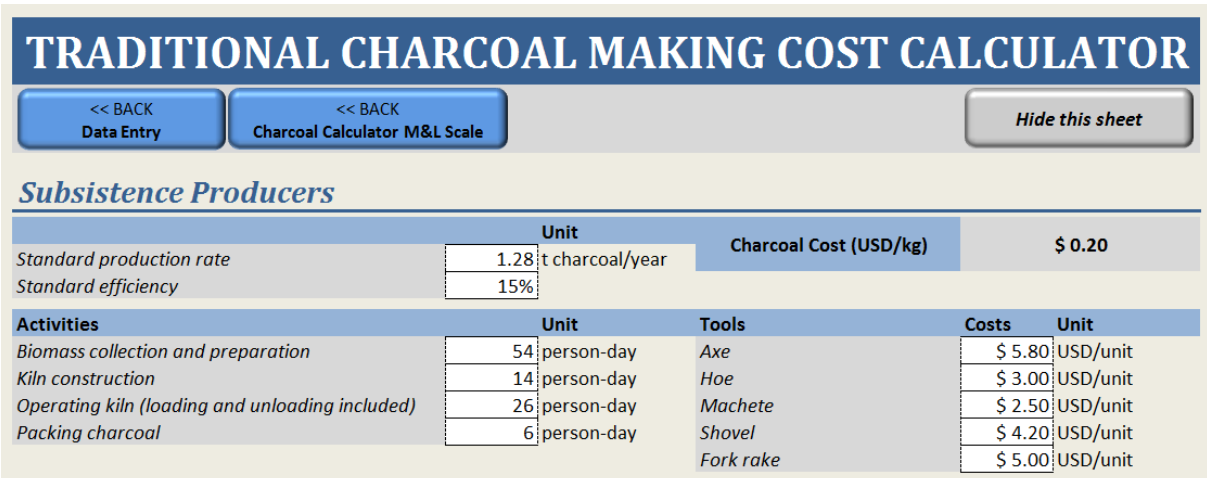


Figure 10: Traditional Existing Charcoal Production

Both calculators require data on the standard production rate, efficiency, labour requirements and equipment used (Figure 11 and 12). Once this information is entered, the user can return to the previous section by clicking on the "<<BACK Data Entry" button. The production cost will be automatically calculated and all relevant information will be inputted in the respective cells.



		Unit		
Standard production rate	1.28	t charcoal/year	Charcoal Cost (USD/kg)	$ 0.20
Standard efficiency	15%			

Activities		Unit	Tools	Costs	Unit
Biomass collection and preparation	54	person-day	Axe	$ 5.80	USD/unit
Kiln construction	14	person-day	Hoe	$ 3.00	USD/unit
Operating kiln (loading and unloading included)	26	person-day	Machete	$ 2.50	USD/unit
Packing charcoal	6	person-day	Shovel	$ 4.20	USD/unit
			Fork rake	$ 5.00	USD/unit

Figure 11: Traditional Small-scale Charcoal Price Calculator

TRADITIONAL CHARCOAL MAKING COST CALCULATOR

<< BACK Data Entry | << BACK Charcoal Calculator Small Scale | Hide this sheet

Commercial Producers

		Unit	Charcoal Cost (USD/kg)	$ 0.16
Standard production rate	50	t charcoal/year		
Standard efficiency	20%			

Activities		Unit	Costs		Unit
Biomass preparation	28	person-day	*Feedstock cost*	25	USD/t
Kiln construction	6	person-day	*Transport cost*	0.5	USD/t/km
Operating kiln (loading and unloading included)	13	person-day	*Storage cost*	3	USD/t
Packing charcoal	3	person-day	*Unskilled worker wage*	0.5	USD/person-h
Supervising charcoal processing	50	person-day	*Skilled worker wage*	2	USD/person-h
Transportation distance (Fs -> Plant)	10	km	*Investment cost*	100	USD

Figure 12: Traditional Medium and Large-scale Charcoal Price Calculator

For this example, the values shown in Figure 11 and Figure 12 are used to carry out the analysis.

5.4 Step 4: Production cost and financial parameters

General inputs required to run the operations are shown in Figure 13. The user will need to provide data on:

Production Cost and Financial Parameters

Labour cost for medium and large scale production		Units			Units
Unskilled worker	$ 0.32	USD/person-hour	*Skilled worker*	$ 0.63	USD/person-hour
Feedstock Collection		**Units**			
Working hours per day (Manual)	8	h/day	*Working hours per day (Mechanized)*	18	h/day
Diesel	$ 1.00	USD/l			
Transportation cost		**Units**			**Units**
Feedstock (field to Charcoal production plant)	$ 0.05	USD/t/km	*Charcoal production plant to market*	$ 1.10	USD/t/km
Charcoal product storage		**Units**			
Charcoal storage cost	$ 3.00	USD/t			
Other costs					
			Plant Overhead (%)	10%	
General and Administrative (%)	5%		*Maintenance (%)*	10%	
Price of Charcoal		**Units**			
Market price (rural areas)	$ 0.10	USD/kg charcoal	*Share of market price paid to small scale Producers*	30%	
Market price (urban areas)	$ 0.29	USD/kg charcoal	*Share of market price paid to medium and large scale Producers*	60%	
Market price (industrial)	$ 0.33	USD/kg charcoal			
Financial parameters			**Basic Construction Materials for Kilns**		
Discount rate (%)	8%		*Brick*	$ 0.10	USD/unit
Loan ratio (%)	90%		*Concrete*	$ 93.67	USD/m³
Loan interest rate (%)	18%		*Oil Drum (200 liter)*	$ 30.00	USD/unit
			Angle iron for frame 40 x 40 x 5 mm	$ 24.00	USD/unit
			Metal Sheet (thickness 30 mm)	$ 24.33	USD/m²
			http://www.themetalstore.co.uk/products/mild-steel-sheet	Investment Details	

NEXT>> Summary of Results by Technology | NEXT>> Summary of Results by Feedstock

Figure 13: General Inputs

1. **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 charcoal production process.
2. **Feedstock collection:** this information will be entered only if the feedstock price calculator is used, refer to Step 2.B.

3. **Transportation cost of feedstock (USD/t/km):** cost of transportation of feedstock from the collection point to the charcoal plant. The user will need to:
   - Identify the current methods of transportation of moving wood forestry/plantation within the country.
   - Define the current transportation prices associated with the transportation method identified above in unit of USD per tonne per km.

> **Guidance:** If the method of transportation is by person or bike, then it is recommended that 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 as given in the following equation:
>
> Transportation cost (USD/tonne/km)
>
> $$= \frac{\text{Hourly wages (USD/hour/person) x Working time (hours)}}{\text{Transportation distance (km) x Feedstock transport (tonne/person)}}$$
>
> 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.

4. **Transportation cost of charcoal (USD/t/km):** cost of transportation of charcoal 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.

5. **Charcoal product storage cost (USD/t):** cost of charcoal storage defined by the user. The user can enter the average storage cost for agricultural products in the country. If this information is not available, instructions on how to estimate this value are provided below.

> **Guidance:** Normally, charcoals are packed (e.g. 30-50 kg per sack) and stored ideally under a shed. The user selects a type of storage, e.g. reusable tarp on crushed rock. For each storage method, average global figures for building costs are provided in Table 2.

6. **Other costs (%):**
   The user enters the percentage of:
   - General and administrative costs,
   - Plant overhead and
   - Maintenance cost.

   These parameters are used to estimate the production cost of charcoal.

7. **Market price of charcoal (USD/kg):**
   The user will also need to:
   - Provide a current market price of charcoal (USD per kg) (price paid by consumers) in rural, urban and industrial markets.

> **Note:** It is assumed that small-scale kilns, e.g. oil drum, casamance and improved pit Liberia, do not have these costs.

- The user will need to identify the share of the market price that is paid to small-scale producers and medium/large semi-industrial producers.
- Table 3 shows some samples on the distribution of market prices along the value chain presented in various countries. For example, in the case of Malawi most charcoal producers receive only 21-33% of the final sales price (market price), transport is about 20-25%, market fee is around 3%, private taxes are around 12-20%, while the share for the retailers is about 24-33%. The user can use this information to determine the price paid to the charcoal producer. In the case of Malawi, if charcoal is ***sold at kiln site*** then the 21-33% applies. If the charcoal is sold at another point, then the costs should include the transportation cost and should be cross referenced with transportation in Step 4.

Guidance: One can consider small-scale producers (typically subsistence producers) as those that mostly sell at kiln site and only receive a portion of the market price. Semi-industrial producers may transport their product to the nearby market and sell it to wholesalers making a portion of the price paid by consumers.

The market price of charcoal and the share paid to producers is used to analyse the total potential revenue of the charcoal system of the selected kiln technologies.

