BEFS

BIOENERGY AND FOOD SECURITY RAPID APPRAISAL (BEFS RA)

User Manual

STRAIGHT VEGETABLE OIL

BEFS Rapid Appraisal

Energy End Use Options Module

Rural Electrification Sub-Module

Section 2: Straight Vegetable Oil

User Manual

Acknowledgements

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

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

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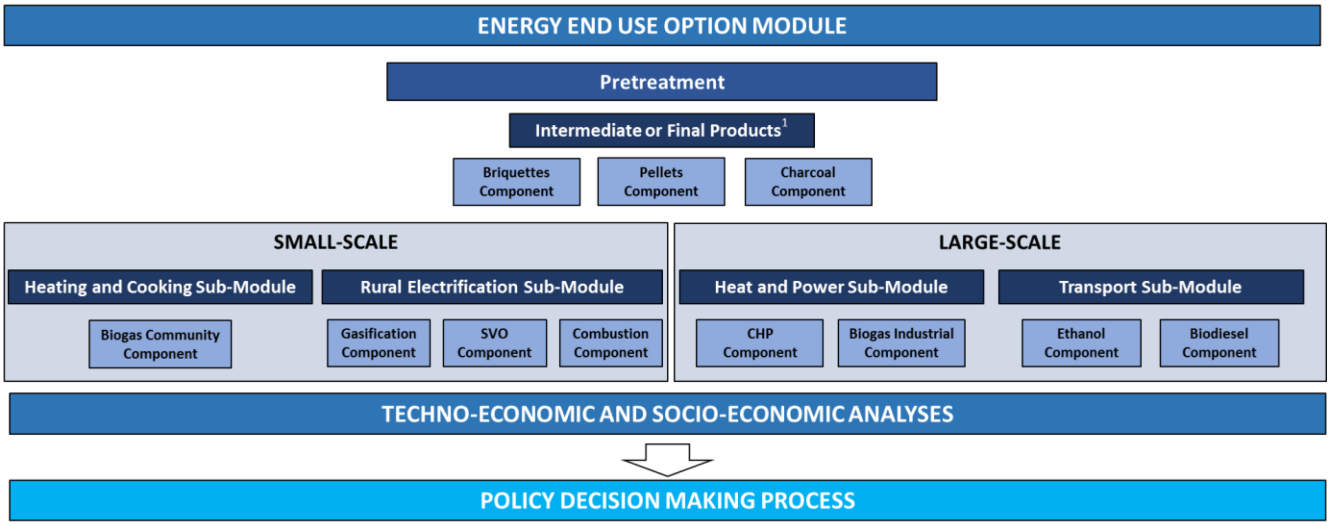
1 Overview of the Energy End Use Option (End Use) Module

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



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

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

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

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

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

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

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

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

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

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 *SVO Component*

The straight vegetable oil (SVO) tool is designed to assist the user in evaluating the potential to develop electricity generation systems to supply electricity in rural areas that have no access to electricity by using SVO as the fuel source. These systems are evaluated comparing 3 typical power generation capacities (10 kW, 40 kW and 100 kW). The boundary of the *SVO Component* is shown in Figure 2. The tool is based on extensive literature reviews on the subject, as well as mass energy balances on the boundaries of the system. The detailed assumptions and calculations used to develop the tool are presented in this training manual.

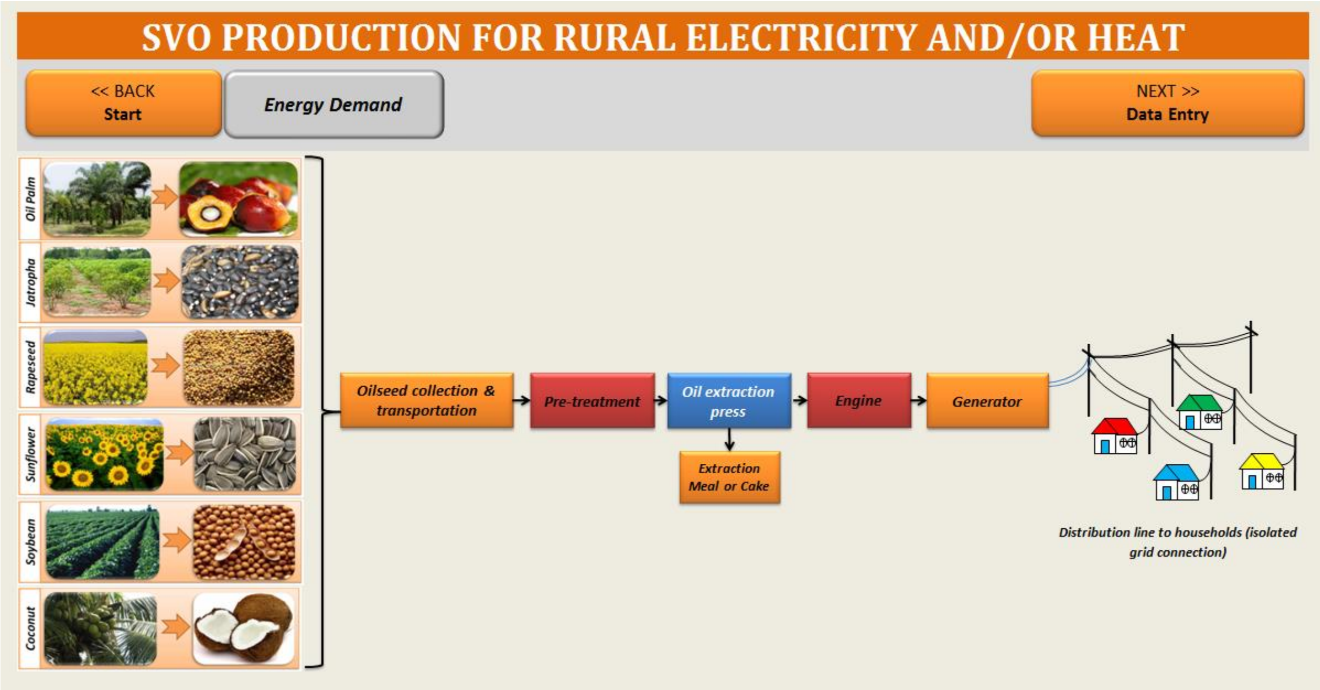


Figure 2: Biomass SVO System for Rural Power Generation

After completing the analysis, the user will have an indication on: 1) the feedstock consumption and the area required to produce enough feedstock to support the various capacities of SVO electrification plants; 2) the potential number of SVO electrification plants that can be developed in the country based on biomass availability; 3) the investment cost required to set up each plant; 4) the associated production cost per kWh for each production scale; 5) the number of households that could be supplied with electricity; and 6) the employment generation potential and financial viability associated to each level of production as shown in Figure 3. The user will also be able to compare across different oleochemical feedstocks and plant capacities in order to identify the most appropriate biomass sources and plant size based on a number of factors, including physical availability, economic and social results.

