Black Soldier Fly Larvae (BSFL) biowaste treatment technology

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Business Model (BM) manual

Date: June 2021, Version: 1.0

BSFL factory

Item	Value	Unit
Treatment capacity	5.0	ton/day
	1825.0	ton/year
BCR	9%	
Waste reduction	45%	
Total Nr staff	29	
Total plant size	783	m2

Project Life Cycle Indicators (Period: 5 years)

Item	Value		Unit
Capital costs	USD	76,114.68	
	USD	41.71	per ton
Operating costs	USD	105,051.99	
	USD	57.56	per ton
Payback Period		1.29	years
Discounted Payback Period		1.57	years
Internal Rate of Return (IRR)		72.6%	
Net Present Value (NPV)	USD	152,721.11	

Business Parameters

Item	Value	Unit
Net Revenue	USD	153,745.96
COGS (Direct & indirect costs)	USD	89,934.26
SG&A	USD	15,117.73
Gross Profit	USD	63,811.70
EBITDA	USD	64,120.82
Operating Profit (EBIT)	USD	48,693.97
Taxes (on profit)	USD	10,712.67
Interests (initial capex)	USD	4,411.03
Net Profit (after taxes)	USD	33,570.27

Business KPIs

Item	Value	Unit
Gross margin	41.5%	
EBITDA margin	41.7%	
Operating margin	31.7%	
Net margin	21.8%	
Markup	71.0%	

Products in kg/d — Compost (0), SDOL (0), Eggs (0), Larvae Oil (crude) (6), Larvae Meal (16), Dried Larvae (24), Fresh Larvae (0), Waste received with tipping fee (0)

Nr staff per category — Post-P. worker (Drying & pressing) (1), Post-P. worker (Sanitizing) (2), Admin & Accounting (1), Sales manager (1), Site manager (1), Nursery manager (0), Waste units manager (1), Nursery staff (6), General worker (16)

Space per unit in m2 — Office space (40), Unit-R (24), Unit-P (82), Unit-N (42), Unit-H (266), Unit-T (252), Unit-W (77)

Capex per year / Cashflow

Capex per year / Cumulative Cashflow

Cumulative Discounted Cashflow

Business Parameters chart — Gross Profit, EBITDA, Operating Profit (EBIT), Net Profit (after taxes)

Business KPIs chart — Gross margin, EBITDA margin, Operating margin, Net margin, Markup

Revenue distribution — Waste received with tipping fee (0%), Fresh Larvae, Dried Larvae (45%), Larvae Meal (40%), Larvae Oil (crude) (15%), Eggs, SDOL, Compost

Operational costs — Materials (direct) (17%), Labor (direct) (53%), Labor (indirect) (17%), Equipment Maintenance and contingencies, Utilities, Selling, General & Administration overhead

Capital costs — Land aqusition, Factory construction (24%), Waste pre-processing, Waste treatment, Harvesting, Nursery / Rearing, Larvae Post-processing, Residue processing, Process installation & integration

Contents

1 Introduction

The aim of the presented business model (BM) is to support planners, engineers, government officials and insect enthusiasts to understand the costs and benefits of a Black Soldier Fly Larvae (BSFL) plant in detail.

The BM can be used for any existing BSFL plant, new developments and as general planning tool to analyse the viability of introducing the BSFL process for organic waste treatment in various potential settings, from small scale decentralised to large-scale centralised plants.

The BM has already pre-filled in figures from an existing BSFL plant in Surabaya, Indonesia. The reflected BSFL plant was installed by the FORWARD project[1] at Puspa Agro, Sidoarjo. The plant setup is a labour intensive, crated system, which is described in Detail by Dortmans, Diener et al. (2017). But users can also use put in their own values to calculate the viability of an existing or planned project.

We assume that the reader of this manual understands the BSFL process, the various steps needed and certain terms used. If you are new to the subject, please read the step-by-step guide[2] before using the BM.

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[1] Link: https://www.eawag.ch/en/department/sandec/projects/mswm/forward-from-organic-waste-to-recycling-for-development/

[2] Can be downloaded here: https://www.eawag.ch/en/department/sandec/projects/mswm/practical-knowhow-on-black-soldier-fly-bsf-biowaste-processing/

2 BSFL process, scenarios and income streams

The BSFL process has several characteristic processing steps which can be described as followed:

- Unit-W : Waste pre-processing unit
- Unit-T : Waste treatment unit
- Unit-H : Harvesting unit
- Unit-N : Nursery unit
- Unit-P : Post-processing unit
- Unit-R : Residue processing unit