Table 3: Cost Structure in Percentage of Market Price of Charcoal

Country	Malawi	Philippines	Pakistan	Nepal	Thailand
Retailer/Urban retailer/ Repacked	24%-33%	19%-35%	12%	8%	46%
Private taxes	12%-20%				
Market fee	3%				
Urban Wholesaler		0%-6%	6%		
Transport	20-25%	6%-15%	10%	12%	
Rural trader		11%-30%			
Stockholder		9%-13%			
Labour (Packing)/Assembler	0%-6%	0%-7%			
Producer	21%-33%	30%-53%	33%	79%	14%
Wood cutter/collector			39%		11%
Land/tee owner		0%-15%			29%

Source: (FAO-RWEDP, 1996; Kambewa, Mataya, Sichinga, & Johnson, 2007)

8. **Financial parameters (%):**

The user identifies the values as a percentage for the following financial parameters:

- Discount rate,
- Loan ratio and
- Loan interest rate.

Guidance: The loan terms are assumed to be the same as the lifetime of the equipment for most technologies.

9. **Basic construction materials for the kilns:**

The user enters the prices of the construction materials required to build the kilns:

- Brick (USD/unit),
- Concrete (USD/m^3),

- Oil drum (USD/unit),
- Angle Iron frame (USD/unit) and
- Metal Sheets (USD/m^2).

These values are used to estimate the investment cost for each kiln. Note that not all construction materials are associated to one kiln; rather, each kiln has different material requirements.

5.5 Step 5 (Optional): Calculation of the production cost of charcoal

After completing all of the data entries required in Steps 1 to 3, the user has the option to enter additional information on the production cost of charcoal by clicking on the "Production Cost" button in the Data Entry Sheet. This will take the user to the budget processing section for the selected feedstock (Figure 14).

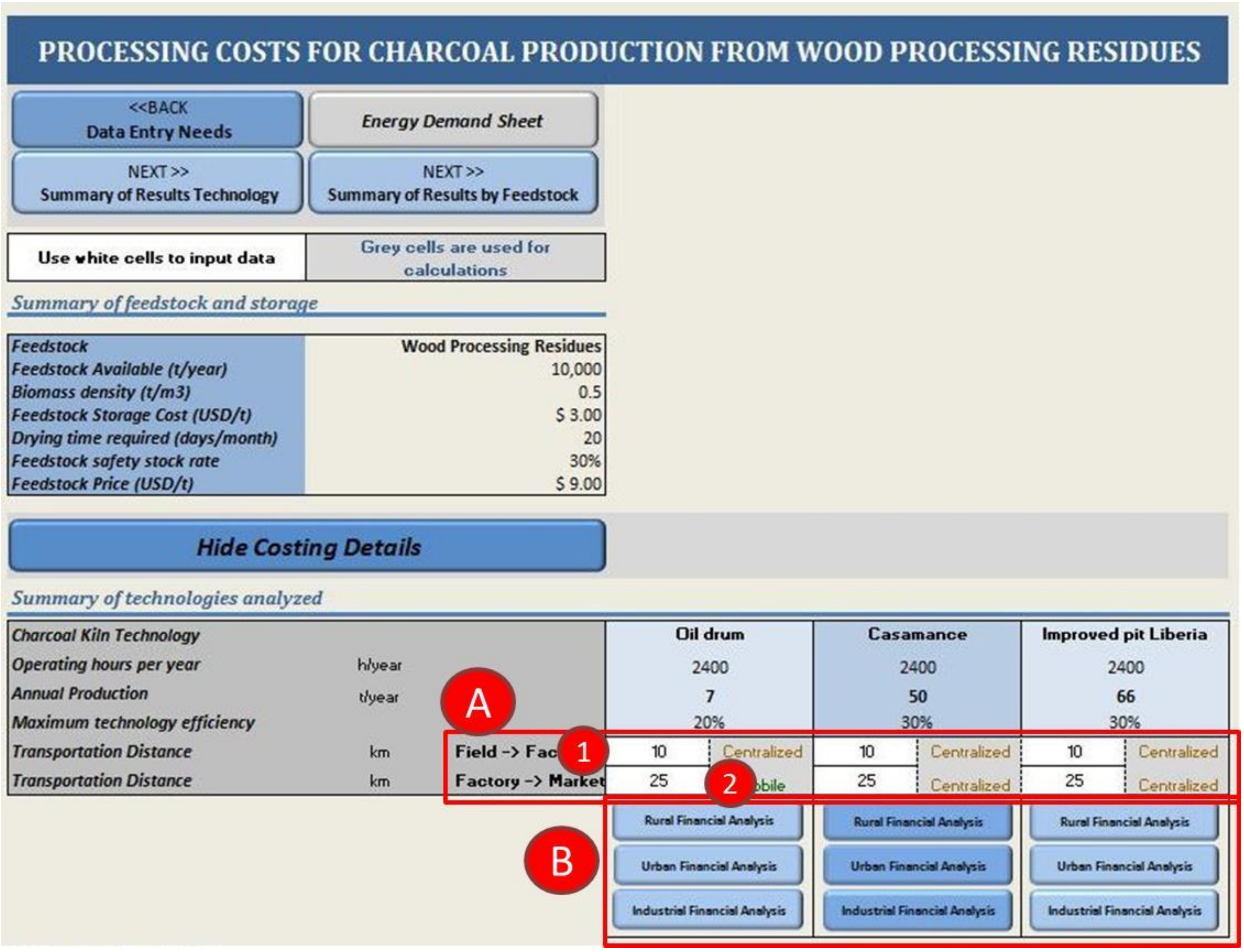


Figure 14: Production Cost Calculation

In this worksheet, the user will:

1. Need to enter additional data in the white cells, specifically on:

Guidance: The oil drum consumes less biomass compared to others. Therefore, the transportation distance could be smaller. The portable steel kiln operates where feedstock is available, so the transportation distance is zero.

- **The transportation distance of the feedstock to the charcoal plant:** The user identifies an estimated transportation distance that will be required to transport the feedstock in kilometres (Figure 14, label 1) for each selected kiln technology. The transportation distance depends on the availability of feedstock in a particular area and the amount of feedstock required for each kiln capacity.

- **The transportation distance of charcoal products to market:** The user identifies an estimated transportation distance that will be required to transport the charcoal to market in kilometres for each kiln technology (Figure 14, label 2).

> **Guidance:** If the producer price is assumed to sell at the kiln site, then the distance should be "zero" and the user should cross reference this with the market prices decisions.

2. Review the financial analysis by pressing the "Financial Analysis" buttons (Figure 14, redbox B). This will open the worksheet detailing the financial analysis for each kiln technology.

6 Assumptions and Limitations of the *Charcoal 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 *Charcoal Component* are:

1. The seven improved kiln technologies considered in this component are: Casamance, Somalia mound, Improved pit Liberia, Standard Beehive, Missouri, Portable steel kiln and Oil drum.
2. Charcoal production capacity (tonnes per year) is for one kiln installation only:
   - Small scale:
     - Oil drum 7 tonnes per year
     - Casamance kiln 50 tonnes per year
     - Improved pit Liberia 66 tonnes per year
   - Medium Scale:
     - Portable steel kiln 183 tonnes per year
     - Standard Beehive 203 tonnes per year
   - Large Scale:
     - Missouri 305 tonnes per year
     - Somalia mound kiln 383 tonnes per year
3. The annual working hours of workers defined by the user in the data entry section include wood pretreatment (e.g. cutting, drying, stacking, etc.), kiln construction and/or installation, wood loading into kiln, kiln operation, charcoal unloading and packing. Biomass collection is only included for the forest harvesting residues option, where the user will have a collection calculator available. Conversely, for other feedstock options it is assumed that collection cost is included in the price defined by the user.
4. Optimum moisture content of the feedstock 18-20%.
5. The financial analysis is performed assuming a time horizon of three years for small-scale technologies and of six years for medium and large-scale technologies. Plant investment takes place at appraisal time for all kinds of plants; as a result, in the cases of Portable Steel Kiln and Somalia Mound, we took

the specific assumption that investment takes place at the beginning of the time horizon for all plants replacements.

6. The cash outflow related to investment takes place the year before the plant starts operating.
7. The debt terms equal the lifetime of the chosen plant (with the exceptions of Portable Steel Kiln and Somalia Mound).

The details of key assumptions and calculation equations, together with a brief discussion of the main related limitations, are presented in the Annex.

7 The Results of the *Charcoal Component*

7.1 Overview of the production cost calculations (optional)

After the user inputs all required data (Steps 1 to 4), then the user has the option to review the detailed production cost as shown in Figure 14. There are three main sections in this worksheet presented in Figure 15.

- **PART 1** (Figure 15, 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, and loan interest. The total production costs (USD/year) of the selected kiln technologies are also summarized.
- **PART 2** (Figure 15, label 2) shows the unit cost of charcoal (USD/kg of charcoal) for each of the selected kiln technologies.
- **PART 3** (Figure 15, label 3) summarizes the loan details, e.g. loan amount, loan interest, annual loan payment, etc., for financial analysis.