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

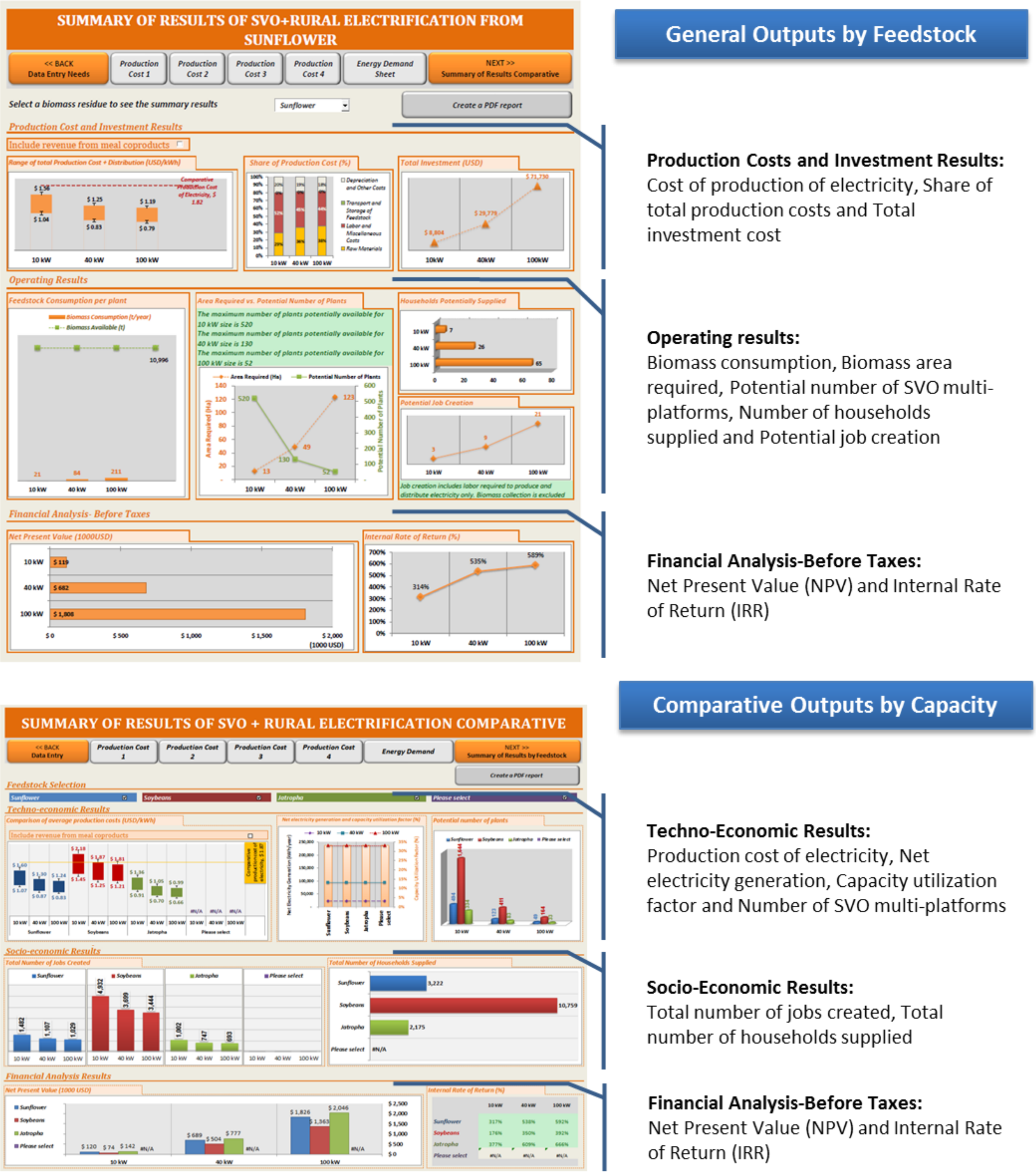


Figure 3: Layout of the SVO Results Sheets

3 Terms and Definitions in the *SVO Component*

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

- **Oleochemical feedstocks** includes a number of edible and non-edible oilseed crops (there are more than 350 oilseed bearing species, with thousands of sub-species), animal fats and oils, recycled or waste oils, and by-products of edible oil and dairy industries. Oleochemical feedstocks play an increasingly important role in society, both as an edible food product and for industrial purposes. One of the most important and well-known products obtained from these raw materials are **vegetable oils** (Bart, Palmeri et al., 2010). In addition, co-products obtained from extraction residues used as meals (in the case of oilseeds) provide a high energy and nutritionally important food source (Mailer, 2004).
- **SVO** is an acronym for Straight Vegetable Oils. This is a term used to describe vegetable oils used directly as fuel without chemical modifications in internal combustion engines. SVO are widely used in rural electrification programs and as part of biofuel mandates in some countries as a replacement to biodiesel, due to the low processing requirements. However, to use it properly, SVO engines must be modified in order to be able to operate with the high viscosities and high flash points of these vegetable oils. This could lead to solidification problems and engine damage in long-term operations.
- **Modified diesel engines** refer to conventional modified diesel engines with internal modification in the valves, pump system and lines performed to support the operation under SVO. Modified diesel engines are used in rural electrification projects mounted on multifunctional platforms where it is connected to a power generator (Rordorf, 2011).
- **The SVO analysis** involves the following steps: collection of the oleochemical feedstocks (biomass), transport and storage at the SVO plant. The first stage comprises the pretreatment processes, where oleochemical feedstocks are dried to remove excess moisture and/or milled for size reduction. After the pretreatment processes, the biomass residue is ready for mechanical extraction of SVO. The obtained vegetable oil passes through a cleaning system and is then fed into a modified diesel engine for power generation. The modified diesel engine generates electricity which is then distributed to households in a given area.

4 Scope and Objective of the *SVO Component*

The aim of the *SVO Component* is to assess the feasibility to develop electricity generation systems based on SVO to supply rural areas where the extension of the national electric grid is not economically or physically viable. It provides the user with a technical foundation to perform an analysis of SVO systems at different scales while considering different types of oleochemical feedstocks. The results of the analysis can be used to identify the viability of SVO production in terms of the most appropriate feedstock, the financial viability of the different production systems, the optimum production capacity and the socio and economic benefits that can be attained for each production system. The information generated by the analysis can also be used as an initial basis to discuss potential strategies to promote the development of SVO-based electrification systems in rural areas without current electricity access.

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

Figure 4: Rapid Appraisal Tool for Rural Electrification

5 Running the *SVO Component*

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

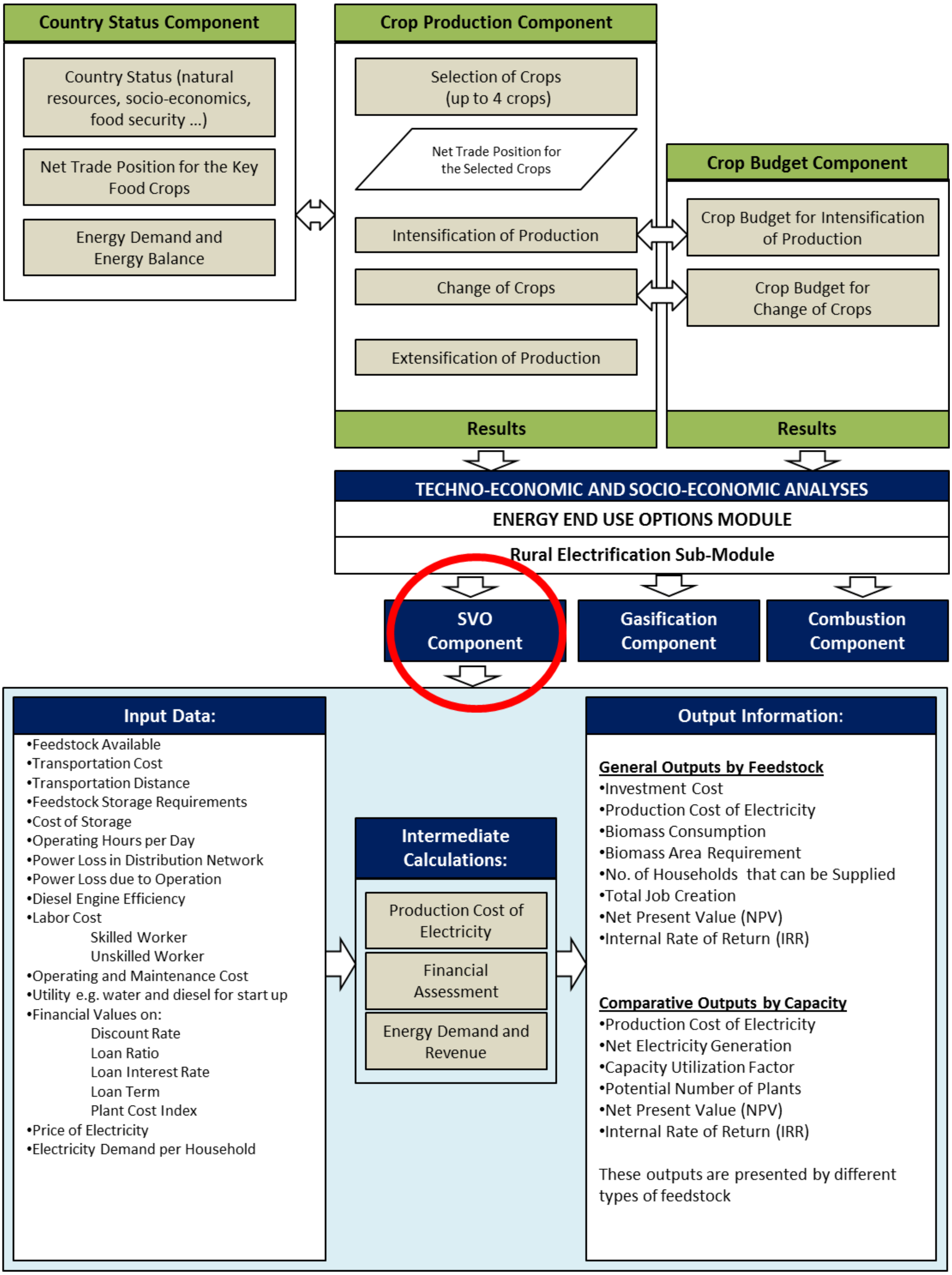


Figure 5: *SVO Component*: Flow of Analysis and Inter-linkages with BEFS RA Modules and Components

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

The following sub-chapters describe each step of the analysis. As an example, sunflower, soybean and jatropha are used as the feedstock for the SVO that are used to feed the power generation system. All input parameters are based on a generic situation.

At the beginning of the analysis, the user must select the language of preference in order to view the tool in that language (Figure 4, label 1). The language choices are: English (EN), French (FR) and Spanish (ES). Next, the user has three options, with the following navigation buttons: “SVO and Rural Electrification Description”, “Data Entry Sheet” and “Energy Demand” as shown in Figure 4.

5.1 Step 1: Energy Demand

The user needs to enter the electricity consumption per household (kWh/month) as it was defined in the *Country Status* module (Figure 6).

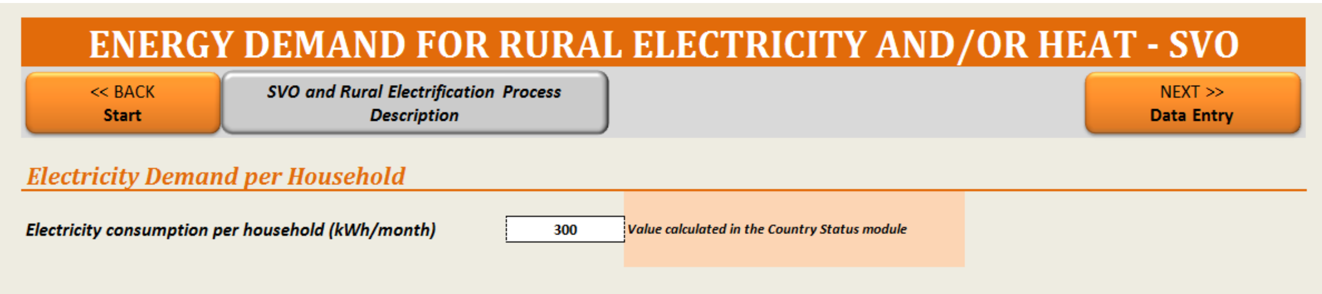


Figure 6: Energy Demand

5.2 Step 2: Defining the feedstock

Step 2.A Selection of the feedstock

The user will:

1. Select the crop(s) from the dropdown menu to be used for producing the SVO. The list includes 6 oil-based crops. Up to four oleochemical feedstocks can be analysed at the same time (Figure 7, label 1).

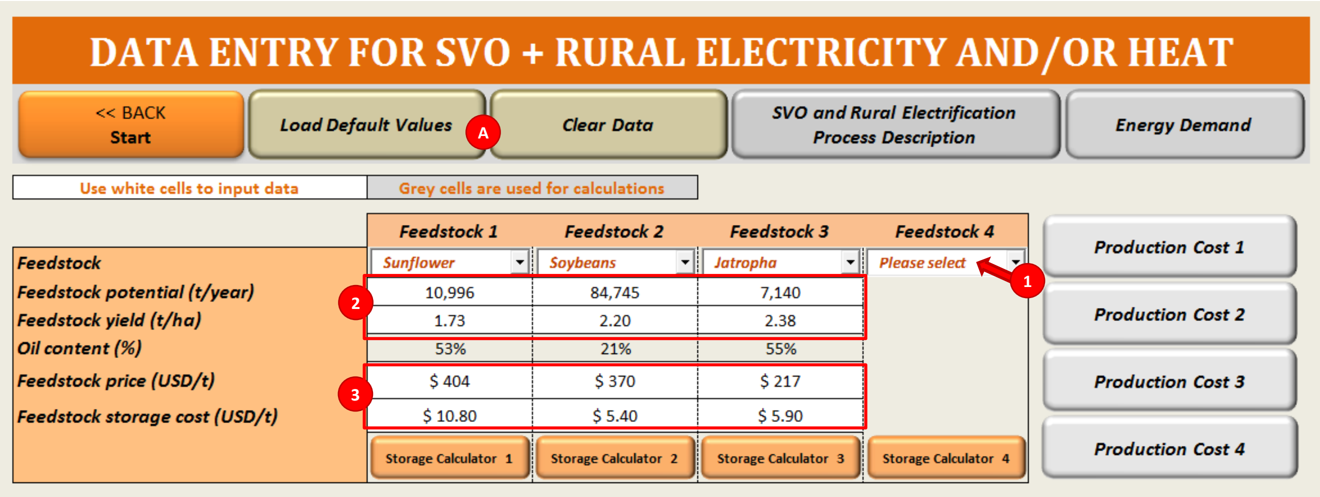


Figure 7: Feedstock Selection

2. Enter data on feedstock available (t/year) and yield (t/ha) of the selected oleochemical feedstocks (Figure 7, label 2). *This information is generated in the Natural Resources module*.
3. Enter data on feedstock price (USD/t) of the selected oleochemical feedstocks (Figure 7, label 3). *The user can input either the market price or the production cost that was estimated in the Natural Resources module – Crop Budget Tool*.
4. The oil content (%) or average percentage of moisture content of the selected oleochemical feedstocks is automatically generated from the technical database in the tool.