Figure 1 gives an overview of the BSFL process with the various processing units.
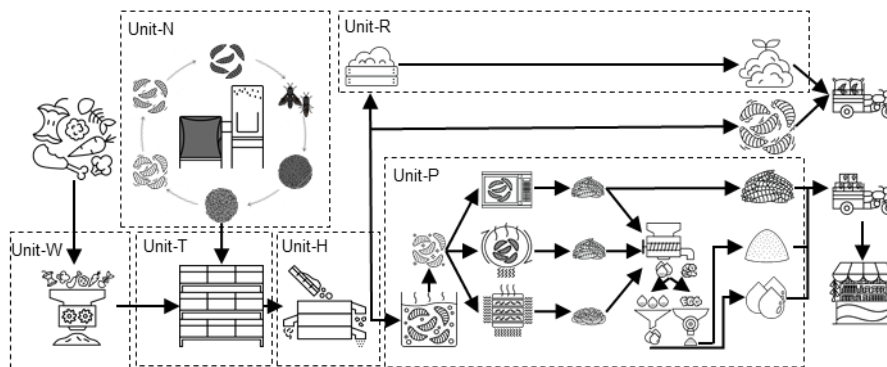

Figure 1: Overview of a complete BSFL process with processing units

The BSFL process can be used in various settings for treating organic waste, from a centralised plant to setups where e.g. the nursery is centralised and the waste treatment and post-processing of the larvae is decentralised. An overview of potential setups can be found in Table 1. Diener, Lalander et al. (2015) described advantages and disadvantages of some of these possibilities.

We have created various BMs to allow you to analyse different scenarios for your BSFL project. The description for each BSFL setup in Table 1 corresponds with the file name of each BM. Depending on your case, you can choose the scenario that reflects your situation best and download the corresponding BM accordingly.

There are various income streams for a BSFL plant, such as products from the BSF larvae, additional products and a gate fee.

BSFL products that are considered in this BM as output from the post-processing unit, are as followed:

- **Dried Larvae:** harvested 17-DOL dried with locally applicable drying technology (e.g. rotary drier, pan drier, microwave etc.)
- **Larvae meal:** Dried larvae processed further with a screw press to extract larvae meal and larvae oil. The larvae meal needs to be further processed with a grinder to make it a fine powder.
- **Larvae oil:** Oil (crude) extracted from the dried larvae after pressing it in a screw press (or similar applicable equipment)

Other potential products from a BSFL plant that can be sold, are:

- **Compost:** residue processed further via composting to a soil enhancing compost
- **5-DOL:** Nursery production can be increased beyond the needs of the BSFL plant and the surplus of 5-DOL sold to other BSFL operations

- **Eggs:** Additional to 5-DOL eggs can also be sold from a surplus production of the nursery

Additional income for a BSFL plant:

- **Gate fee:** A BSFL plant that processes organic waste can charge a gate fee for the processing service, which can be an additional source of income for the operation.

Table 1: Overview of potential scenarios for implementation of a BSFL plant

		Centralised		Decentralised		
Scenario 1	**BM Name**	Centralised BSFL plant				
	Input	Organic waste				
	Output	BSFL products, Compost				
Scenario 2	**BM Name**	Centralised nursery		**BM Name**	Decentralised waste treatment and post-processing	
	Input	Nursery feed		**Input**	Organic waste, 5-DOL	
	Output	5-DOL		**Output**	BSFL Products, Compost	
Scenario 3	**BM Name**	Centralised nursery and post-processing		**BM Name**	Decentralised waste treatment	
	Input	Nursery feed, 17-DOL		**Input**	5-DOL	
	Output	BSFL Products		**Output**	17-DOL, Compost	

3   How to use the BM

3.1   Structure of the model

Although we created several BMs for the various scenarios, the general structure for each BM remains the same. The general structure of the excel model is described in the table below.

Table 2: Overview of structure of model with tabs and description

Tab Name	Description
Info	Information sheet with brief model introduction and reference to this manual
1.0-General Input	General input data for the model such as plant capacity, production of products, product prices etc.
2.1-Material Input	Material used in the BSFL process in the various processing step
2.2-Equipment Input	Equipment used in the BSFL process in the various processing step
2.3-Staff Input	Type and number of staff required for the BSFL plant
3.1-Process Overview	Overview of BSFL process with results, shown and mass balance with details for material, staff, equipment for each processing step
3.2-Results Dashboard	Overview of business model results with financial metrics, graphs and predictions
4.1-Settings Database	BSFL process database with data for each process step, such as larvae weight, survival rate, conversion rates for post-processing etc.
4.2-Settings Internal	Settings for currency conversion and model structure such as process names etc.
5.0-Appendix	Additional information such as overview of financial analysis, cost breakdown and cost overview for each process unit incl. Selling General & Administration (SG&A)

3.2   Input of values

The model is locked (password protected) and only cells that have a light orange background can be modified. These cells either allow the input of numbers, text or contain a dropdown menu. An example is given in Figure 2, where the Plant capacity can be selected by entering any number reflecting the tons of waste to be treated per day. The equipment quantities category e.g. allows the choice between Yes & No in a dropdown menu.
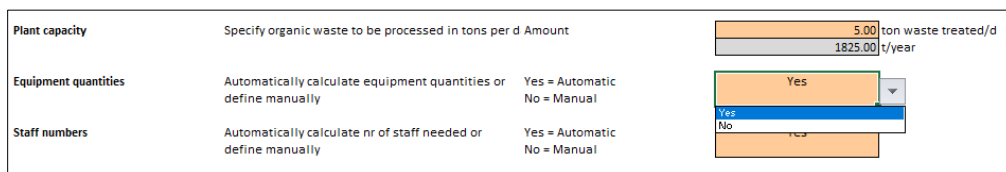

Figure 2: Example of cells that can be modified

Any other cell in the model, e.g. cells with light grey background, cannot be modified. This should avoid any unwanted edits in cells that might contain formulas, which could lead to a crash of the model.