Summary of Technologies Analyzed

Charcoal kiln technology			Oil drum		Casamance		Improved pit Liberia	
Operating hours per year	h/year		2400		2400		2400	
Annual production	t/year		7		50		66	
Maximum technology efficiency			20%		30%		30%	
Transportation distance	km	Field -> Factory	10	Centralized	10	Centralized	10	Centralized
Transportation distance	km	Factory -> Market	25	Mobile	25	Centralized	25	Centralized
			Rural Financial Analysis		Rural Financial Analysis		Rural Financial Analysis	
			Urban Financial Analysis		Urban Financial Analysis		Urban Financial Analysis	
			Industrial Financial Analysis		Industrial Financial Analysis		Industrial Financial Analysis	

1

Production Cost Details

			Capacities (t charcoal/year)					
			7		50		66	
Inputs	**Unit**	**Unit Price (USD/Unit)**	**Quantity (Unit/year)**	**Total (USD/year)**	**Quantity (Unit/year)**	**Total (USD/year)**	**Quantity (Unit/year)**	**Total (USD/year)**
Feedstock	t	$ 9.00	32.9	$ 296	165.7	$ 1,491	220.9	$ 1,989
Subtotal				$ 296		$ 1,491		$ 1,989
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)**
Unskilled worker	# employee	$ 0.32	1.0	$ 768	1.0	$ 768	2.0	$ 1,536
Skilled worker	# employee	$ 0.63		$ -	1.0	$ 1,512	-	$ -
Subtotal				$ 768		$ 2,280		$ 1,536
Transport of feedstock	**Unit**	**Unit Price (USD/t/km)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**
Feedstock (farm to plant)	km	$ 0.05	10.0	$ 16	10.0	$ 83	10.0	$ 110
Charcoal (plant to market)	km	$ 1.10	25.0	$ 181	25.0	$ 1,367	25.0	$ 1,823
Subtotal				$ 197		$ 1,450		$ 1,933
Storage	**Unit**	**Unit Price (USD/t)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**	**Quantity (Unit)**	**Total (USD/year)**
Feedstock	t/year	$ 3.00	6.8	$ 20	51.7	$ 155	68.9	$ 207
Charcoal products	t/year	$ 3.00	0.7	$ 2	5.0	$ 15	6.6	$ 20
Subtotal				$ 22		$ 170		$ 227
Investment	**Unit**		**Depreciation (USD/year)**		**Depreciation (USD/year)**		**Depreciation (USD/year)**	
Equipment	USD/year		$ 21.74		$ 17.69		$ 260.24	
Building	USD/year		$ 5.43		$ -		$ -	
Installation	USD/year		$ 2.17		$ -		$ 26.02	
Total investment depreciation			$ 29.35		$ 17.69		$ 286.27	
Maintenance cost		10%		$ 3		$ 2		$ 29
Subtotal				$ 32		$ 19		$ 315
Other costs	**Unit**	**Rate (%)**	**Specific Rate (%)**	**Total (USD/year)**	**Specific Rate (%)**	**Total (USD/year)**	**Specific Rate (%)**	**Total (USD/year)**
Plant overhead	USD		0%	$ -	0%	$ -	0%	$ -
General and administrative cost	USD		0%	$ -	0%	$ -	0%	$ -
Loan interest	USD		18%	$ 10	18%	$ 6.0	18%	$ 98
Subtotal				$ 10		$ 6		$ 98
			Total (USD/year)	**Share (%)**	**Total (USD/year)**	**Share (%)**	**Total (USD/year)**	**Share (%)**
Total operating costs			$ 1,283	97%	$ 5,391	100%	$ 5,684	93%
Total fixed costs			$ 32	2%	$ 19	0%	$ 315	5%
Total other costs			$ 10	1%	$ 6	0%	$ 98	2%
Total production costs			$ 1,326		$ 5,417		$ 6,097	

2

	Capacities (t charcoal/year)		
	7	50	66
	Oil Drum	Casamance	Improved pit Liberia
Unit cost of charcoal + transport (USD/kg of charcoal)	$ 0.202	$ 0.109	$ 0.092

3

			Oil Drum		Casamance		Improved pit Liberia	
Average loan interest	**Unit**	**Loan ratio (%)**	**Total investment (USD)**	**Loan amount (USD)**	**Total investment (USD)**	**Loan amount (USD)**	**Total investment (USD)**	**Loan amount (USD)**
Loan amount	USD	90%	$ 88.04	$ 79.24	$ 53.06	$ 47.76	$ 858.80	$ 772.92
Loan interest rate	%			18%		18%		18%
Annual loan payment	USD/year			-$ 36.44		-$ 21.96		-$ 355.48
Loan terms	year			3		3		3
Total loan payment	USD			-$ 109.33		-$ 65.89		-$ 1,066.45
Loan interest	USD			-$ 30.09		-$ 18.14		-$ 293.53
Average loan interest	USD/year			-$ 10.03		-$ 6.05		-$ 97.84

Figure 15: Detail of Production Costs of Charcoal by Kiln Technology

For the wood processing residues, the total production cost of oil drum technology is 1,326 USD per year, the unit cost of charcoal is 0.202 USD/kg. Note that due to space limitations, Figure 15 shows only 3 options from 7 that were previously selected.

7.2 The summary results by feedstock

The information presented in this section aims to generate information to put into perspective the charcoal sector in the country, the implications in the implementation of improved charcoal processing technologies as well as the uses of alternative biomass from residues. The results aim to answer the following questions:

- What are the biomass savings that can be realized through the implementation of more efficient charcoal production technologies?
- What are the investment cost requirements for the improved technologies?
- What is the cost of production of charcoal using improved vs traditional technologies and how does it compare to traditional production cost?
- What is the employment effect from the different improved charcoal technologies and how does it compare to traditional technology?
- How many end users (households or industries) can be supplied under different kilns?

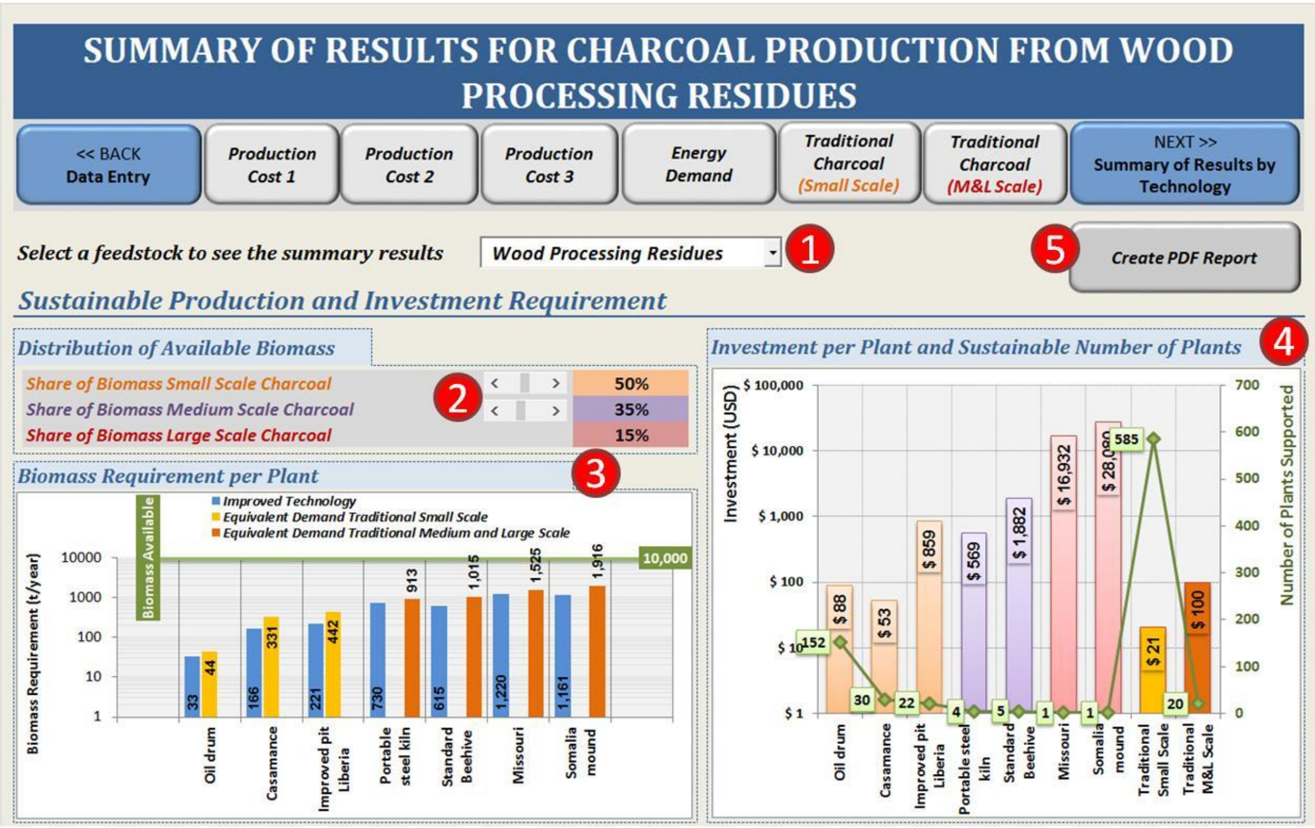


Figure 16: Sustainable Production and Investment Results

1. The user first selects the feedstock (Figure 16, label 1) that is to be reviewed from the drop down menu. The results for that specific feedstock will be generated.