For this example, the following were selected: Feedstock 1 "Sunflower", Feedstock 2 "Soybeans", and Feedstock 3 "Jatropha" (Figure 7).

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

Step 2.B.1 The user can enter *the existing prices* of storage of agricultural products in the country as a proxy. The price should be entered in the respective cell for each feedstock (USD/tonne). If this information is not available, then the user should go to the next step.

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

1. Identify a type of feedstock storage likely associated with the conditions of his/her country from the options presented in Table 1.
2. For the selected storage option, look up the global building cost provided in Table 1.
3. Enter the proxy value (USD/tonne) in the respective cell for each feedstock.

Table 1: Estimated Cost of Storage in Steel Bins

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

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

For this example, all feedstock are stored on bins with a concrete floor. The cost of storage is $10.80 for sunflower, $5.40 for soybeans and $5.90 for jatropha. The user must input each cost in the corresponding cells, as shown in Figure 8, label 1.

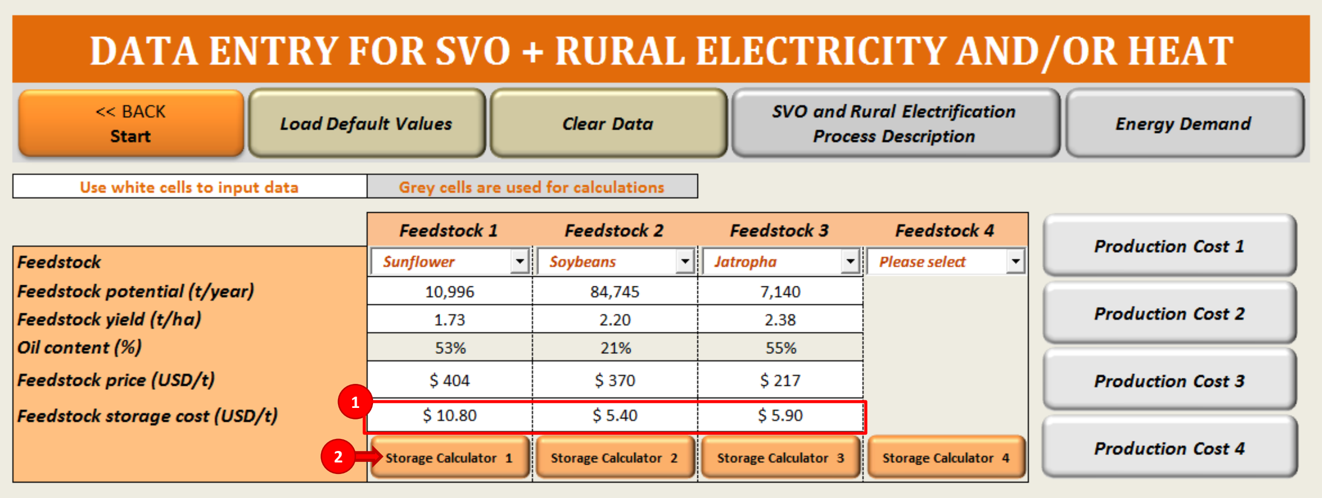


Figure 8: Feedstock Storage Cost

Step 2.C.3 In order to calculate the storage capacity needs, the user needs to click on the "Storage Calculator" (Figure 8, label 2). This will take the user to the Biomass Storage Calculator (Figure 9). In this worksheet, the user will need to:

1. Selects the harvesting month(s) of the crop (Figure 9, label 2).
2. Enter the biomass safety stock rate (%). This is the percentage of oleochemical feedstock needed to secure continuous supply of feedstock to deal with uncertainty in production due to seasonal availability, flood, drought, and other factors. This stock rate % is used to estimate the storage capacity (Figure 9, label 1).
3. Click on "Calculate" (Figure 9, label 3) to automatically compute the amount of maximum storage capacity required (tonnes) and the minimum safety storage (tonnes per month) for each of the pre-defined capacities (Figure 9, label 4).
4. Clicks "OK" to return to the Data Entry Needs sheet (Figure 9, label 5).
5. Repeat the same steps for all feedstock.

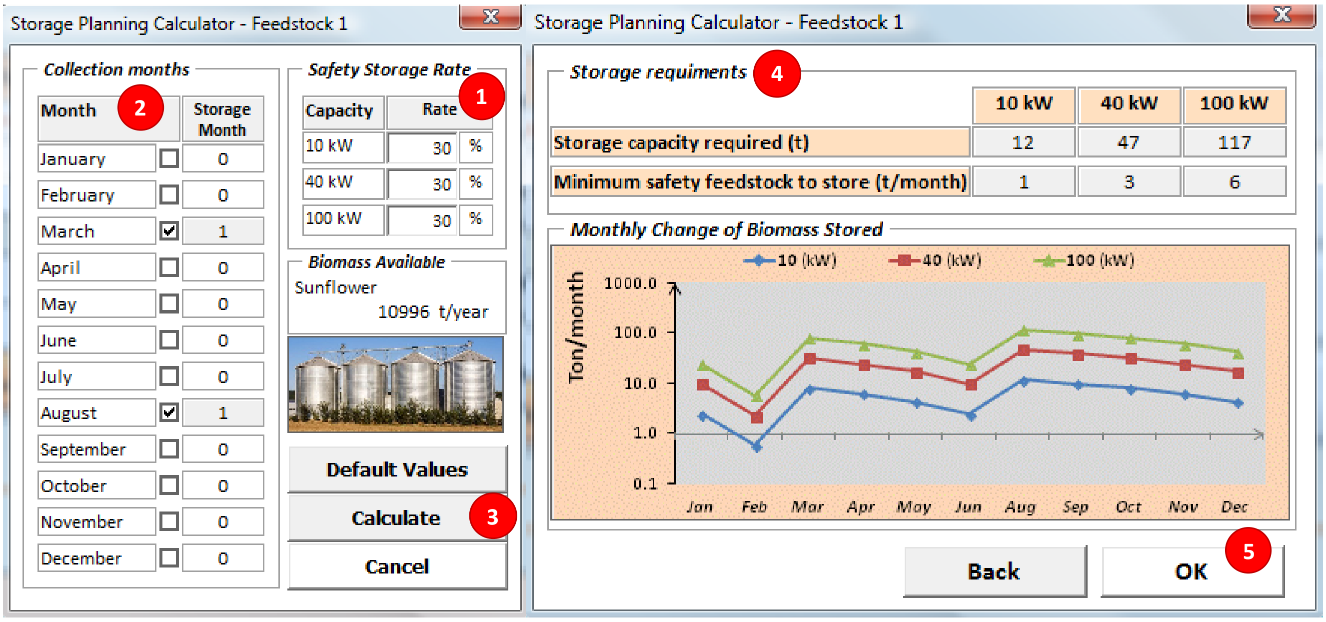


Figure 9: Storage Calculator of Feedstock

In this example, Feedstock 1 is harvested in 2 months: March and August. As a result, the storage capacity required is 12 t to secure sufficient biomass for a 10kW production capacity. The minimum safety feedstock to store is 1 t per month (Figure 9).

5.3 Step 3: Defining the electricity price

The electricity price is used to analyse the total revenue of power generation by the SVO electrification plant. The user selects a method to define the price of electricity from the following options:

A. Method 1: Use a calculator to define the price of electricity based on a diesel generator system. To run this option the user must:

1. Select "Method 1" to define the price of electricity (Figure 10, label 1).
2. Click on "Electricity Price Calculator" (Figure 10, label 2).
3. Enter the following data in the "Electricity Price Calculator" (Figure 10, red box). However if specific data are unavailable, then default values are provided in the tool (Figure 10, label 3).
   - Current electricity generation technology:
     - Diesel generator capacity (kW)
     - Operating hours per day
     - Operating day per year
     - Typical efficiency (%)
   - Cost parameters:
     - Diesel cost (USD/litre)
     - Transportation cost of diesel (USD/t/km)
     - Transportation distance (km)
     - Operating and maintenance cost (USD/kWh)
     - Equipment cost (USD)
4. Once all data is entered, click on "Calculate" (Figure 10, label 4).

5. The comparative production cost of electricity will be generated (Figure 10, label 5). This is linked to the "Data Entry Needs" worksheet and will be used for further calculation.

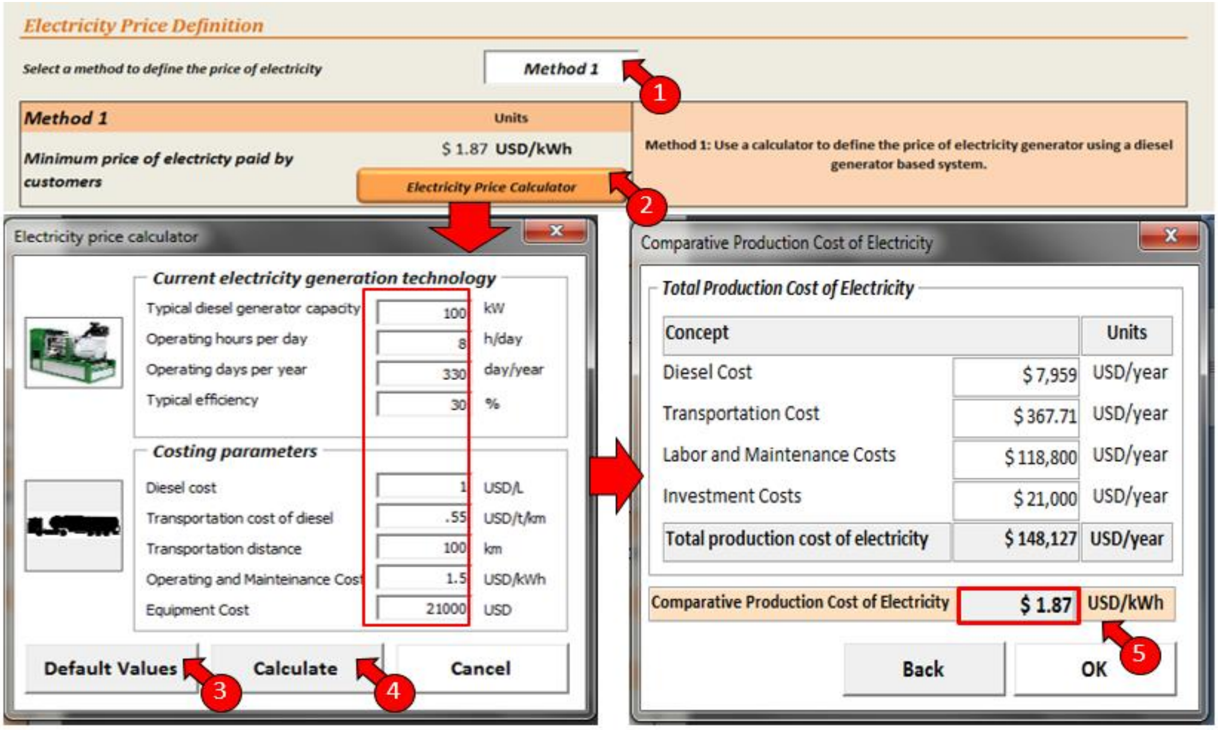


Figure 10: Electricity Price Definition - Method 1

B. **Method 2**: Use an electricity price identified by the user. The user identifies a price of electricity in unit of USD/kWh. This price can be the current price from the national grid or the price of electricity that is generated from decentralized energy options, e.g. solar energy, mini-small hydro power, etc. To run this analysis, the user has to:

1. Select "Method 2" to define the price of electricity (Figure 11, label 1).
2. Enter the price of electricity paid by the customer (Figure 11, label 2).