3.3   Level of use

You can follow two approaches to use the model, which we labelled "simple use" and "advanced use".

3.3.1 Simple use

Simple use would be the option if you don't have any data available, limited hands-on experience with BSFL and just want to get a feeling how much a certain size plant would cost. You can tweak some basic input parameters and see how that would affect the output, capital and operational costs and viability of your project and so on.

Please note:

All values used for the calculations are based on the pre-filled in values, which are from the specific BSFL plant setup in Indonesia, thus using Indonesian prices only. The costs at your location might be different (e.g. rental costs, costs of manufacturing certain items, material costs etc.), nevertheless you can obtain in this way indicative values that will help you get started.

Following the simple use approach, we would recommend modifying only values in the section "1.1 Basic Input" in the "1.0-General Input" tab, which can be seen in Figure 3. The inputs are described in the excel model. You don't have to worry about any other inputs or tabs. After changing the input values to reflect your needs, you can directly check the results in the tabs "3.1-Process Overview" and "3.2-Results Dashboard". If you want to change some parameters, go back to the basic input, do the modifications and check the results again.

Important:

- *USD as currency conversion is selected by default (change to other currency conversion if desired by using the drop down menu; exchange rates from June 2021)*
- *"Yes" has to be selected for the categories Equipment quantities & Staff numbers to allow automatic calculation of results (see red box in Figure 3)*
- *The "1.0 Basic Input" is slightly different for the various BMs; there might be more or less options depending on the scenarios; e.g. BSFL product selection is not available for the decentralised plant in scenario 3, as the unit does not create any BSFL products.*

Category	Description	Input	Input value	Unit
Currency conversion	Choose currency to be used for the results	Currency	USD	
Organic waste source	Organic waste to be treated	Waste stream	FORWARD data	
	Bioconversionrate (BCR) for selected waste source	BCR	9%	
Plant capacity	Specify organic waste to be processed in tons per day	Amount	5.00	ton waste treated/d
			1825.00	t/year
Equipment quantities	Automatically calculate equipment quantities or define manually	Yes = Automatic No = Manual	Yes	
Staff numbers	Automatically calculate nr of staff needed or define manually	Yes = Automatic No = Manual	Yes	
Product selection	Specify the BSFL products to be produced (total sum of all categories must be 100%)	Fresh Larvae	0%	of fresh larvae produced
		Dried Larve	50%	of fresh larvae produced
		Larvae Meal & Oil	50%	of fresh larvae produced
			Check: OK	
Gate fee & by-products	Specify how much of waste received is charged with gate fees per year	Waste received with tipping fee	0%	of total waste received
	Specify amount of residue sold per year	Residue sold	0%	of total residue produced
Nursery products sale	Specify egg overproducton for sales	Overproduction Eggs	0%	additional egg production for sale
	Specify estimated sales of overproduced eggs	Estimated Eggs sales	90%	of overproduction of eggs
	Specify 5DOL overproducton for sales	Overproduction 5DOL	0%	additional 5DOL production for sale
	Specify estimated sales of overproduced 5DOL	Estimated 5DOL sales	90%	of overproduction of 5DOL
Product loss factor	Determine amount of product potentially lost during manufacturing and handling	Product loss factor	5%	of product production
Factory and land	Specify if land and factory are rented, shall be aquired or not be taken into account	Factory costs	Renting land and factory	
Capital costs financing	Specify if initial costs (capex) for BSFL plant shall be financed with loan	Initial capital loan	Yes	

Figure 3: Overview of input parameters of the basic input section of the BM for the centralised plant (Scenario 1); only the values shown in the snapshot need to be adapted to the given context if the "simple use" approach is followed.

3.3.2   Advanced use

Users that have gained hands-on experience with BSFL, maybe have already a running BSFL plant or want to adapt certain costs and prices to their local context, can follow the "advanced use" approach. This option will give you the freedom to adapt any of the input values of the BM to your needs.

The first section that can be further adapted is the section "2.0 Advanced input" in the "1.0-General Input" tab, which can be seen in Figure 4.