2. The biomass available for the selected feedstock needs to be distributed among the available production scales (small, medium, and large) (Figure 16, label 2). This decision will affect the number of plants that can be potentially supplied of each selected technology.
3. Conversely, the biomass available for the selected feedstock is compared with the biomass demand required to run each technology (Figure 16, label 3). Additionally, this chart informs the user the amount of biomass that would be required to match the production rate of the improved technology by using a traditional technology (yellow and orange bars). These calculations are based on kiln efficiencies for traditional and improved technologies.
4. The investments requirements and the sustainable number of plants for each selected technology are presented and compared with traditional technologies (Figure 16, label 4).

In this example, it is assumed that the charcoal sector in the country is comprised of 50% small-scale, 35% medium-scale and 15% large-scale charcoal producers. Focusing on the oil drum technology, to produce seven tons per year of charcoal using this type of technology needs about 33 t/year. To produce the same amount of charcoal using the traditional technology would require 44 t/year. Comparing the two technologies indicates that an 11 t/year of biomass can be saved by using the improvement oil drum technology. On the other hand, one realizes that the investment cost for the oil drum technology is 88 USD, while a traditional technology would require 21 USD. A similar comparison can be performed for the other technologies as shown in Figure 16.

5. The socio-economic benefits of charcoal production from selected feedstock are presented as follows:
   - Total Number of Jobs (Figure 17, label 1) is based on the sustainable number of plants supported for the selected feedstock (Figure 16, label 4).
   - Total Number of Consumers Supplied with Charcoal (Figure 17, label 2) - The user can alternate the results of this chart across three different categories (rural, urban and industries) (Figure 17, label 3).

Figure 17: Socio-Economic Benefits Results

Deploying the improved oil drum based technology will have some socio-economic trade-offs. Using the availability of wood residues available in the country to produce charcoal with the oil drum technology can potentially create 152 jobs and supply energy for 800 rural households. If, instead, traditional charcoal production technologies are used, 585 jobs for small-scale producers can be created and supply energy to 600 rural households. For other technologies results, refer to Figure 17.

6. Economic and Financial results are presented and compared across three categories as follows:
   - Production cost of charcoal (Figure 18, label 1),
   - Net Present Value (NPV) (Figure 18, label 2) and
   - Profitability Index (Figure 18, label 3).

   The user can alternatively select the market price (rural, urban, and/or industrial) shown in charts by clicking the appropriate checkboxes (Figure 18, label 1).

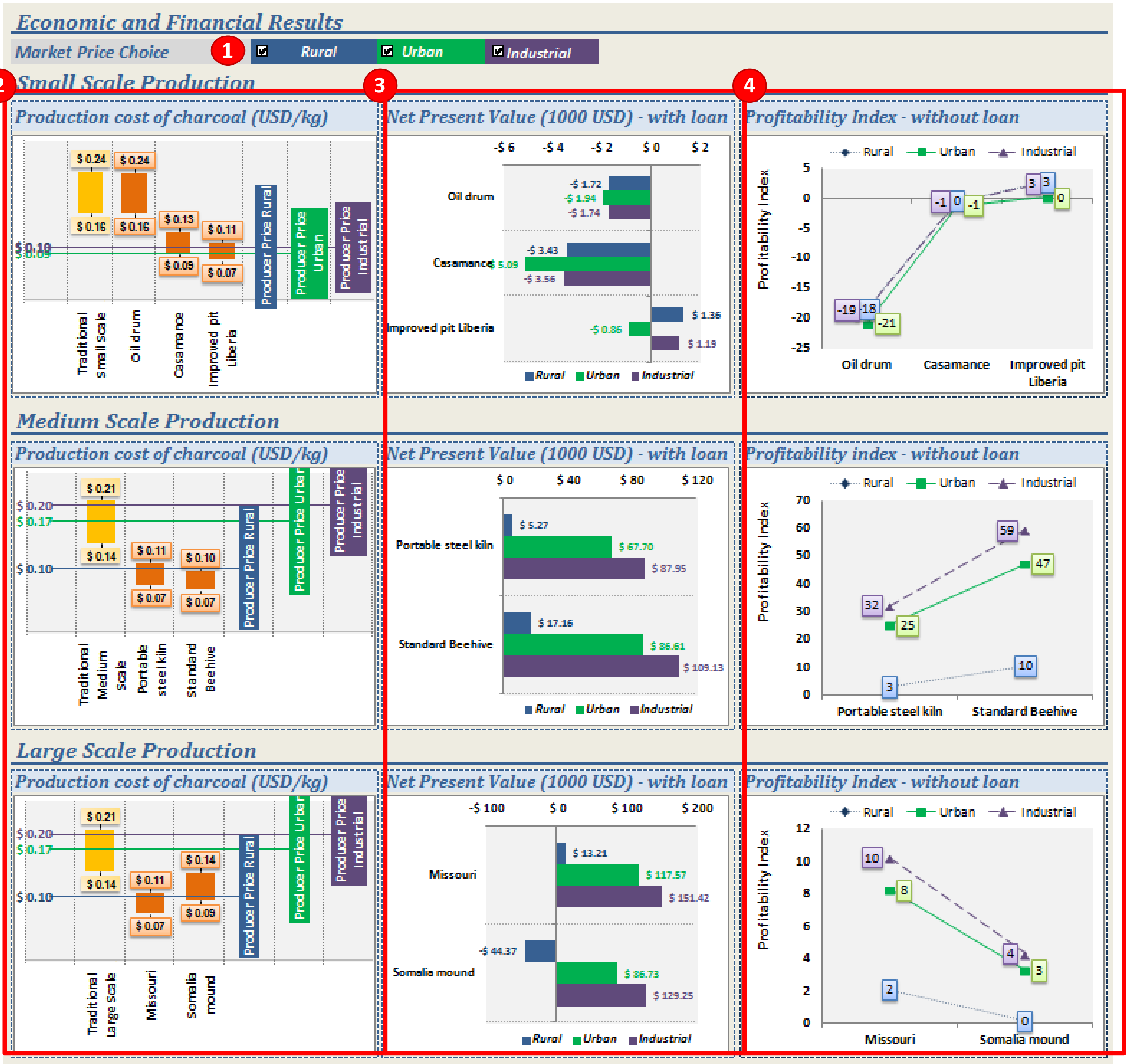


Figure 18: Economic and Financial Results – Small-Scale

For the wood processing residues, the production cost using the portable oil drum technology ranges 0.16-0.24 USD/kg, it has a negative net present value (NPV) and the profitability index is smaller than one for all three price markets as shown in Figure 18.

These parameters indicate that charcoal production from wood processing residues is not economically feasible when using the oil drum.

7.3 The summary of results by technology

The information presented in this section aims to help the user in the decision-making process to support the development of biomass charcoal production in rural and urban areas, including industrial, using three types of feedstock and comparing one technology at time.

The results aim to answer the following questions:

Guidance: These results can help identify the type of feedstock and kiln technology that is most viable for charcoal production.

- What is the production cost of charcoal by different types of feedstock?
- Which feedstock has the highest and lowest charcoal production cost?
- How many jobs are created from charcoal systems by different types of feedstock?
- Which type of feedstock provides highest and lowest benefits?
- Which type of feedstock should be promoted for charcoal production?