Note: This price might include subsidies. It is advised to take this into consideration and carefully assess the likelihood that this price reflects the true price paid by rural consumers.

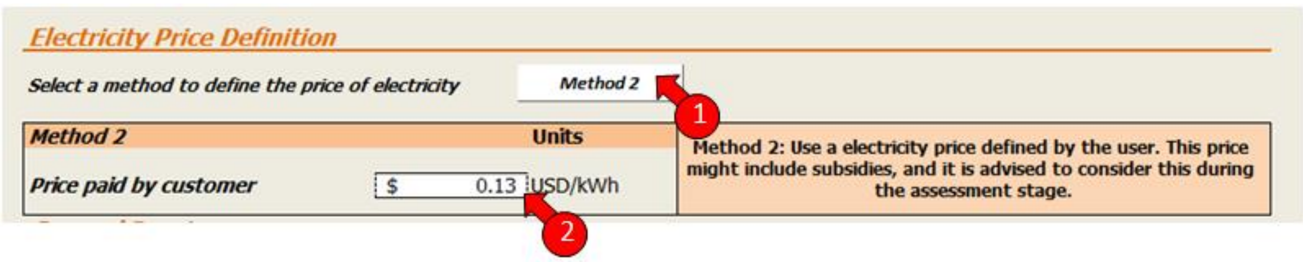


Figure 11: Electricity Price Definition - Method 2

For this example, the user can use the minimum price of electricity paid by customers, which is 1.87 USD/kWh (result of Method 1 as shown in Figure 10) or 0.13 USD/kWh (Method 2 for defining the price paid by customer as shown in Figure 11) for further analysis.

5.4 Step 4: Production cost and financial parameters

General inputs required to run the operations are shown in Figure 12. The user will need to provide data on:

Production Cost and Financial Parameters

Labour		**Unit**			**Unit**
Unskilled worker	$ 1.25	USD/person-h	***Skilled worker***	$ 2.00	USD/person-h
Utilities		**Unit**			
Diesel	$ 1.00	USD/litre	***==>Required to start up the engine***		
Transportation cost		**Unit**			
Feedstock (collection point to plant)	$ 0.09	USD/t/km			
Other costs		**Unit**			**Unit**
General and administrative (%)	10%		***Maintenance (%)***	25%	
Plant overhead (%)	20%		***Miscellaneous (%)***	20%	
Financial parameters		**Unit**	***Investment cost update***		
Discount rate	10%				
Loan ratio	50%		***Plant Cost Index during 4/2014***	157.30	
Loan interest rate	12%		http://base.intratec.us/home/ic-index		
Loan terms	5	year			

Figure 12: General Inputs

1. **Labour cost (USD/person-hour)**: the labour rate for unskilled and skilled workers (USD per person per hour). These parameters are required to calculate the labour cost of SVO extraction and electricity production processes.
2. **Utilities cost**: the price of diesel needed for start-up. This price will be directly entered by the user in the corresponding cell in USD per litre.
3. **Transportation cost of feedstock (USD/t/km):** cost of transportation of feedstock from the collection point to the SVO electrification plant. The user will need to:
   - Identify the current methods of transportation typically used to move agriculture commodities within the country.
   - Define the current transportation prices associated to the transportation method identified above in unit of USD per tonne per km.

Guidance: This can be based on unprocessed agricultural goods.

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

Transportation cost (USD/tonne/km)

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

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

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

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

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

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

5.5 Step 5: Calculation of the production cost of electricity

After entering the data in Steps 1 to 4, the user can click on any of the "Production Cost" buttons (Figure 13, label 1).

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

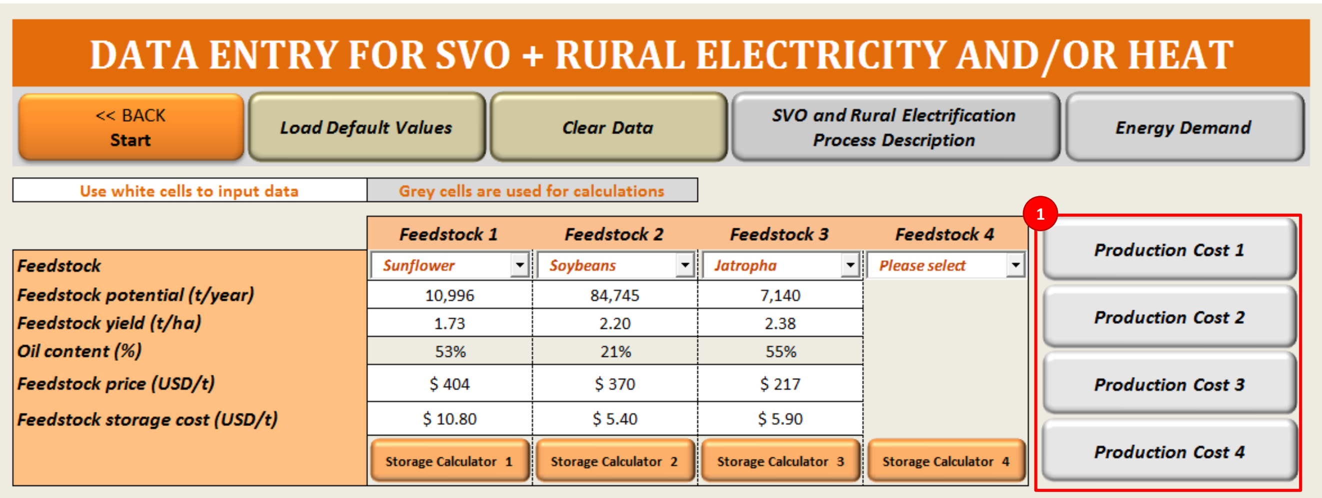


Figure 13: Production Cost Calculation

This will take the user to the budget processing section for the selected feedstock (Figure 14).

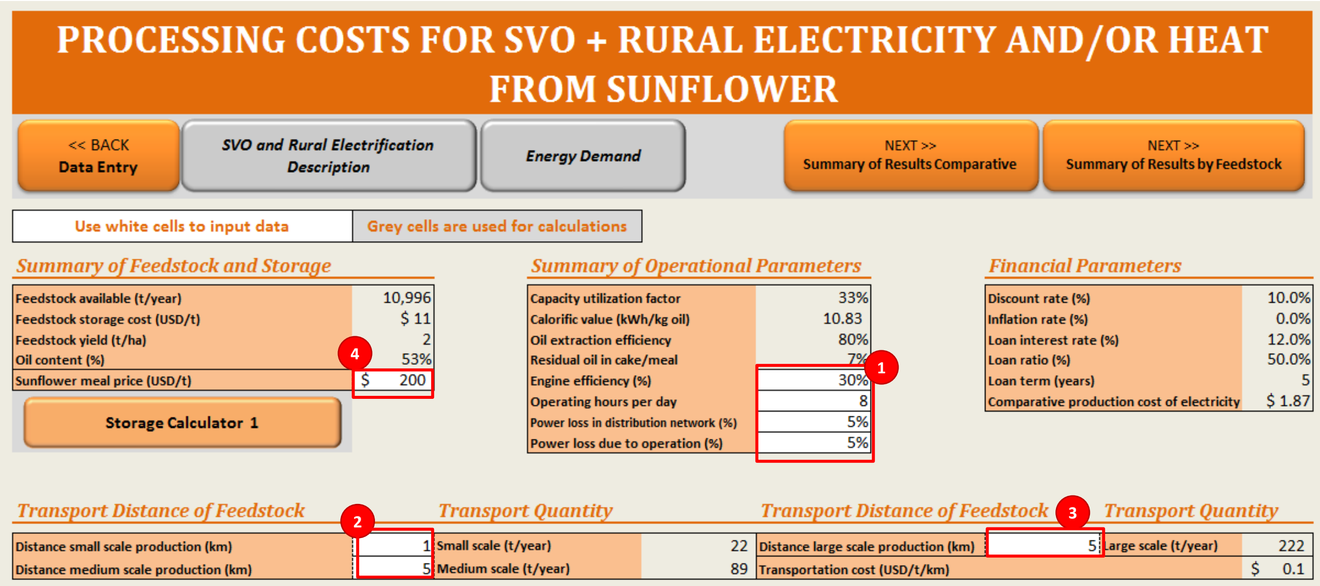


Figure 14: Processing Costs for Oil Extraction and Power Generation

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

1. **Power losses due to operation (%):** losses due to inappropriate operation of the SVO-engine system. These losses are assumed to be 15%. However, a parameter can be entered directly by the user (Figure 14, label 1).

> **Note:** These include lack of control and monitoring of units measuring combustion pressure, air leakage, or temperatures, etc. These lead to lower power outputs than the installation capacity.

2. **Operating hours per day:** The user enters the operating hours per day to run the SVO electrification plant. The daily operating hours are used to compute the total annual operating hours and the capacity factor, assuming the SVO electrification plant runs for 365 days per year (Figure 14, label 1).

> **Guidance:** The operating hours should be related to electricity demand in a given rural location. For example, operate six hours per day in the evening to meet the lighting demand in rural area A.

3. **Power losses in distribution network (%):** The user identifies the power loss (%) in the distribution network. If this information is not readily available, the following database can be used: http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS (The Wold Bank, n.d.) (Figure 14, label 1).

> **Guidance:** The power loss in distribution from the current electric grid could be used as proxy.