Please note:

- *The first category of "2.0 Advanced Input" section in tab "1.0-General Input" is slightly different for the various BMs; depending on the scenario there are more or less product categories or an added price category, e.g. price for 5-DOL for the BM of the decentralised units in scenarios 2&3*
- *The centralised plants in scenario 2&3 (nursery w or w/o post-processing) has an additional option to include transport costs; if "Yes" is selected, further details can be specified in the tab "2.4-Transport input" of the BM (more details can be found in section five of the manual); the tab "2.4-Transport input" is only available in these BMs*

Category	Description	Input	Input value	Unit
Gate fee, BSFL products & residue prices	Specify the sales price for the gate fee, bsfl products and resdiue	Waste received with tipping fee	119.00	per kg
		Fresh Larvae	16,000.00	per kg
		Dried Larvae	110,000.00	per kg
		Larvae Meal	150,000.00	per kg
		Larvae Oil (crude)	140,000.00	per kg
		Eggs	15,000,000.00	per kg
		5DOL	750,000.00	per kg
		Compost	1,000.00	per kg
Utility costs	Specify the water, electricity and fuel costs for the BSFL process	Electricity	1,500.00	per kWh
		Water	3,000.00	per m^3
		Diesel	5,000.00	per kg
		Gasoline	8,000.00	per kg
		LPG	5,400.00	per kg
Factory & office	Specification of overall factory costs	Factory rent	100,000.00	m2/yr
		Factory land aquisition	1,500,000.00	per m2
		Factory construction	750,000.00	per m2 building construction
		Factory space occupation factor	30%	-
		Factory supplies	-	per yr
	Office space and utility usage	Office space per employee (non factory workers)	10.00	m2/employee (managers, admin, sales)
		Water user per employee	35.00	L/day
		Energy use per m2 office	234.00	kWh/m2/year
Process equipment and costs	Process equipment insallation / Integration costs	Costs to install equipment	2.5%	of capital cost
	Specify contingencies for unexpected process costs	Contingencies for COGS	0.0%	of direct material and labour costs for production
	Specify maintenance costs	Maintenance and contingencies	5%	of capital cost
	Salvage value of equipment after end of useful life	Salvage value (= end of life sales valu	0%	of capital cost
Residue processing	Processing parameters for residue to compost conversio	Retention time	30.00	days
		space per tons	0.67	m2 per ton
Staff ratios	Specify the ratio of workers to unit managers, admin staff, sales and site managers	Unit managers	15.00	workers/manager
		Admin staff	5%	of all employees excl site manager
		Sales manager	70.00	ton fresh larvae/year/sales manager
		Site manager	3.00	Unit managers/site manager (min. 1)
Plant operation	Define the operating parameters of the plant	Plant operation per day	8.00	h
		Days of operation per week	7.00	d
		Weeks per year	52.00	weeks
		Days of operation per year	365	days
Annual working hours	Specify the annual working hours per employee	Nr of weeks in a year	52.00	weeks
		Nr of working hours per week	40.00	h
		Nr of working hours per day	8.00	h
		Nr of weeks of holidays	4.00	weeks
		Effective annual working hours (Full Time Equivalent)	1920	h/FTE
Funding / Financing of initial capital costs	Define the paramters for the interest calculation for the initial capital loan	Loan Amount	USD -	(total capex costs in year 00)
		Annual interest rate	6.0%	
		Term of loan in years	10.00	years
		Total months	120.00	months
		Monthly Rate	0.50%	per month
		Monthly Payment	USD -	per month
		Total amount payable	USD -	after 10 years
		Total interest payable	USD -	after 10 years
Financial parameters	Specify rates for the financial calculations of net present value, IRR and anual salary increase	Equity	17.5%	
		Equity weight	30.0%	
		Debt	9.6%	
		Debt weight	70.0%	
		Profit tax	22.0%	
		Weighted Average Cost of Capital (WACC) calculated	10.5%	For information only
		WACC chosen	11.0%	Used for NPV calculation
		Annaul salary increase (inflation corrected)	0.0%	

Figure 4: Input parameters in the section "2.0 Advanced input" in the "1.0-General Input" tab (example of the integrated plant BM of scenario one)

Thereafter you can further adapt the inputs in following tabs:

- 2.1-Material Input   : Material prices, quantities etc.
- 2.2-Equipment Input   : Equipment prices, quantities utility usage etc.
- 2.3-Staff input   : Staff salary, Nr of staff etc.
- 4.1-Settings Database : BSFL process parameters (larvae weight, survival rate, etc.)
- 4.2-Settings Internal   : Currency exchange rates

After you have completed the modifications, you can check the results in the "3.1-Process Overview" and "3.2-Results Dashboard".

Important:

- *If you want to manually enter e.g. the number of equipment used, or staff numbers, it is important that you select "No" in the "1.0 Basic Input" section for the respective category (see Figure 5Figure 5) at the beginning*

| Equipment quantities | Automatically calculate equipment quantities or define manually | Yes = Automatic No = Manual | No |
| Staff numbers | Automatically calculate nr of staff needed or define manually | Yes = Automatic No = Manual | No |

Figure 5: Example selection if equipment and staff inputs are done manually, i.e. "No" has to be selected for each category (red box)

We show in detail how to modify the inputs of the various tabs mentioned before, in section five of this manual.

4 Results of the BM

The output or results of the model can be found in the tabs "3.1-Process Overview" and "3.2-Results Dashboard".