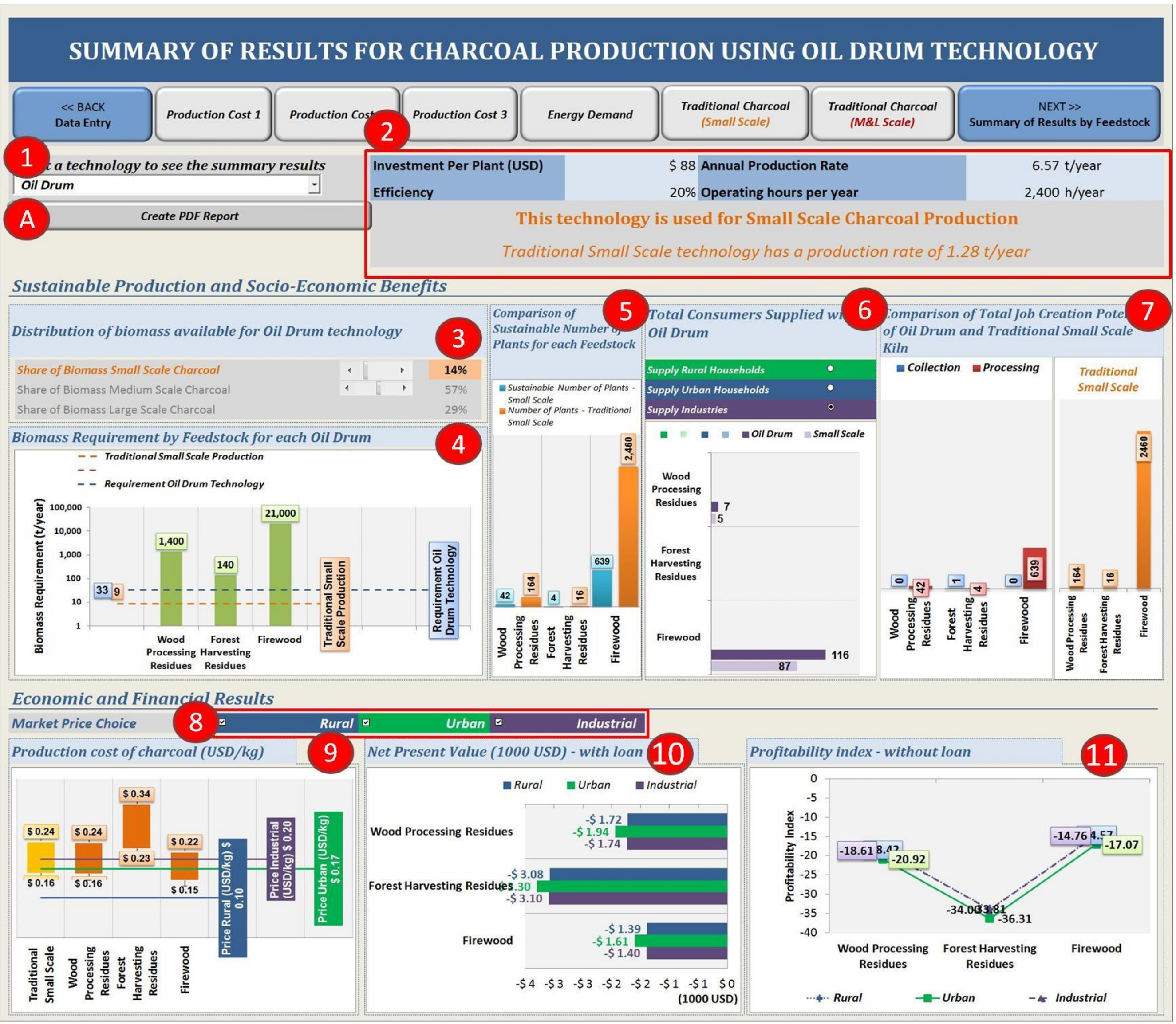


Figure 19: Layout of Comparative Results

Guidance: In this case, the dotted lines represent biomass requirements of improved and traditional technologies, while green bars stand for the biomass available for all feedstock options. In case of one of these bars appears below the dotted lines, it means that there is not enough biomass available to supply the selected technology.

Comparisons of results are presented according to the selected kiln technology (Figure 19, label 1), as follows:

- Investment per plant, efficiency, annual production rate, operating hours per year, and production scale of selected technology (Figure 19, label 2).
- Distribution biomass available for selected technology, according to production scale (Figure 19, label 3).
- Biomass requirement for selected technology (Figure 19, label 4).
- Comparison of sustainable number of plants supported for each feedstock (Figure 19, label 5).
- Comparison of total consumers supplied (selected technology vs. traditional)(Figure 19, label 6).
- Comparison of total job creation potential (selected technology vs. traditional) (Figure 19, label 7).
- Comparison of production cost of charcoal (selected technology vs. traditional) (Figure 19, label 9).
- Comparison of NPV (Figure 19, label 10).
- Comparison of profitability index (Figure 19, label 11).

For the selected oil drum technology, all feedstock options provide sufficient biomass to meet production. However, considering the difference in charcoal production rates between the oil drum (7 t/year) and the traditional small-scale (1.28 t/year), a larger number of small-scale plants can be potentially installed when using traditional technology. But, the number of consumers that can be supplied with oil drum technology is greater than with traditional technology.

The production cost of wood processing residues is the lowest cost. Using forest harvesting residues provides the highest production cost and negative NPV for rural markets.

8 Annex

8.1 Methodology and outputs

This section describes the methodologies integrated in the *Charcoal 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

This section presents the detailed calculation used to determine the input cost for the seven pre-defined kilns. The equations for calculation are presented in Table 4.

Table 4: Inputs Cost Equations

Item	Equation and Assumption	Remark
Quantity of feedstock (QF)	QF = CP/ kiln efficiency Where: QF is Quantity of feedstock (tonne per year) CP is Charcoal products (tonne per year)	
Total Inputs cost	TIC = (QF x Cf) Where: TIC is Total Inputs cost (USD per year) QF is Quantity of feedstock (Tonne per year) Cf is unit cost of feedstock (USD per Tonne)	
Charcoal production (CP) (tonnes per year)	Small-scale: Oil drum 7 tonnes per year Casamance kiln 50 tonnes per year Improved pit Liberia 66 tonnes per year Medium-scale: Portable steel kiln 183 tonnes per year Standard Beehive 203 tonnes per year Large-scale: Missouri 305 tonnes per year Somalia mound kiln 383 tonnes per year	(Burnette, 2010; FAO, n.d.-a, n.d.-c, n.d.-e; Kumar & Sarkar, 2009; Rautiainen et al., 2012)
Kiln efficiency (%)	Small-scale: Oil drum efficiency 20% Casamance efficiency 30% Improved pit Liberia efficiency 30% Medium-scale: Portable steel kiln efficiency 24% Standard Beehive efficiency 33% Large-scale: Missouri efficiency 33% Somalia mound efficiency 42%	(Kammen & Lew, 2005)(Burnette, 2010)

8.1.2 Cost calculation of required labour

The equations and assumptions for calculating labour costs based on the charcoal kiln technology are shown in Table 5.

Table 5: Labour Cost Equations

Item	Equation and Assumption	Remark
Number of unskilled workers	Small-scale Oil drum is 1 person Casamance kiln is 1 person Improved pit Liberia is 2 person Medium-scale Portable steel kiln is 2 person Standard Beehive is 2 person Large-scale: Missouri is 2 person Somalia mound kiln is 14 person	Assumption: Unskilled workers should be trained to ensure the high charcoal yield. For the casamance, portable steel kiln and Somalia Mound the labour cost includes construction cost of the kilns for each cycle. This is considered as a variable cost in the financial analysis.
Number of skilled workers	Small-scale Oil drum is 0 person Casamance kiln is 1 person Improved pit Liberia is 0 person Medium-scale Portable steel kiln is 0 person Standard Beehive is 1 person Large-scale: Missouri is 1 person Somalia mound kiln is 1 person	
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	hours per year for all kiln technologies are defined as result of hours per day and days per year of operation defined by the user in “Data Entry Needs”	
Total unskilled worker cost (USD per year)	Unit cost of unskilled worker x number of unskilled worker x operating hours per year	
Total skilled worker cost (USD per year)	Unit cost of skilled worker x number of skilled worker x operating hours per year	
Total labour cost (USD per year)	Total unskilled worker cost + Total skilled worker cost	

8.1.3 Cost calculation of required transportation

The equations used to calculate transportation costs are shown in Table 6.

Table 6: Transportation of Feedstock and Charcoal Products Cost Equations

Item	Equation and Assumption	Remark
Transportation of feedstock (collection point to plant) (USD per year)	UTC1 x Transportation distance x QF Where: QF is Quantity of feedstock (Tonne per year) UTC1 IS Unit transportation cost of feedstock (USD/Tonne/km)	QF is calculated in Table 4. Transportation distance is input by the user in “processing budget” (km).
Transportation of charcoal (plant to market) (USD per year)	UTC2 x Transportation distance x QP Where: QP is Quantity of product (tonne per year) UTC2 IS Unit transportation cost of charcoal (USD/Tonne/km)	QP is defined in Table 4. Transportation distance is input by the user in “processing budget” (km).

8.1.4 Cost calculation of storage

The equations used to calculate storage costs are as shown in Table 7.

Table 7: Storage Cost Equations

Item	Equation and Assumption	Remark
Feedstock Storage Capacity (Tonne/year)	[QP x 8 hours/day] x [1+Safety stock rate (%)] x Drying days x 12 months / Operating hours per year Where: QP is Quantity of product (Tonne per year)	Portable steel option does not require storage. The kiln plant is built at collection point. QP is defined in Table 4.
Storage cost of feedstock (USD per year)	Unit storage cost x Storage Capacity	Unit storage cost input by user processing in "Data Entry Needs" (USD/tonne).
Product Storage Capacity (tonne/year)	Safety stock rate x Charcoal production	Safety Stock Rate has been assumed for Oil drum, Casamance and Improved pit Liberia options as 10%.
Storage cost of charcoal products (USD per year)	Unit storage cost x Product Storage Capacity	

8.1.5 Fixed cost calculation

Fixed costs consist of equipment costs, building costs and installation costs. The equations used to calculate fixed costs and the associated depreciation are shown in Table 8.