4. **Engine efficiency (%):** The typical modified diesel engine efficiency by using SVO as fuel is 25-35%. The assumed value is 30% (Figure 14, label 1).

5. **The transportation distance of feedstock to SVO electrification plant:** The user identifies an estimated distance, in kilometres, that will be required to transport the feedstock. The transportation distance depends on the availability of biomass in a particular area and the amount of biomass required for each production capacity (Figure 14, labels 2 and 3).

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

6. **The meal price:** The user identifies the market price in USD/t of the meal co-product of the selected feedstock. In this example, the value used was 200 USD/t (Figure 14, label 4).

Once all data is entered, the user must click on "<<BACK Data Entry" to return to the Data Entry Needs sheet. The user can repeat the same steps for all feedstock.

For this example, the "Production Cost 1" is "Sunflower". The values that were used to carry out the analysis are:
Power losses due to operation (%): 5%
Operating hours per day: 8
Power losses in distribution network (%): 5%
Engine efficiency (%): 30%
The transportation distance of feedstock to SVO plant:
Distance for small scale plant: 1 km
Distance for medium scale plant: 5 km
Distance for large scale plant: 5 km
The transportation quantities are automatically generated:
Small scale plant: 22 t per year
Medium scale plant: 89 t per year
Large scale plant: 222 t per year
These parameters are used for further analysis.

6 Assumptions and Limitations of the *SVO 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 SVO electrification component are:

1. Three electricity generation capacities are considered: 10kW, 40kW and 100kW.
2. The lifetime of the equipment is considered to be 20 years for the financial analysis.
3. The oil extraction efficiency has been pre-defined for each feedstock option.
4. The SVO electrification plant is based on a mini-grid option which integrated local generation, transmission and distribution of electricity.
5. The estimated quantity of cable to set up the transmission and distribution system is estimated assuming that 10 metres of cable/household are needed.

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

7 The Results of the *SVO Component*

7.1 Overview of the production cost calculation (optional)

After the user inputs all required data (Steps 1 to 5), then the user has the option to review the detailed production cost as shown in Figure 15. There are five main sections in this worksheet as explained below.

PART 1 (Figure 15, label 1) shows the distribution of the production cost along the following categories: inputs, labour, transportation of feedstock, storage, investment, plant overhead, general and administrative cost, loan interest, and income tax. The total production costs (USD/year) of the three power generation capacities (10kW, 40kW and 100kW) are presented for comparative analysis.

PART 2 (Figure 15, label 2) shows the total net power generation, which is the electricity in unit of kWh per year (note that the self-consumption, used to run the operation and power loss in transmission and distribution network, has been subtracted). These values are used to calculate the revenue of the SVO power generation system. The results are presented for all three power generation capacities.

PART 3 (Figure 15, label 3) shows the unit cost of electricity (USD/kWh) for all three power generation capacities.

PART 4 (Figure 15, label 4) summarizes the loan details, e.g. loan amount, loan interest, annual loan payment, etc., for financial analysis.

PART 5 (Figure 15, label 5) the "Financial Analysis" buttons will open the worksheet with the details on the financial analysis for each power generation system.

Production Cost Details

	Capacities (kW of power generation)		
	10	40	100
Operating hours per year	2,920	2,920	2,920
5	Financial Analysis 10 kW	Financial Analysis 40 kW	Financial Analysis 100 kW

1

Inputs	Unit	Unit Price (USD/unit)	10 kW Quantity (Unit/year)	10 kW Total (USD/year)	40 kW Quantity (Unit/year)	40 kW Total (USD/year)	100 kW Quantity (Unit/year)	100 kW Total (USD/year)
Feedstock (Oilseed)	t	$ 404.0	22	$ 8,980	89	$ 35,920	222	$ 89,800
Diesel for start up	litre	$ 1.0	569	$ 569	2,274	$ 2,274	5,685	$ 5,685
Subtotal				*$ 9,549*		*$ 38,194*		*$ 95,486*

Labour and Miscellaneous Cost	Unit	Unit Price (USD/person /h)	10 kW Quantity (Unit)	10 kW Total (USD/year)	40 kW Quantity (Unit)	40 kW Total (USD/year)	100 kW Quantity (Unit)	100 kW Total (USD/year)
Unskilled worker	# employee	$ 1.3	2	$ 7,300	7	$ 25,550	17	$ 62,050
Skilled worker	# employee	$ 2.0	1	$ 5,840	2	$ 11,680	4	$ 23,360
Miscellaneous cost	%		20%	$ 2,628	20%	$ 7,446	20%	$ 17,082
Subtotal				*$ 15,768*		*$ 44,676*		*$ 102,492*

Transport of Feedstock	Unit	Unit Price (USD/t/km)	10 kW Quantity (Unit)	10 kW Total (USD/year)	40 kW Quantity (Unit)	40 kW Total (USD/year)	100 kW Quantity (Unit)	100 kW Total (USD/year)
Feedstock (farm to plant)	km	$ 0.1	1	$ 2	5	$ 40	5	$ 100
Subtotal				*$ 2*		*$ 40*		*$ 100*

Storage	Unit	Unit Price USD/t	10 kW Quantity (Unit)	10 kW Total (USD/year)	40 kW Quantity (Unit)	40 kW Total (USD/year)	100 kW Quantity (Unit)	100 kW Total (USD/year)
Feedstock	t	$ 10.80	12	$ 130	47	$ 508	117	$ 1,264
Subtotal				*$ 130*		*$ 508*		*$ 1,264*

Investment	Unit	Years	10 kW Total (USD)	10 kW Depreciation (USD/year)	40 kW Total (USD)	40 kW Depreciation (USD/year)	100 kW Total (USD)	100 kW Depreciation (USD/year)
Equipments	USD	20	$ 4,879	$ 244	$ 19,514	$ 976	$ 48,786	$ 2,439
Building	USD	20	$ 2,020	$ 101	$ 2,644	$ 132	$ 3,891	$ 195
Installation	USD	20	$ 287	$ 14	$ 1,148	$ 57	$ 2,871	$ 144
Distribution network	USD	20	$ 1,652	$ 83	$ 6,609	$ 330	$ 16,523	$ 826
Total investment			$ 8,838		$ 29,915		$ 72,070	
			Total Depreciation	$ 442	Total Depreciation	$ 1,496	Total Depreciation	$ 3,604
Maintenance cost	%	25%		*$ 110*		*$ 374*		*$ 901*
Subtotal				$ 552.37		$ 1,869.71		$ 4,504.40

Other Costs	Unit	Rate (%)	10 kW Total (USD/year)	40 kW Total (USD/year)	100 kW Total (USD/year)
Plant overhead	USD	20%	$ 2,650	$ 7,521	$ 17,262
General and administrative cost	USD	10%	$ 2,808	$ 9,077	$ 21,614
Loan interest	USD	0%	$ 74	$ 250	$ 603
Income tax	USD	-	$ -	$ -	$ -
Subtotal			5,532	16,848	39,479

	10 kW Total (USD/year)	10 kW Share (%)	40 kW Total (USD/year)	40 kW Share (%)	100 kW Total (USD/year)	100 kW Share (%)
Total operating costs	*$ 25,448*	*81%*	*$ 83,418*	*82%*	*$ 199,341*	*82%*
Total fixed costs	*$ 552*	*2%*	*$ 1,870*	*2%*	*$ 4,504*	*2%*
Total other costs	*$ 5,532*	*18%*	*$ 16,848*	*16%*	*$ 39,479*	*16%*
Total production costs	$ 31,532		$ 102,135		$ 243,325	

Power Generation

2

	Unit	10 kW Quantity (Unit)	40 kW Quantity (Unit)	100 kW Quantity (Unit)
Power generation	kWh/year	*27,740*	*110,960*	*277,400*
Electricity-self use	kWh/year	*-2,774*	*-11,096*	*-27,740*
Power loss in distribution network	kWh/year	*-1,387*	*-5,548*	*-13,870*
Subtotal		23,579	94,316	235,790

Total Production Cost+Distribution

3

	Capacities (kW of power generation)		
	10	40	100
Unit cost of electricity (USD/kWh)	$ 1.34	$ 1.08	$ 1.03

4

Average loan interest	Unit	Loan ratio (%)	10 kW Total investment (USD)	10 kW Loan amount (USD)	40 kW Total investment (USD)	40 kW Loan amount (USD)	100 kW Total investment (USD)	100 kW Loan amount (USD)
Loan amount	USD	50%	*$ 8,838*	*$ 4,419*	*$ 29,915*	*$ 14,958*	*$ 72,070*	*$ 36,035*
Loan interest rate	%			*12%*		*12%*		*12%*
Loan payment	USD/month			*$ -98*		*$ -333*		*$ -802*
Annual loan payment	USD/year			*$ -1,180*		*$ -3,993*		*$ -9,619*
Loan terms	year			*5*		*5*		*5*
Total loan payment	USD			*$ -5,898*		*$ -19,964*		*$ -48,095*
Loan interest	USD			*$ -1,479*		*$ -5,006*		*$ -12,060*
Average loan interest	USD/year			*$ -74*		*$ -250*		*$ -603*

Figure 15: Detail of Production Costs of Electricity by Power Generation Capacity

For this example, the total production cost of electricity when using sunflower SVO to run a 10kW capacity is 31,532 USD/year and the unit cost of electricity is estimated at 1.34 USD/kWh. Moreover, the total power generation is 23,579 kWh/year. For other pre-defined capacities, refer to Figure 15.

7.2 The summary results by feedstock

The information presented in this section aims to help the user in the decision making process to support the development of SVO-based power generation systems in his/her country. The results aim to answer the following questions:

- What are the investment costs and production costs per kWh?
- How much oleochemical feedstocks are required to support each of the electricity generation scales analysed in the tool?
- How much land is required to supply feedstock needs?
- What are the potential numbers of SVO power generation plants that can be developed based on the availability of feedstock at the national level?
- How many households can gain access to electricity through SVO power generation systems?
- How many jobs can be created through the deployment of SVO power generation systems?
- What is the financial viability of different SVO electrification systems in terms of feedstock and production capacity?
- Which type of feedstock is more appropriate to promote the development of SVO power generation systems?

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

1. The user first selects the feedstock from the dropdown menu that he/she wants to review (Figure 16, label 1). The results for that specific feedstock will be generated.
2. The production cost and investments results are presented as follows:
   - Cost of production and distribution of electricity (USD per kWh) (Figure 16, label 2). The user can compare the production cost to the price of electricity (according to the method selected in Step 3).
   - Share of production cost (%) (Figure 16, label 3).
   - Total investment cost (USD) of the SVO system by power generation capacity (Figure 16, label 4).
3. Additionally, the user can alternatively include revenue from meal co-products. This will have an impact on total production costs***.*** *This option appears only for feedstock for which meal co-products can be obtained* (Figure 16, label 5).