The tab "3.1-Process Overview" shows a process flow diagram with material and mass flows and also gives details for each processing unit (output, utility costs, labor and equipment). The idea is to visually represent the BSFL plant setup and some of the BM results for a first overview.
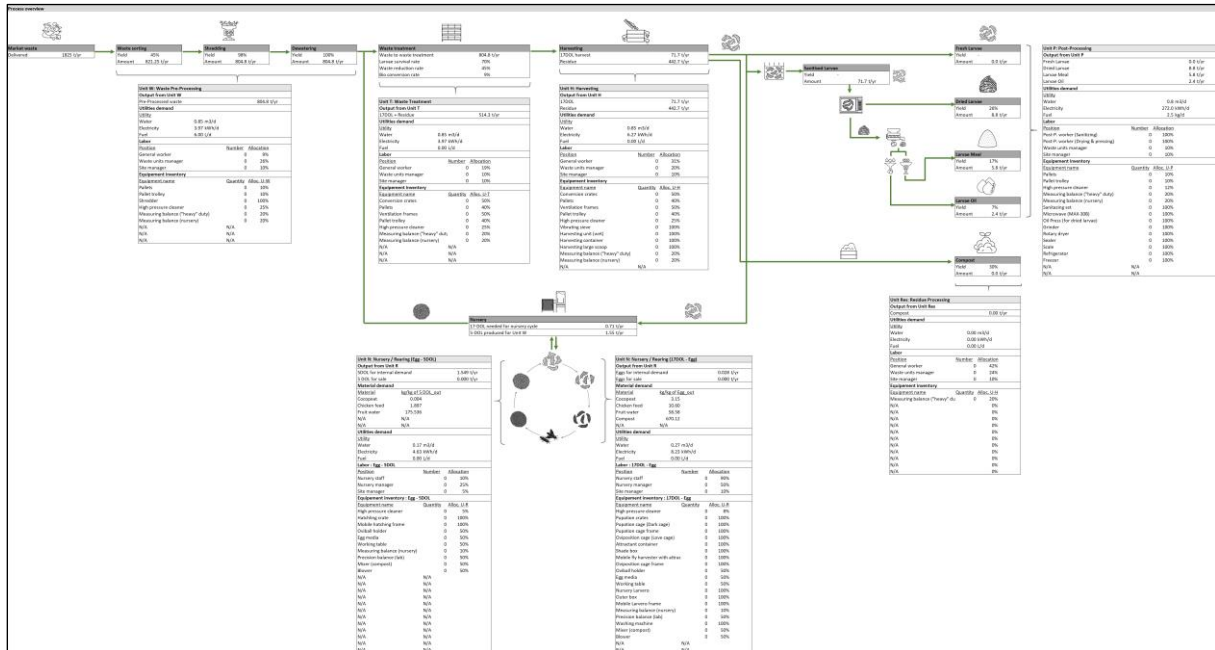

Figure 6: Example of the results shown in the "3.1-Process Overview" tab (example results for the integrated plant in scenario one are shown)

Please note:

The process overview is modified for each BM of the three scenarios according to the plant setup. The process overview of the centralised nursery w or w/o post-processing (scenario 2&3) shows e.g. only the nursery and post-processing part and none of the other units.

The tab "3.2-Results Dashboard" summarises the results of the BM. The results are structures in three parts. The first part (see Figure 7) gives the results for various key parameters structured in different groups, i.e. BSFL factory, project life cycle indicators (for a project duration of 5 years), business parameters and business Key Performance Indicators (KPIs). The results are also shown graphically.

Please note:

The operational costs are distinguished between different categories: Direct costs, indirect costs and Selling, General & Administration (SG&A):

- *Direct costs are costs that are directly related to creating the product (BSFL products or fresh larvae), i.e. direct labor or material costs*
- *Indirect costs are indirectly related to creating the product, such as management costs to supervise production staff, depreciation and maintenance costs of equipment and utility costs for the production*

- *SG&A are any costs that can be considered overhead costs, and are not related to the production of the product, e.g. administration, sales, management or transport costs*
- *Direct and indirect costs can be e.g. grouped together to create the indicator Costs of Goods Sold (COGS)*

Following financial results are presented:

- **Net revenue**: Sum of the revenues generated (i.e. sales)
- **Gross profit:** Corresponds to the net revenue minus the COGS. This does not include the SG&A costs.
- **EBITDA:** Corresponds to the net revenue minus the operational costs and SG&A but excluding depreciation and amortization, and Interests and taxes. EBITDA stands for Earnings Before Interest Tax Depreciation & Ammortization.
- **EBIT:** Corresponds to the net revenue minus the COGS and SG&A costs. Interests and taxes are not deducted.
- **Net profit:** Corresponds to the EBIT minus interests and taxes.
- **Margins** are the ratio of the different results listed above divided by the net revenue, e.g. gross margin is the gross profit divided by net revenue.