Table 8: Fixed Cost Equations

Item	Equation and Assumption	Remark
Equipment $cost_i$ (USD)	$\Sigma(UMC_i \times MQ_i)$ Where UMC is Unit Material Cost (USD/unit). MQ material quantity (units) i is kiln technology	UMC and MQ units changes according to type material. This is defined in "Data Entry Needs". The user can check details on quantities and assumptions used for MQ in section 8.1.9. In Charcoal Tool, by clicking on investment button in "Data Entry Needs" additional results on equipment materials and costs are presented.
Building $cost_i$ (USD)	Equipment $cost_i$ (USD)* Building Percentage (%)/(1- Building Percentage (%)) Where, i is kiln technology	The user can check details on assumptions used for Building cost in section 8.1.9. In Charcoal Tool, by clicking on investment button in "Data Entry Needs" additional results on equipment materials and costs are presented.
Installation $cost_i$ (USD)	Equipment $cost_i$ (USD)* Installation Percentage (%) Where, i is kiln technology	The user can check details on assumptions used for installation cost in section 8.1.9. In Charcoal Tool, by clicking on investment button in "Data Entry Needs" additional results on equipment materials and costs are presented.
Equipment $Depreciation_i$ (USD per year)	Equipment $cost_i$ (USD)/life $time_i$ Where, i is kiln technology	Straight line method of depreciation calculation
Building $Depreciation_i$ (USD per year)	Building $cost_i$ (USD))/life $time_i$ Where, i is kiln technology	Straight line method of depreciation calculation
Installation $Depreciation_i$ (USD per year)	Installation $cost_i$(USD))/life $time_i$ Where, i is kiln technology	Straight line method of depreciation calculation
Total investment $depreciation_i$ (USD per year)	Equipment $Depreciation_i$ + Building $Depreciation_i$ + Installation $Depreciation_i$	Straight line method of depreciation calculation
Maintenance $cost_i$ (USD per year)	10% of Total $depreciation_i$	

8.1.6 Calculation of other costs

This step shows the equations for calculating plant overhead, general and administrative costs, average loan interest payment (called as loan interests) and corporate tax (Table 9).

Table 9: Other Costs Equations

Item	Equation and Assumption	Remark
Plant Overhead $_i$ (USD per year)	Plant Overhead Percentage (%) x (Total labour cost $_i$ + Maintenance cost $_i$)	Plant Overhead Percentage (%) is defined by used in “Data Entry Needs”. It is assumed that this concept only applies to medium and large scale technologies only (Portable steel kiln, Standard Beehive, Missouri and Somalia mound).
General and Administrative Cost $_i$ (USD per year)	General and Administrative Cost Percentage (%) x (Total inputs cost $_i$ + Total labour cost $_i$ + Maintenance cost $_i$ + Plant overhead $_i$)	General and Administrative Cost Percentage (%) is defined by used in “Data Entry Needs”. It is assumed that this concept only applies to medium and large scale technologies only (Portable steel kiln, Standard Beehive, Missouri and Somalia mound).
Loan Interest $_i$ (USD per year)	Loan amount $_i$ = Loan ratio (%) x Total investment cost $_i$ Annual loan payment $_i$ (USD/year) = PMT([Loan interest rate],[Loan term], Loan amount$_i$) Total Loan payment $_i$ = Annual loan payment $_i$ x Loan terms Loan interest payment $_i$ = Total Loan payment $_i$ - Loan amount $_i$ Average Loan interest payment $_i$ = Loan interest payment $_i$ divided by business lifetime	PMT is financial function in Microsoft excel for calculating the payment for a loan based on constant payments and a constant interest rate. Loan instalments are calculated on a yearly basis for simplicity and for consistency with the chosen time unit (year).

8.1.7 Total production cost and unit cost of charcoal calculation

The equations used to calculate total operating costs, total fixed costs, total other costs of charcoal, total annual production cost and unit production costs per kg are shown in Table 10.

Table 10: Total Production Cost Equations

Item	Equation and Assumption	Remark
Total Operating Costs $_i$ (USD per year)	annual inputs cost $_i$ + annual labour cost $_i$ + annual transportation cost $_i$ + annual storage cost $_i$	
Total Fixed Costs $_i$ (USD per year)	Total Depreciation$_i$ + annual maintenance cost $_i$	
Total Other Costs $_i$ (USD per year)	annual plant overhead $_i$ + annual general &administration cost $_i$ + annual loan interest$_i$	
Total Annual Production Cost $_i$ (USD per year)	Total Operating Costs $_i$ + Total Fixed Costs $_i$ + Total Other Costs $_i$	
Production cost per kg $_i$	Total Production Cost $_i$ divided by charcoal production	

8.1.8 Charcoal kiln technologies

The summary of the selected kiln technologies are presented in Table 11 and Table 12.

Table 11: Summary of Selected Kiln Technologies

Kiln Technology	Kiln Size	Charcoal Production per Cycle	Kiln Efficiency	Operating Cycle	Estimate Production	Estimate Production*	Lifetime of Kiln
	m^3	Tonnes	%	Days	Tonnes per day	Tonnes per year	
Oil drum	0.2	12-18 kg	20%	14-26 hours	0.02	7	3 years
Casamance	8	1.1 tonnes	30%	8 days	0.14	50	3 years of chimney
Improved pit Liberia	8	1.1 tonnes	30%	5-6 days	0.18	66	3 years
Portable steel kiln	7	1-1.5 tonnes	24%	2-3 days	0.50	183	3 years
Standard Beehive	49	5 tonnes	33%	9 days	0.56	203	6 years
Missouri	180	17.6 tonnes	33%	21 days	0.84	306	6 years
Somalia mound	22	4.2	42%	4-10 days	1.05	383	1.5mm metal sheet has 5 cycles and 2.5 mm metal sheets has 15 cycles

* Estimate annual production of charcoal based on the operating cycle of each type of kiln.

Table 12: Charcoal Kilns Technologies

Kiln's Type	Production Process	Heat Source	Capacity (tonnes/year)	Total Capital Cost (2008 C$)	Capital Cost per Tonne	Lifetime of Kiln	Number of Ovens	Capacity of One Vessel	Specific Weight Wood (Dry)	Moisture Content Wood	Efficiency Yield of Charcoal	Average Production Time of One Vessel	References
					(2008 C$)			m3 s wood per vessel	tonne/m3	%, wet basis			
Twin-retort carbonization plant (for 2 units)	Semi-continuous system	Internal and heating fuel gas	900	712,100	79.1	10 years	1 with 2 vessel	3	0.5	50%	33%	Carbonized 12 hrs + 20 hr. for cooling	(Reumerman & Frederiks, 2002)
Euro kiln	Semi-continuous system	Internal and heating fuel gas	840		0.0		2 vessel	1 ton of charcoal		various	n.a.	40-48 hrs of production cycle	(Rautiainen et. al., 2012)
Waggon retort (tunnel)	Semi-continuous system	Internal		no longer in wide use due to high maintenance costs of the steel wagons and the shell of the tunnel			1 tunnel				n.a.		(Rautiainen et. al., 2012)
O.E.T Calusco Tunnel Retort	Semi-continuous system	External and recirculated heating gas	6000		0.0		1 tunnel, 45 m. long				n.a.	25-35 hours of production cycle	FAO, 2008
Adam-retort kiln	Batch	External and recirculated heating gas	47	800	3.4	5 years					34%	Carbonized 12 hrs + 12 hrs for cooling	(Biocoal, 2009) (Adam, 2009)
Portable steel kiln (Retort)	Batch	Internal	2,721	1,255,535	461.4	3 years					24%		(FAO, 1985)
Mark V Portable kiln	Batch			5,000				300-400kg			20-25%		UNCHS/HABITAT; 1993
Retort	Batch	Internal	14,512	3,138,840	216.3						26%		(FAO, 1985)
Earth pit kiln	Batch	Internal	17	480	28.2						20.45%	Carbonization 5-10 days	(Pari et al., 2004)
Liberia improved pit kiln	Batch	Internal									30%	Carbonization 48 hours and cooling 3 days	Padon., 1986