Guidance: Only the following oleochemical feedstocks can produce edible meals which can be marketed: sunflower, soybean, rapeseed. The remaining feedstocks produce extraction cakes. These have other potential applications (e.g. fertilizers) which are not considered in this tool.

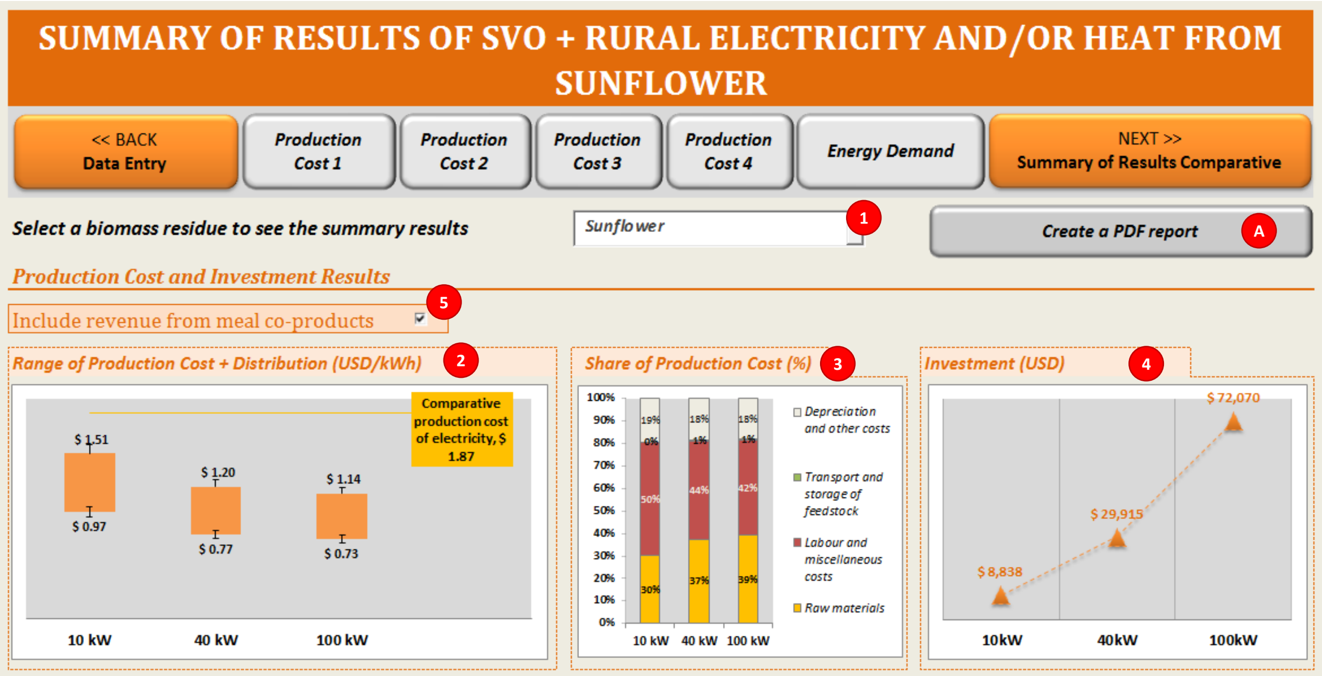


Figure 16: Production Cost and Investment Results

> **In the example for sunflower, the production cost plus the distribution cost of 10kW ranged between 0.97-1.51 USD per kWh. These unit costs are lower than the electricity price 1.87 USD/kWh (Method 1 in Step 3 was selected). Therefore, this plant is feasible and an attractive investment. The total investment cost of 10kW is 8,838 USD. For other pre-defined capacities refer to Figure 16.**

4. The technical and operating results are presented as follows:
   - Feedstock required to operate each of the production capacities (t per year) (Figure 17, label 1).
   - Feedstock area required to produce enough biomass to run the SVO systems (hectare) (Figure 17, label 2).
   - Number of SVO electrification plants based on the availability of oleochemical feedstock (Figure 17, label 3).
   - Number of households which can be supplied by the different electrification systems (Figure 17, label 4).
   - Total number of jobs that can be created through the implementation of the SVO electrification systems analysed by the tool (Figure 17, label 5).

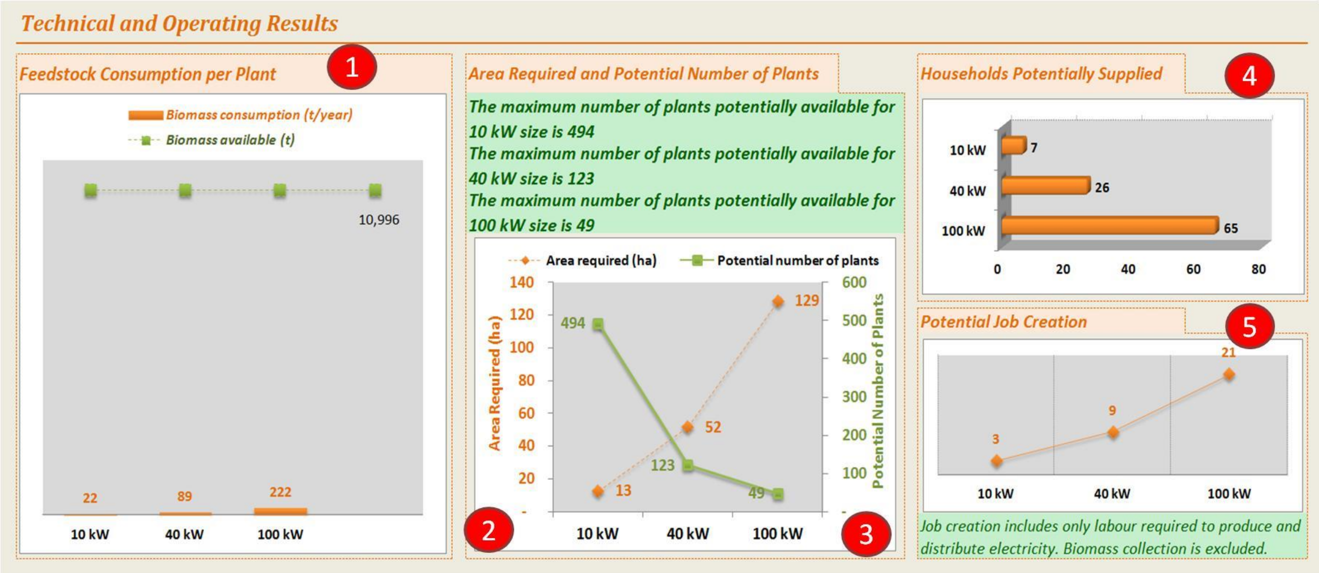


Figure 17: Operating Results

In the example for sunflower, the feedstock available is 10,996 t per year, which is sufficient enough to supply the feedstock needed for the three production capacities.
Considering the feedstock availability, approximately 494 potential plants of 10kW capacity (which requires 13 hectares of area of feedstock) can be developed. The development of a 10 kW SVO-run plant can supply energy to 7 households. In addition, the potential job creation from the SVO plant of 10kW capacity is three jobs to run plant processing. So if all 494 plants are developed, this will entail about 1560 jobs.
For other pre-defined capacities, refer to Figure 17.

5. The financial analysis (before tax return) results are presented as follows:
   - Net Present Value (NPV) (Figure 18, label 1)
   - Internal Rate of Return (IRR) (Figure 18, label 2)

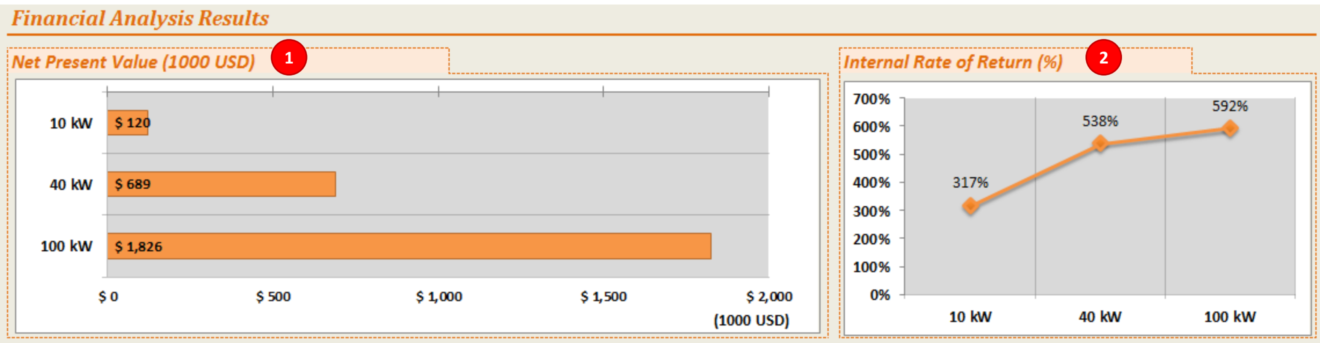


Figure 18: Financial Analysis Results

For the sunflower example, the net present value (NPV) and internal rate of return (IRR) for all plant capacities are positive as shown in Figure 18. It can be concluded that SVO electrification using sunflower is feasible for power generation at all plant capacities (Figure 18).

The user can save and print the results in PDF format by using "Create a PDF report" and following the instructions (Figure 16, label A).

7.3 The summary of comparative results

The information presented in this section aims to help the user in the decision making process to support the development of the biomass SVO for power generation in rural areas from four types of feedstock.

1. The user first selects the feedstock, by clicking on it, that he/she wants to review. The results for that specific feedstock will be generated.
2. Comparison results are presented on:
   - Production costs according to feedstock (USD/kWh) (Figure 19, label 1)
   - Net electricity generation and the percentage of the overall potential full capacity (i.e. plant operates 24 hours a day) that is currently being used according to each of the selected feedstock (Figure 19, label 2)
   - Potential number of SVO electrification plants which can be developed according to each feedstock (Figure 19, label 3)
   - Total number of jobs that can be created (Figure 19, label 4)
   - Total number of households that can be supplied (Figure 19, label 5)
   - Comparison of NPV (before taxes) across the selected feedstock options (Figure 19, label 6)
   - Comparison IRR (before taxes) across the selected feedstock options (Figure 19, label 7)

Guidance: These results can help identify the type of feedstock and production scale that is most viable and should, therefore, be promoted for the SVO system.

The user can save and print the results in PDF format by using “Create a PDF report” and following the instructions (Figure 19, label A).