Figure 7: First section of the results of the BM in tab "3.2-Results Dashboard"

The second section breaks down the operational costs into further detail. The benefit of the BM is that it separates the costs per processing unit, which is reflected in this analysis. You can analyse which processing unit contributes the most to the operational costs, how much of the operational costs are attributed to COGS or SG&A and so on.
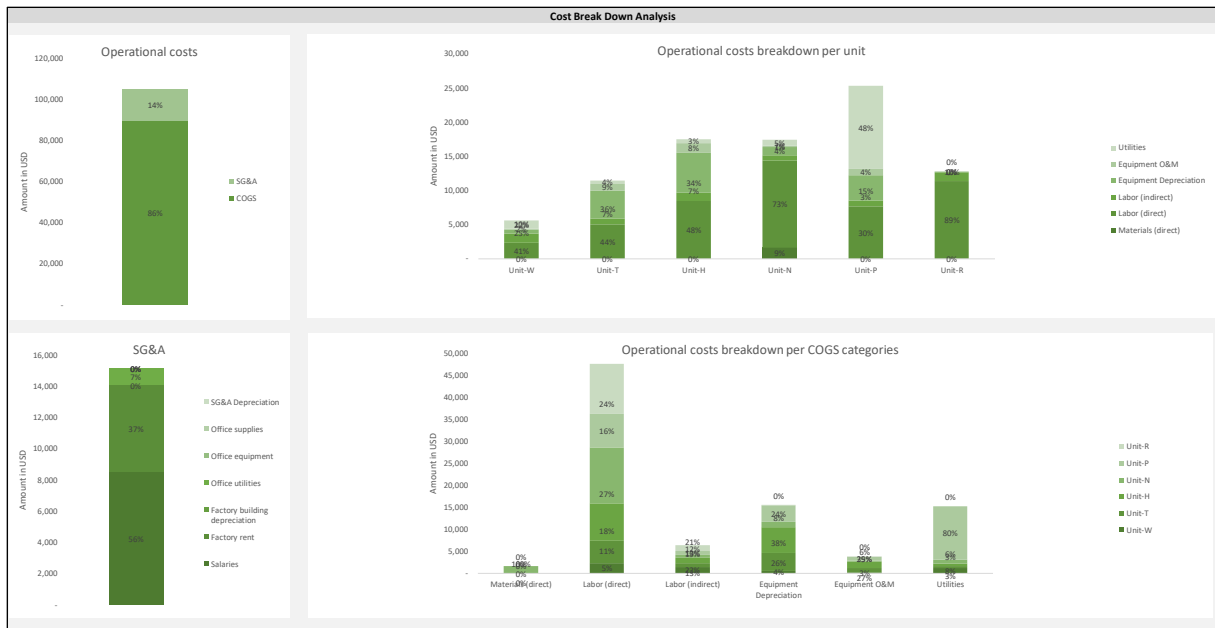
Figure 8: Cost breakdown analysis as second section of the results dashboard

The last section of the results is a sensitivity analysis. The Net Present Value (NPV) is plotted against the scale of the plant (Figure 9). This graphs helps to asses, at what scale the analysed plant is reaching a positive NPV, indicating a viable business opportunity. A negative NPV indicates, that the project is financially not viable, and the inputs need to be tweaked.

Please note:

The horizontal axis (x-axis) changes depending on the scenario; e.g. the graph of for centralised nursery (scenario 2) has kg 5-DOL produced per day as x-axis and so. Also the centralised plants of scenario 2&3 have two graphs in this section compared to only one for the other BMs.
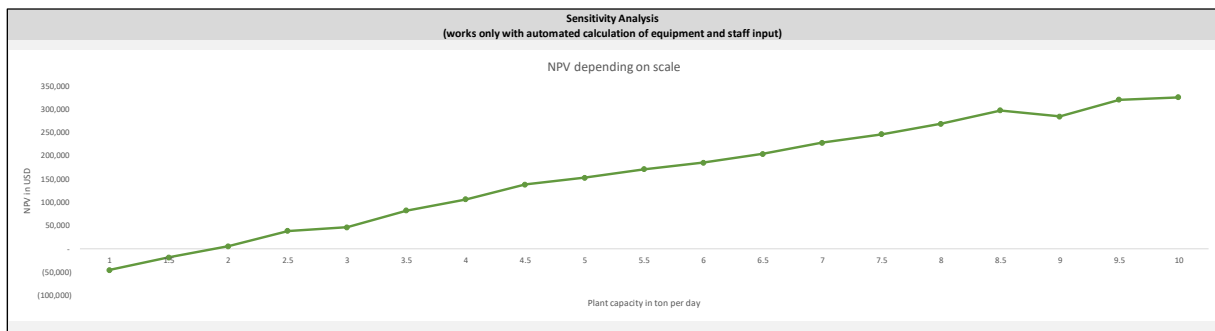

Figure 9: Example of sensitivity analysis for the integrated plant (scenario 1); NPS is plotted against scale of the plant in tons per day

If you would like to see the underlying data for section one and two (factory and financial parameters, and cost break down analysis), please refer to the Appendix tabs "5.1-Financial Analysis" and "5.2-Cost Breakdown Analysis".

5   How to modify the model

In this section, we will show you in detail how you can modify the various inputs of the model. This is important if you are following the "advanced use" approach and want to fine tune the model as good as possible to your local context.