Kiln's Type	Production Process	Heat Source	Capacity (tonnes/year)	Total Capital Cost (2008 C$)	Capital Cost per Tonne	Lifetime of Kiln	Number of Ovens	Capacity of One Vessel	Specific Weight Wood (Dry)	Moisture Content Wood	Efficiency Yield of Charcoal	Average Production Time of One Vessel	References
					(2008 C$)			m3 s wood per vessel	tonne/m3	%, wet basis			
Earth pit kiln	Batch	Internal	37	825	22.3								(FAO, 1983)
Yoshimura kiln	Batch	-	16	760	47.5						26.40%	Carbonization 10 days	(Pari et al., 2004) Ando et al., n.d.
Flat kiln	Batch	Internal	31	825	26.6						16.60%	Carbonization 2-3 days	(Pari et al., 2004) Ando et al., n.d.
Flat kiln	Batch	Internal	72	3,055	42.4								(Okimori et al., 2003)
Fabricated Masonry block kiln	Batch		11	310	28.2								(Dionco-Adetayo, 2001)
Brick kiln	Batch	Internal	126	1,470	1.9	6 years							(FAO, 1985)
Argentine half orange or beehive brick kiln	Batch	Internal				5-8 years	1 brick kiln	30 ton of air dry wood	0.85	25%	27%	13-14 days of production cycle of 9-10 ton of charcoal	(FAO, 1983)
Brazilian beehive kiln	Batch	Internal	203	2,450	2.0	6 years	1 brick kiln				33%	9 days of 5 ton of Charcoal	(FAO, 1983)
Missouri kiln (concrete & steel)	Batch	External	305	7,714		6 years	1 brick kiln	180 m3 of Charcoal			20-33%	3 weeks of production cycle	Rautiainen et. al., 2012 and Kammen and Lew, 2005
Lambiotte kiln	Continuous (it was closed down in 2002)	Internal and recirculated heating gas	7,300	1,600,000	11.0	20 years				<25%, at about 10 mm. size			(Herla, 2008) and (Rautiainen et. al., 2012)
Drum kiln	Batch		3	54	18.0	n.a.					20.7%	Carbonization 1 day	(Pari et al., 2004) Ando et al., n.d.
Oil drum 200Liters	Batch	External	5	28	1.9	3 years		60-80 kg of wood			20%	varied by biomass type and size, Max. 9 hours per batch	(Burnette, 2010)
Double drum kiln	Batch		4	260	53.4	n.a.							(Pari et al., 2004)

Kiln's Type	Production Process	Heat Source	Capacity (tonnes/year)	Total Capital Cost (2008 C$)	Capital Cost per Tonne	Lifetime of Kiln	Number of Ovens	Capacity of One Vessel	Specific Weight Wood (Dry)	Moisture Content Wood	Efficiency Yield of Charcoal	Average Production Time of One Vessel	References
					(2008 C$)			m3 s wood per vessel	tonne/m3	%, wet basis			
ACREST Mobile charcoal kiln	Batch	External	18.25	64	3.5	n.a.					30%	107 minutes for dried grass	ACREST, 2011

Source:(Adam, 2009; Ando, Ishibashi, Pari, & Miyakuni, n.d.; Burnette, 2010; Dionco-Adetayo, 2001; FAO, n.d.-a, n.d.-c, n.d.-e, 2008; Kammen & Lew, 2005; Kumar & Sarkar, 2009; Maenpaa et al., 2011; Paddon & Harker, 1980; Paddon, 1986; Rautiainen et al., 2012; Reumerman & Frederiks, 2002)

8.1.9 Detail of the estimation of investment cost

The investment cost of improved pit Liberia, portable steel kiln and Somalia mound were estimated based on the number of oil drum sheets used for kiln construction, including the other material costs, as presented in Table 13.

Table 13: Estimate Investment Cost of Kilns based on the Oil Drum Sheet Price

Kiln Technology	Kiln Size	Charcoal Production per Cycle	Operating Cycle	Number of Production Cycle per Year	Estimate Annual Production	Number of Oil Drum Sheet
	m^3	Tonnes	days		Tonnes per Year	Pieces
Oil drum	0.2	12-18 kg	14-26 hours	365	7	2 oil drum and other material
Casamance	8	1.1	8 days	45	50	
Improved pit Liberia	8	1.1	5-6 days	60	66	10
Portable steel kiln	7	1-1.5 tonnes	2-3 days	121	183	18
Standard Beehive	49	5 tonnes	9 days	40	203	N/A
Missouri	180	17.6 tonnes	21 days	17	306	N/A
Somalia mound	22	4.2	4-10 days	52	383	15

* The investment cost of oil drum kiln is reported in Burnette, 2010, the exchange rate is 28.57 Baht/USD.

** The investment cost of Casamance is estimated based on the current price of material in Thailand (MOC, 2014).

*** The investment cost of standard beehive is reported in Kumar & Sarkar, 2009 page 25.

**** The investment cost of Missouri is estimated based on the investment cost at 15,000 USD for 350m^3 of charcoal production capacity reported in FAO, 2010 page 38.

<u>**Oil drum kiln**</u>

The list of materials used to construct the oil drum charcoal kiln is presented in the table below. The user can use this list for estimating the investment cost and using the current price of these materials in the country.

Table 14: Materials for Oil Drum Charcoal Kiln

Material	Unit	Oil Drum Requirement
200 liter oil drum	pcs.	1
Asbestos pipe 4 inches dia. X 1 m.	pcs.	1*
4 inches wide asbestos 90º pipe joint	pcs.	1*
Galvanized sheets	pcs.	3*
4 wooden corner posts	pcs.	4*
Cement blocks	pcs.	5*
Green bamboo pole (3-5 m long; 12 cm wide)	pcs.	1*

Source: Burnette, 2010

* The cost of these items is accounted at 55-60% of total cost.

Dimension of oil drum		Oil drum 55 gallon			
	Diameter	22.5	Inches =	57	cm
	Height	34.5	Inches =	88	cm
	Circumference	70.65	Inches =	179	cm
Note: conversion factor		1	Inch =	2.54	cm
Therefore, the dimension of metal sheet made from oil drum is					
	Width	0.9	m		
	Length	1.8	m		
Area of oil drum metal sheet		1.57	m^2		
Price of Oil drum (estimate)		13.33	USD/drum		

Casamance kiln

The steel sheet is used for chimney and air inlet tube production (Oduor, Githiomi, & Chikamai, 2006). The list of materials used to construct the Casamance kiln is presented in the table below. The user can use this list for estimating the investment cost and using the current price of these materials in the country.

Table 15: Materials for Casamance kiln

Material	Unit	Casamance Kiln Requirement
Metal sheet 0.63m x 1.8m x 3mm (Chimney diameter 0.2m x 1.8 m)	pcs.	1
Metal sheet 0.16 m x 0.5m x 3 mm (air inlet)	pcs.	4
Grass or foliage and Soil for top cover		Free of charge

Source: Oduor, Githiomi, & Chikamai, 2006

Improved pit Liberia

The metal sheet is mainly used for three covering sheets and one chimney (Paddon, 1986). The dimension of the metal sheet for producing covering sheets and chimney is 2.44m x 1.22m for a total of five pieces. Therefore, the total area is 14.884 m^2. It is equivalent to oil drum sheet = 14.884/1.57 = 9.48 or 10 oil drum sheets (Note: 1.57 m^2 is the area of one oil drum sheet).

The other material cost is estimated at 70% of total oil drum sheet cost. As a result, the investment cost of the improved pit Liberia kiln is 13.33 x 10 pcs. x 1.7 = 227 USD.

The materials that are required for constructing the improved pit Liberia kiln are presented in the table below. The user can use this list for estimating the investment cost and using the current price of these materials in the country.

Table 16: Materials for Improved Pit Liberia Kiln

Material	Unit	Improved Pit Liberia Requirement
Angle iron for frame 40 x 40 x 5 mm	m.	12.2
Mild-steel covering sheet: 2440 x 1220 x 1.5mm (for covering sheets)	pcs.	3
Flat mild steel: 2440 x 1220 x 1.0 mm (for tubes and plugs)	pcs.	2
Flat mild steel bar: 40 x 4 mm (for making slide bolts and slots)	m.	3*
Round mild steel bar (for making handles): 12mm dia.	m.	3*
Mild steel bolts or short pieces of rod: 30 x 12 mm dia.	pcs.	20*
Steel chain to support central metal sheet	m.	2*

Source: Paddon, 1986

* The costs of these items are accounted at 15-20% of total cost of this kiln.

Portable steel kiln

The cost of portable steel kiln is estimated based on using oil drum as the raw material of kiln construction. The cost covers 18 oil drums and other costs (accounted at 50% of total oil drum cost) as following:

The total cost of portable steel kiln = 18 x 13.33 USD x 1.5 = 360 USD.

The material required for constructing the portable steel kiln is presented in Table 17. The user can use this list for estimating the investment cost and using the current price of these materials in the country.

Table 17: Materials for Portable Metal Kiln

Material	Unit	Portable Steel Kiln 7m^3 Requirement
Bottom section of kiln: Corten 'A' sheet steel: 7.3m x 0.7m x 3mm	pcs.	1
Top section of kiln: Corten 'A' sheet steel: 7.3m x 0.7m x 2mm	pcs.	1
Top cover: Corten 'A' sheet steel: diameter 2.5m x 2mm	pcs.	1
Chimney (steel pipe): diameter 10mm dia. x 1.8 m	pcs.	4
Collar and air inlet channels: 10mm wide steel 90º pipe joint	pcs.	8*
50 mm angle iron to support the top section and cover	pcs.	16*
Round mild steel bar (for making handles): 12mm dia.	m.	1*

Source: Emrich, 1985; FAO, n.d.-f

* The cost of these items is accounted at 25% of total cost of this kiln.