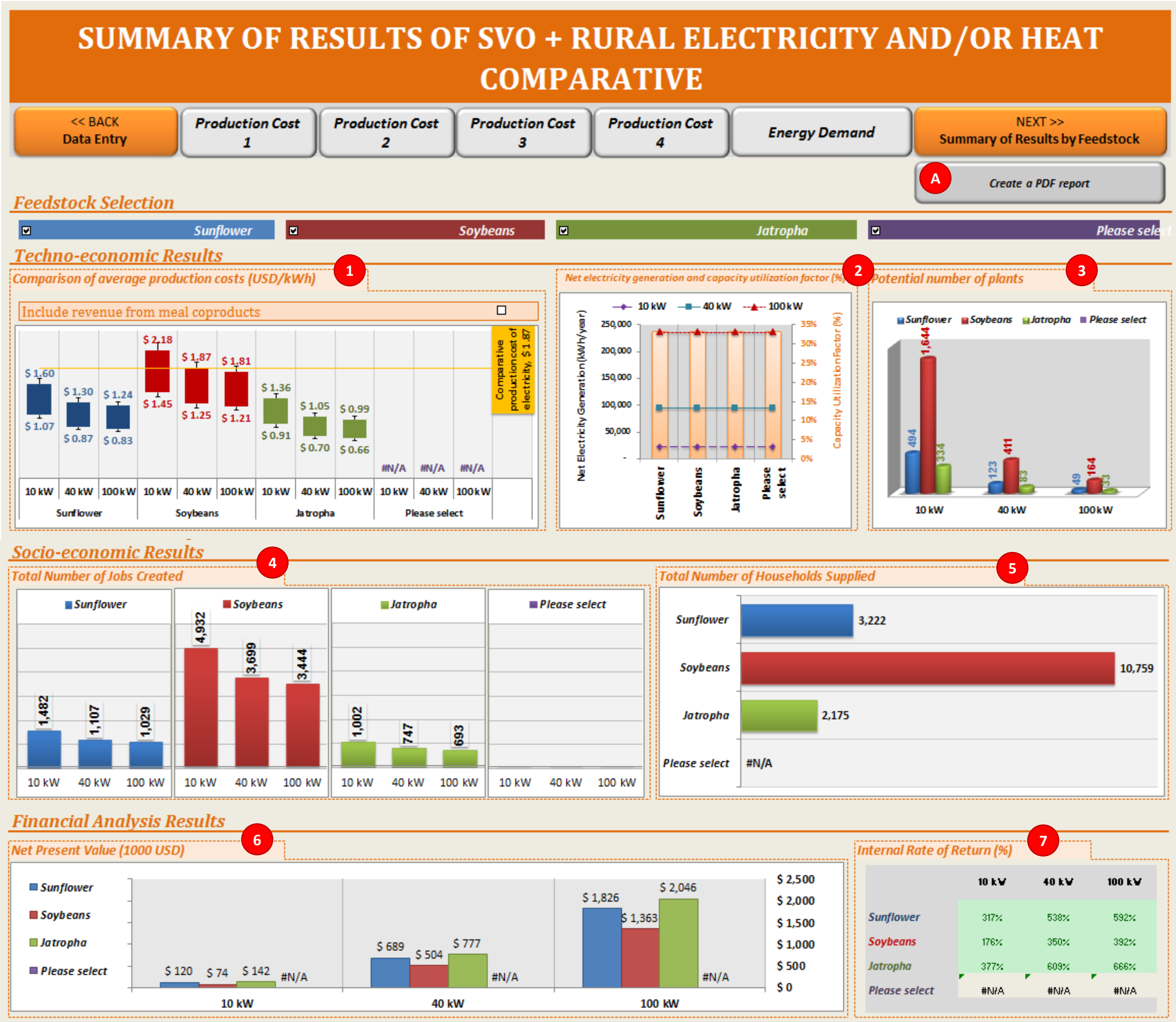


Figure 19: Layout of Comparative Results

For this example, the production cost of electricity when using soybean as feedstock is the highest for all plant capacities when compared to the other feedstock. Sunflower and jatropha have the lowest production cost. Notably, all of the feedstock provide positive NPV and IRR as shown in Figure 19. From this analysis, the user can conclude that:

1. Sunflower, soybean and jatropha are all feasible feedstock alternatives for power generation for the three production capacities.
2. The highest revenue could be obtained when using jatropha as feedstock, but fewer plants can be developed.
3. Soybean is the feedstock that is more widely available to support the development of a greater number electrification plants.

8 Annex

8.1 Methodology and outputs

This section describes the methodologies integrated in the *SVO Component*. It also includes a description of the equations which support the analysis. The equations are not visible to the user, but their structure and content might be important for those who will update them and/or work on the improvement of the tool.

8.1.1 Cost calculation of required inputs

The required inputs consist of the cost of feedstock (biomass) and the price of diesel. The equations used to calculate the cost of these items are presented in Table 2.

Table 2: Inputs Cost Equations

Item	Equation and Assumption	Remark
Quantity of feedstock	QF = PG/[PC x engine efficiency x OE x OC x (1-Power losses due to operation)] Where: QF is Quantity of feedstock (t per year) PG is Power generation (kWh per year) OE is Oil extraction efficiency (%) OC is Oil Content (%) PC is Power conversion potential (kWh per kg of feedstock)	PC is varied depending on the type of feedstock. A power loss due to operation is assumed at 15%. Oil extraction efficiency and oil content depend on the selected feedstock.
Diesel consumption to start up the generator	C = 50% x PC x OP/(10.7 x engine efficiency) Where: PC is Power generation capacity (kW) OP is Operating hours of start-up period (hours per year) DS is Specific diesel consumption (kWh per litre)	PC is: 10kW, 40kW and 100kW capacity. Default value of OP is 365 hours per year (1 hour per day). Default value of DS is assumed to be 3.33. 10.7 is the calorific value of diesel in kWh/l.
Total Inputs cost	TIC = (QF x Cf) + (DC x Cd) Where: TIC is Total Inputs cost (USD per year) QF is Quantity of feedstock (t per year) DC is Diesel consumption (litres per year) Cf is unit cost of feedstock (USD per t) Cd is unit cost of diesel (USD per litre)	
Power generation (PG) (kWh per year)	Power capacity (kW) x Operating hours per year Where, Operating hours per year= Operating hours per day x 365 days per year	Operating hours per year entered by the user.

To calculate the biomass consumption as feedstock

The quantity of feedstock is calculated based on the power generation in kWh per year and the power conversion of biomass to electricity through the SVO system.

$$\text{Engine efficiency (\%)} = \frac{\text{Power Output}}{\text{Power input}}$$

$$= \frac{\text{Power capacity (kW) x Operating hours } \left(\frac{\text{h}}{\text{year}}\right)}{\text{Power Conversion Potential } \left(\frac{\text{kWh}}{\text{kg biomass}}\right) \text{ x Biomass consumption } \left(\frac{\text{kg}}{\text{year}}\right)}$$

Where:

$$\text{Power Conversion Potential} = \text{Calorific Value SVO } \left(\frac{\text{MJ}}{\text{kg SVO}}\right) \text{ x } \frac{\text{1kWh}}{\text{3.6 MJ}}$$

Therefore, biomass consumption (kg/year) is calculated by:

$$= \frac{\text{Power capacity (kW) x Operating hours } \left(\frac{\text{h}}{\text{year}}\right)}{\text{Power Conversion Potential } \left(\frac{\text{kWh}}{\text{kg SVO}}\right) \text{ x engine efficiency (\%) x oil extraction efficiency (\%)X oil content (\%)}}$$

However, the actual power generation takes into account the power losses. These losses are due to an inappropriate operation of the SVO-engine system. These include the lack of control and monitoring of units measuring gas pressure, air leakage, or temperatures etc. Therefore, these causes lead to lower power output than the installation capacity. These losses are assumed to be 5%.

Therefore, biomass consumption (kg/year) is calculated by:

$$= \frac{\text{Power capacity (kW)x Operating hours } \left(\frac{\text{h}}{\text{year}}\right)}{\text{Power Conversion Potential } \left(\frac{\text{kWh}}{\text{kg SVO}}\right) \text{ x engine efficiency (\%) x oil extraction efficiency (\%) x oil content (\%) x (1−Power losses due to operation (\%)}}$$

8.1.2 Cost calculation of required labour

This step presents the equations and assumptions for calculating the labour and miscellaneous cost based on the power generation capacity as shown in Table 3.

Table 3: Labour and Miscellaneous Cost Equations

Item	Equation and Assumption	Remark
Number of unskilled labour	10kWcapacity is 1 person 40kWcapacity is 3 person 100kWcapacity is 6 person	(Nouni et al., 2007) (Dasappa, Subbukrishna, Suresh, Paul, & Prabhu, 2011)
Number of skilled labour	10kWcapacity is 1 person 40kWcapacity is 1 person 100kWcapacity is 2 person	(Dasappa et al., 2011)
Total unskilled labour cost (USD per year)	Unit cost of unskilled labour x number of unskilled labour x operating hours per year	Unit cost of unskilled labour (USD/person/hour) Input entered by user in "Data Entry Needs" Operating hours per year same as Table 3.
Total skilled labour cost (USD per year)	Unit cost of skilled labour x number of skilled labour x operating hours per year	Unit cost of skilled labour (USD/person/hour) Input entered by user in "Data Entry Needs" Operating hours per year same as Table 3.
Miscellaneous cost (USD per year)	Percentage of miscellaneous cost (%) x (Total unskilled labour cost + Total skilled labour cost)	Percentage of miscellaneous cost input by the user. Default value is 10%.
Total labour cost (USD per year)	Total Unskilled labour cost + Total skilled labour cost + Miscellaneous cost	

Note that a miscellaneous costs consist of labour benefits, health & life insurance, operating supplies and/or laboratory charges (if any).

8.1.3 Cost calculation of required transportation

This step presents the calculation equations of transportation cost as shown in Table 4.

Table 4: Transportation of Feedstock Cost Equations

Item	Equation and Assumption	Remark
Transportation of feedstock (field to plant) (USD per year)	Unit transportation cost x Transportation distance x QF Where: QF is Quantity of feedstock (t per year)	Unit transportation cost (USD/t/day/km) and Transportation distance (km) entered by the user QF is calculated in Table 2.

8.1.4 Cost calculation of storage

Table 5 presents the calculating equations for estimating the storage cost.

Table 5: Storage Cost Equations

Item	Equation and Assumption	Remark
Storage Capacity (t/year)	The estimate storage capacity in "Storage Calculator#" worksheet by pressing on the "Storage Calculator"	
Storage cost (USD per year)	Unit storage cost x Storage Capacity	Unit storage cost (USD/t/day) entered by user based on guidance provided in the manual.

8.1.5 Fixed cost calculation

Fixed cost consists of the cost associated with equipment, building, installation and distribution network. Table 6 presents the equations and assumptions applied to calculate the fixed cost and the depreciation cost.