5.1   Change of currency

The first selection in the basic input section is the currency conversion. All pre-filled in cost values in the model are in USD and reflect local costs in Surabaya, Indonesia. If you select IDR, CHF, or EUR in the dropdown, the USD values are converted into the selected currency for the results of the BM. The exchange rates are per June 2021.

If you start to fill your own values, e.g. in EUR as base currency, the exchange rates can be modified. Please go to tab "4.2-Settings Internal" to update the rates.

Internal Settings

Please note: The current base currency is US Dollars (USD). Any conversion value for CHF, IDR, EUR is based on an exchange rate of USD to the other currency, e.g. CHF : USD -> 1.11604 : 1; If you want to use any other base currency, e.g. EUR, please change the exchange rates for the other currencies to the current rate (from EUR to CHF, USD, IDR) and put 1 next to EUR.

Currency	Exchange rates
CHF	1.11604
USD	1
EUR	1.21828
IDR	0.00007

Figure 10: Currency settings in the tab "4.2-Settings Internal", where it is possible to change the exchange rates. USD is currently set as base currency with exchange rates for other currencies

If you would like to use e.g. EUR as your new base currency, follow these steps:

1.   Put "1" as exchange rate in the line of "EUR"
2.   Check for the current exchange rates of EUR to USD, CHF, IDR if you wish to convert EUR into one of those currencies; use e.g. https://www.xe.com/
3.   Fill in the exchange rates in the column "exchange rate"

Now you need to fill in the EUR amount in any cost related model input and convert to any other mentioned currency. If you would like to keep the base currency for the results, select the base currency in the drop down menu in the basic input, in this case "EUR" (Conversion rate is 1:1). An example of a change to EUR as base currency can be seen in Figure 11.

Currency	Exchange rates
CHF	0.9162
USD	0.82083
EUR	1
IDR	0.00006

Figure 11: Base currency changed to EUR with respective exchange rates for other currencies (as of June 2021)

5.2 Material input

In the "2.1-Material Input" tab, any material that is used for the BSFL process is specified. If you would like to add a material that is needed for any processing step, add first the name of the material, function and price per unit in the table (see Figure 12). If a material is specifically used for the Unit-P, use the dropdown menu in the column "Materials for Unit-P: Specific for Product" to connect the material to the respective product that it is used for in the production.

2.1 Advanced Input - Materials section							
Material Code	**Material Name**	**Function / Description**	**Materials for Unit-P: Specific for Product**	**Price per unit**	**Price per unit conversion**	**Unit**	**Comment**
ma0001	Raw waste			-	USD -		
ma0002	Cocopeat			5,000.00	USD 0.35	per kg (sold in blo	recycled in process; co
ma0003	Chicken feed			6,900.00	USD 0.49	per kg (sold in 50kg bag)	
ma0004	Fruit water			-	USD -		no costs; by-product f
ma0005	Lignocellulosic material (bulk material)			-	USD -	per kg (for compo	e.g. dry leaves, straw
ma0006	Compost			-	USD -		min. 60% MC needed

Figure 12: Snapshot of the "2.1-Material Inpu" tab showing the first part of the input

Thereafter assign the quantity of the material used to the respective processing step. Cocopeat e.g. is used only in the Nursery for the egg production (U-N-Egg) and the hatching and growing to 5-DOL (U-N-5DOL). Thus, the amount of cocopeat required for these processing units is entered in the intersection of the columns of the nursery and the row for cocopeat (see Figure 13; highlighted with a red box).

Important:

The material quantities (or usage) for the processing step are expressed as kg or nr (#) per kg of output of the respective processing unit. In the case of cocopeat, e.g. 3.15 kg cocopeat per kg of egg produced are needed in the nursery. To update these values with your material selection, try to measure the material usage per output of the corresponding processing step at your site (e.g. on a daily basis: measure quantities of material fed into the processing unit and measure the output of product of the same unit per day; the ratio of kg material / kg output will give you the value to be put into the cells here).

Material input per processing unit									
U-W	**U-T**	**U-H**	**U-N-Egg**	**U-N-5DOL**	**U-N-17DOL**	**U-P**	**U-R**	**SG&A**	
in # or kg per kg of pre proc. waste_out	in # or kg per kg of 17DOL+R_out	in # or kg per kg of 17DOL_out	in # or kg per kg of Egg_out	in # or kg per kg of 5DOL_out	in # or kg per kg of 17DOL_out	in # or kg per kg of Product	in # or kg per kg of Residue		**Total**
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
0.000	0.000	0.000	3.150	0.004	0.000	0.000	0.000	0.000	**3.154**
0.000	0.000	0.000	10.600	1.897	0.000	0.000	0.000	0.000	**12.497**
0.000	0.000	0.000	58.580	175.536	0.000	0.000	0.000	0.000	**234.116**
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
0.000	0.000	0.000	670.119	0.000	0.000	0.000	0.000	0.000	**670.119**
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**

Figure 13: Specification of quantity of material used for the respective processing step; example of cocopeat use in the nursery.

5.3   Equipment input

The "2.2-Equipment input" tab lists all equipment that is used for operating the BSFL plant. In this tab you can specify following parameters for each item:

- Name
- Processing capacity
- Quantity
- Utility usage
- Capital costs
- Expected lifetime
- Allocation of equipment to the processing units.