This kiln can be built by local craftsmen in a workshop which has basic welding, rolling, drilling and cutting facilities (Paddon & Harker, 1980).

Somalia mound

Cost of material used for the Somalia mound construction is estimated as following:

- For kiln size 22m^3, the area of metal sheet cover is 10 m^2. Therefore, the number of metal sheets used = 10/1.57 = 6.4 = 7 pcs (Note: 1.57 m^2 is the area of one oil drum sheet). The metal sheets will be pasted overlapping. Therefore, the total number of metal sheets is assumed at 15 pieces.

- The assumption of charcoal production by using the Somalia mound is 7 days per cycle of production period and the total cost of (15 x 13.33) = 200 USD is used for 5 cycles of charcoal production (Paddon, 1986). Therefore, the cost of 200 USD is used for producing 21 tonnes of charcoal (as shown in Table 18).
- The annual cycle of production = 365/7 = 52 cycle per year. As a result, for one year of charcoal production by using the Somalia mound costs = 52* 200/5 = 2,080 USD.

The user can use this list for estimating the investment cost and using the current price of these materials in the country for the Somalia mound as shown in Table 18.

Table 18: Materials for Somalia Mound

Material	Unit	Somalia Mound
		Requirement
Metal sheet 0.9m x 1.8 m x 1.5 mm (made of oil drum)	pcs.	15
Thorny branch wood and Soil for top cover (approx. 5 cm thickness of soil covered)		Free of charge

Source: http://www.fao.org/docrep/s5780e/s5780e06.htm

Missouri kiln

The material required for constructing the Missouri kiln (180 m^3) is presented in Table 19. The user can use this list for estimating the investment cost and using the current price of these materials in the country.

Table 19: Materials for Missouri Kiln

Material	Unit	Missouri Kiln
		Requirement
Concrete using expanded shale aggregate	m^3	46
Steel tons total (Reinforcement, door frames, air ducts, doors, and miscellaneous)	metric tonne	4.4
Stoneware flue pipes (37 m of 150 mm diameter)	pcs.	1*
Engineering and construction service charge		Approx. 35% of material cost

Source: http://www.fao.org/docrep/x5328e/x5328e08.htm#7.4.2. Construction

* The cost of this item is accounted at 2-5% of total cost of this kiln.

Standard beehive kiln

The material required for constructing the standard beehive kiln (50 m^3) is presented in Table 20. The user can use this list for estimating the investment cost and using the current price of these materials in the country.

Table 20: Materials for Standard Beehive Kiln

Material	Unit	Standard Beehive Kiln
		Requirement
Common bricks	pcs.	8500
Steel tons total (Reinforcement)	metric tonne	0.145
Construction service charge		Approx. 20% of material cost

Source: http://www.fao.org/docrep/x5328e/x5328e08.htm#7.4.2. Construction

8.2 Data requirements for running the tool

Table 21 includes the data requirements for running the *Charcoal Component*. A suggested data source is provided.

Table 21: Data Requirements for Running the Tool

Data	Definition and Sources
Biomass and its residue	The user selects the biomass/wood 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 the fuel consumption of machinery typically used in agricultural or forestry operations to calculate a proxy for this value.
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, the user can estimate this based on the selection of the type of storage available in the country and use the estimated global cost for building this type of storage provided in the tool. For small-scale kilns, e.g. oil drum kiln, casamance and improved pit Liberia including portable steel kiln, no storage is required and thus building costs are equal to zero.
Feedstock safety stock rate (%)	This value defines the percentage of biomass that should be reserved to operate the plant during shortage periods.
Current charcoal kiln technology	The user enters the data of current charcoal production in the country. The required information is: current kiln technology and its efficiency, investment costs, plant overhead cost, administrative cost, skilled and unskilled labour costs, loan, transportation distance (of both biomass/feedstock and charcoal), current wood storage capacity and lifetime of kiln.
Kiln technologies	The user selects improved kiln technologies that the user wants to evaluate among the following: Casamance, Somalia mound, Improved pit Liberia, Standard Beehive, Missouri, Portable steel kiln and Oil drum.
Charcoal storage building cost (USD per tonne).	The user identifies the cost for storing charcoal. The user can enter the current prices on storage for agricultural products in the country. If this information is not available in the country, the user can estimate this based on the selection on the type of storage available in the country and use the estimated global cost for building this type of storage provided in the tool. For small scale kilns, e.g. oil drum kiln, casamance and improved pit Liberia, no storage is required and thus building costs are equal to zero.
Charcoal safety stock rate (%).	The user determines the charcoal stock rate to ensure sufficient supply of charcoal in the market.
Labour cost	Unskilled and skilled workers in unit of USD per employee per hour.

The cost of transportation of feedstock (field/collection 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 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 feedstock to charcoal plant in kilometres by kiln technology	It is determined based on the availability of biomass in a particular area in relation to the amount required to operate each of the kiln technologies.
The cost of transportation of charcoal 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 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 charcoal products to market in kilometres by production capacity	The user identifies an estimated transportation distance that will be required to transport the charcoal to market in kilometres, according to kiln technologies.
Current market price of charcoal	Market price of charcoal (USD/kg) in rural and urban area including industrial.
Costing parameters	Percentage of plant overhead cost, general and administrative cost, maintenance cost and miscellaneous cost.
Financial parameters	Discount rate (%): it allows the user to assess the value of future costs and benefits with respect to current ones, and is in general determined by the prevailing rate of returns on capital markets. It can be interpreted in terms of "opportunity cost", i.e. the foregone return which is given up investing in the project under scrutiny rather than in financial markets. When dealing with a firm's cost of capital, the discount rate is commonly calculated as the average return that must be granted to those who invest (through debt or equity) in the firm's assets. For this reason, in several applications the discount rate is not expected to be smaller than the loan interest rate. Loan ratio (%): it is the percentage of the initial investment that is funded through a loan. Loan interest rate (%): it is the (fixed) interest rate on the loan obtained to fund (part of) the initial investment. Loan term (years): it is the duration of the loan, which in turn depends on the lifetime of the selected plant.
The types and quantities of typical fuels used for heating and cooking	Fuels are briquettes, fuelwood, kerosene and LPG that used for heating and cooking in urban and rural household including industrial (kg per day per household).
Price of fuels used for heating and cooking	The current price of fuels such as briquettes, fuelwood, kerosene and LPG in unit of USD/kg.

8.3 Main financial indicators and working hypotheses[6]

Net Present Value

The Net Present Value (NPV) is the sum of discounted cash flows arising from an investment project, and is a measure of the profitability of such a project. It is typically calculated according to the following formula[7]:

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

Where I_0 is the initial investment, n is the time horizon of the project valuation (three or six years in our case, depending on the chosen production plant), while CF_t is the cash flow arising at time *t* and r is the chosen discount rate. When choosing on the opportunity to undertake an investment project, a positive *NPV* implies that the project itself is expected to be profitable, while a negative *NPV* implies that the project is not lucrative. In choosing between multiple projects, those with larger *NPV* are to be preferred.

An important working hypothesis adopted in the tool is linked to the use of the same discount rate (the one chosen by the user) for all cash flows involved in the calculation of Net Present Values. This is likely to affect the results, but is needed to keep matters as simple as possible. This also suggests an important caveat concerning the choice of the discount rate: the chosen value is likely to affect the results of the analysis significantly, so that it must be chosen carefully or, better, a sensitivity test by using several plausible values for such a rate should be performed.

Profitability Index

The Profitability Index (PI) is defined according to the following formula[8]:

$$PI = \frac{PV \text{ of cash flows arising after the initial investment}}{\text{Initial Investment}}$$

Where *PV* stands for *Present Value*. In our setting, it is therefore the ratio between the present value of cash flows arising from period 1 to the end of the chosen time horizon (thus up to year three or to year six depending on the chosen plant) over the value of the initial (i.e. time 0) investment. This is a measure of the amount of dollars obtained (in Present Value) per dollar invested. As a result, a value larger than 1 implies a profitable investment while a value lower than 1 implies that the investment should not be undertaken.

In the assessment of the PI, the cash flows obtained in the absence of a loan are used, to avoid the possibility of having a 0 initial investment and the related calculation problems.

An important caveat for the PI is related to the fact that it does not properly account for the scale of the project. In other words, a very small project might have a significantly higher PI than a large one, but the latter can be more profitable in terms of NPV.

[6] This part (together with the financial parameters definitions in Table 21) is mostly based on Brealey et al. (2011), chapters 2, 5 and 9, and on Ross et al. (2002), chapter 6. The concepts are only very briefly sketched for the sake of simplicity.
[7] Slight modifications may be needed to account for specific project features.
[8] Also for the *PI,* slight modifications are introduced in specific cases.

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