Table 6: Fixed Cost Equations

Item	Equation and Assumption	Remark
Equipment cost (EC) (USD)	The database of cost details is provided and adjusted by considering the replacement equipment that has a lifetime less than the project lifetime. The cost consists of Biomass pretreatment processes, SVO system, Gas cleaning system, engines system. EC at current period = EC (base year) x [Plant Cost Index (current period) / Plant Cost Index (base year)]	(The World Bank 2009) (Bouffaron, Castagno et al. 2012) (Wiskerke, Dornburg et al. 2010) (SCENARIO GLOBAL ENERGY 1999; Rordorf 2011) Plant cost index (current period) input by the user.
Building cost (BC) (USD)	The database of cost is provided including: building of SVO system, modified diesel engine, water pool, and civil work. BC at current period = BC (base year) x [Plant Cost Index (current period) / Plant Cost Index (base year)]	Plant cost index (current period) input by the user.
Installation cost (IC) (USD)	The database of cost is provided including: Feasibility study, Development and Engineering, Installation, Erection, commissioning, Training, Shipping, Duty, Insurance, Clearance, etc. IC at current period = IC (base year) x [Plant Cost Index (current period) / Plant Cost Index (base year)]	(The World Bank 2009) (Bouffaron, Castagno et al. 2012) (Wiskerke, Dornburg et al. 2010) (SCENARIO GLOBAL ENERGY 1999; Rordorf 2011) Plant cost index (current period) input by the user.
Distribution network cost (USD)	(27.1 x Power capacity (kW)) + (7.5 x10 x Number of households access electricity) Where: Connection and earthing: 27.1 USD/kW. Primary electricity cable: 7.5 USD/m Average electricity cable length : 10 m/household	(Bouffaron, Castagno, & Herold, 2012)(Wiskerke, Dornburg, Rubanza, Malimbwi, & Faaij, 2010)
Total investment (USD)	Equipment cost + Building cost + Installation cost + Distribution network cost	
Equipment Depreciation (USD per year)	Equipment cost divided by project life time	Straight line method of depreciation calculation
Building Depreciation (USD per year)	Building cost divided by project life time	Straight line method of depreciation calculation
Installation Depreciation (USD per year)	Installation cost divided by project life time	Straight line method of depreciation calculation
Distribution network Depreciation (USD per year)	Distribution network cost divided by project life time	Straight line method of depreciation calculation
Total depreciation (USD per year)	Equipment Depreciation + Building Depreciation + Installation Depreciation + Distribution network Depreciation	Straight line method of depreciation calculation
Maintenance cost (USD per year)	Percentage of maintenance cost (%) x Total depreciation	Percentage of maintenance cost input by the user. Default value is 10%.
Total of Fixed cost (USD per year)	Total depreciation + Maintenance cost	

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

8.1.6 Calculation of other costs

The plant overhead is defined as a charge to the production for services, facilities and payroll overhead. The general and administrative cost comprises rents, insurances, managerial, administrative and executive salaries. Table 7 shows the equations for calculating the cost associated with plant overhead, general and administrative cost, average loan interest payment and corporate tax.

Table 7: Other Costs Equations

Item	Equation and Assumption	Remark
Plant Overhead (USD per year)	Percentage of plant overhead (%) x (Total labour cost + Maintenance cost)	Percentage of plant overhead input by the user. Default value is 30%.
General and Administrative Cost (USD per year)	Percentage of general & administrative cost (%) x (Total inputs cost + Total labour cost + Maintenance cost + Plant overhead)	Percentage of general & administrative cost input by the user. Default value is 5%.
Average loan interest payment (USD per year)	Loan amount = Loan ratio (%) x Total investment cost Loan payment (USD/month) = PMT([Loan interest rate/12],[12x Loan term], Loan amount) Annual Loan payment = Loan payment (USD/month) x 12 months Total Loan payment =Annual Loan payment x Loan terms Loan interest payment = Total Loan payment - Loan amount Average Loan interest payment = Loan interest payment divided by project lifetime	PMT is a financial function in Microsoft Excel for calculating the payment for a loan based on constant payments and a constant interest rate.

8.1.7 Total production cost and unit cost of electricity calculation

Table 8 presents the calculation equations of the total operating costs, total fixed costs, and total other costs. The final results of these costs are used to compute the total production cost of electricity and unit production cost per kWh.

Table 8: Total Production Cost Equations

Item	Equation and Assumption	Remark
Total Operating Costs (USD per year)	annual inputs cost + annual labour cost + annual transportation cost + annual storage cost	
Total Fixed Costs (USD per year)	depreciation fixed cost +annual maintenance cost	
Total Other Costs (USD per year)	annual plant overhead + annual general &administration cost + annual Loan payment + annual income tax	
Total Production Cost (USD per year)	Total Operating Costs + Total Fixed Costs + Total Other Costs	
Production cost per kWh	Total Production Cost divided by Power generation	The equation of power generation (kWh per year) is presented in Table 3.

8.1.8 Project revenue calculation

Table 9 presents the equations for calculating the potential revenue of the SVO system.

Table 9: Potential Revenue Equations

Item	Equation and Assumption	Remark
Potential revenue (USD per year)	[Power generation - Electricity self-use - Power loss in distribution network]x Price of electricity Where, Power loss in distribution network (%) x Power generation	Power generation same as in Table 3. Electricity self-use (kWh per year) assumed 10% of power generation. Power loss distribution entered by the user in Step 4.
Price of electricity (USD/kWh)	user selects option: Method 1 or Method 2 to define the price of electricity paid by customer	Input data by the user in “Data Entry Needs”.

8.2 Data requirements for running the tool

Table 10 includes data requirements for running the *SVO Component*.

Table 10: Data Requirements for Running the Tool

Data	Definition and Sources
Oleochemical Feedstocks	The user selects the oleochemical feedstocks. Detailed analysis
Price of feedstock	If the price of feedstock is not available, the user will need information on hourly wages for skilled and unskilled workers (USD per employee per hour) and fuel consumption of machinery typically used in agricultural or forestry operations to calculate a proxy for this value.
Price of diesel	The user enters the current price of diesel (USD/litre).
Feedstock storage cost (USD per t)	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 on the type of storage available in the country and use the estimated global cost for building this type of storage that is provided in the tool. Moreover, the size of the storage site or container is estimated using the biomass storage calculator.
Feedstock safety stock rate (%)	The user defined this value by entering it in each biomass storage calculator. This value defines the percentage of biomass that should be reserved to operate the plant during shortage periods.
The user selects the option to identify the price of electricity paid by customer (USD/kWh).	The price of electricity can be the price for the national grid or the price of electricity that is generated by other energy resources, e.g. diesel generator, solar energy, hydro power, natural gas, etc. To estimate the price of electricity by using a diesel generator, the user inputs the capacity of the diesel generator (kW), operating hour per day, operating day per year, transportation cost and transportation distance of diesel including labour and maintenance cost in the “Electricity price calculator”.
Labour cost	Unskilled and skilled workers in the unit of USD per employee per hour.
Working hours of feedstock collection	Working hours of feedstock collection for manual and mechanized method.
The cost of transportation of feedstock (field/collecting point to plant) in unit of USD per t per km.	Cost of transportation of feedstock from the collection point (or field) to SVO plant, the user enters the cost of transportation in unit of USD per t per km. If transportation is done on foot or by bike, the user can include this cost in the collection cost of feedstock. Alternatively, the user estimate the cost by using the cost of labour per hour, working time, the amount of material that can be transported and the approximate kilometres that can be travelled under the selected method.

Data	Definition and Sources
The transportation distance of feedstock to SVO plant in kilometres by power generation capacity	Transportation distance is determined based on the availability of biomass in a particular area in relation to the amount required to operate each of the power generation capacities.
Operating hours per day for SVO system	The user will provide an estimated number of hours per day that the system is expected to operate. Most literature indicates that SVO systems are operated only for a few hours during the day. For example, in cases where the SVO system supplies only household electricity, these operate 4 hours, usually during the night. The user may want to determine this value based on potential energy demands.
Power loss in distribution network (%)	This information can be the current loss in the national electric grid. Alternatively, a link is provided to a World Bank global database compiling national distribution losses. Please visit: http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS
Power loss due to operation (%)	The user estimates the losses due to operation. These losses are due to inappropriate operation of the SVO-engine system. These include lack of control and monitoring of units measuring gas pressure, gas composition, air leakage, or temperatures, etc.
Modified diesel engine efficiency (%)	This parameter is provided by modified diesel engine manufacturer.
Costing parameters	Percentage of plant overhead cost, general and administrative cost, maintenance cost and miscellaneous cost.
Financial parameters	Inflation rate (%) Discount rate (%) Loan ratio (%) Loan interest rate (%) Loan term (years), Plant cost index http://base.intratec.us/home/ic-index
Electricity Demand per household	The user inputs data from the *Country Status* module. The electricity consumption will be estimated based on the type of appliances typically used in a rural household, the quantity of these appliances per rural household and the average hours of operation of the appliances. Note that this value will be used as a proxy to identify the number of potential households that can be supplied with electricity. A more detailed and localized analysis according to energy demand profiles and time framework will need to be carried out for adequate planning and implementation of an SVO system.

9 References

Agriculture and Rural Development of Alberta. (2014). "Bushel / Tonne Converter." from http://www.agriculture.alberta.ca/app19/calc/crop/bushel2tonne.jsp.

Bart, J. C. J., N. Palmeri, et al. (2010). Biodiesel science and technology: From soil to oil, CRC Press Taylor & Francis Group.

Bouffaron, P., F. Castagno, et al. (2012). "Straight vegetable oil from Jatropha curcas L. for rural electrification in Mali–A techno-economic assessment." Biomass and Bioenergy **37**: 298-308.

Mailer, R. J. (2004). OILSEEDS | Overview. Encyclopedia of Grain Science. C. Wrigley. Oxford, Elsevier**:** 380-385.

Rordorf, J. (2011). Opportunities for a sustainable rural energy supply through renewable energies in developing countries. Master-Programme Sustainability and Quality Management. Berlin, Germany, Berlin School of Economics and Law - Institute of Management Berlin. **MSc:** 156.

SCENARIO GLOBAL ENERGY (1999). "PART II BIO-ENERGY OPTIONS AND RURAL INDIA." INDIA INFRASTRUCTURE REPORT 2007 **1979**: 165.

State of Michigan. (2003). "Grain Bins and Tanks." from http://www.michigan.gov/documents/Vol1-27GrainBinsandTanks_120836_7.pdf.

The World Bank (2009). Pacific Islands Coconut Oil Power Generation: A how-to guide for small stationary engines, Asia Sustainable and Alternative Energy Program**:** 47.

Wiskerke, W., V. Dornburg, et al. (2010). "Cost/benefit analysis of biomass energy supply options for rural smallholders in the semi-arid eastern part of Shinyanga Region in Tanzania." Renewable and Sustainable Energy Reviews **14**(1): 148-165.