The following steps show how to add equipment to the list and what to fill in, using a shredder as an example (indicated with "->"):

1. Enter the name in first column after the designation code
   -> "Shredder"
2. Select if the equipment requires utilities (water, electricity or fuel)
   -> "yes"
3. Enter the processing capacity, amount and unit, if desired (only for information if it is new equipment)
   -> 8000 kg waste/shredder/day
4. Enter the quantity of equipment needed for the process (only required if the automatic calculation is <u>not</u> selected in the basic input)
   -> automatic calculation was chosen, thus no value in manual column
5. Enter the run timer per day in h of the equipment
   -> 5h per day
6. Enter the utility usage of the equipment. For equipment using fuel, a dropdown menu in the "Fuel type" column allows the selection of Diesel, LPG or Gasoline. Select the correct fuel type.
   -> 1.2 kg/h, Diesel

Please note:

The equipment capacity of the pre-filled in values is used to calculate the quantities of equipment automatically. If "Yes" is selected in the basic input for automatic calculation of equipment, the calculated Nr in the grey column "Model calculation" is used. If "No" is selected and the equipment Nr is entered manual, the value in the orange column "Manual input" is used for the internal calculations. If you use the exact same setup as represented here, you can also adapt the capacities of your chosen equipment, e.g. shredder, to your equipment present on site. The model then calculates the nr of equipment needed using the updated capacity input.

			Equipment processing capacity		Quantity			Run Time		Water		Electricity		Fuel			
	Designation code	Name	Equipment requires utilities?	Amount	Unit	Model calculation	Manual input	Run time/d	Unit	Amount	Unit	Amount	Unit	Amount	Unit	Fuel type	
10	eq0004	Pallets	No	42	crates/pallet/MRT	120											Y
11	eq0005	Ventilation frames	No	6	Frames per pallet	720											N
12	eq0006	Pallet trolley	No	2520	kg waste/trolley	2											N
13	eq0007	Shredder	Yes	8000	kg waste/shredder/da	1		5.00	h		m3/h		kW	1.2	kg/h	Diesel	Y
14	eq0008	High pressure cleaner	No	2520	kg waste/unit/d	2		7.94	h	0.429	m3/h	2	kW		kg/h		Y
15	eq0009	Vibrating sieve	Yes	3150	kg residue/sieve/d	1		3.08	h		m3/h	0.7457	kW		kg/h		Y
16	eq0010	Harvesting unit (wet)	No	84	crates/unit	5											N
17	eq0011	Harvesting container	No	1	container/harvesting u	5											N
18	eq0012	Harvesting large scoop	No	1	scoop/harvesting unit	5											N
19	eq0013	Pupation crates	No	5000	Prepupae/crate	54											N
20	eq0014	Pupation cage (Dark cage)	No	16	Crates/cage	4											N

Figure 14: "2.2-Equipment input" tab showing the input parameters using the example of the shredder (inside red box); input parameters from name to fuel type.

7. In the next step the floor space is required for the equipment. This value is needed to estimate the overall footprint of the BSFL plant. Select "Yes" if the entered equipment required floor space in the plant. If it is stackable equipment, e.g. crates, only enter the projected floor space usage of the stack. Enter the space requirements in m2 (see Figure 15). -> "Yes", 4.00 m2

8. Specify the capital costs of the equipment in your chosen currency. -> USD 1,750

9. Enter the expected lifetime of the equipment and. -> 5 years (Nr of years is used to calculate depreciation using the straight line method)

10. Add any comments if needed

		Capital cost				Depreciation			
Occupies floor space?	Footprint in m2 (projected if stackable)	Unit capital cost	Unit capital cost conversion		Lifetime expectancy [yr]	remaining ("salvage") value		Depreciation per yr	comment/note
No			-	IDR	-	10	IDR	-	IDR	-	
No	0.24	4.90	IDR	81,666.67	5	IDR	-	IDR	16,333.33	
Yes	1.57	10.50	IDR	175,000.00	5	IDR	-	IDR	35,000.00	
No	1.57	17.50	IDR	291,666.67	5	IDR	-	IDR	58,333.33	
No	2.00	210.00	IDR	3,500,000.00	5	IDR	-	IDR	700,000.00	incl. Cloth, frame, etc. that
Yes	4.00	1,750.00	IDR	29,166,666.67	5	IDR	-	IDR	5,833,333.33	
Yes	0.25	630.00	IDR	10,500,000.00	3	IDR	-	IDR	3,500,000.00	
Yes	4.00	1,750.00	IDR	29,166,666.67	5	IDR	-	IDR	5,833,333.33	
No		1,004.50	IDR	16,741,666.67	5	IDR	-	IDR	3,348,333.33	
No		420.00	IDR	7,000,000.00	5	IDR	-	IDR	1,400,000.00	
No		1.40	IDR	23,333.33	3	IDR	-	IDR	7,777.78	
No	0.24	4.90	IDR	81,666.67	5	IDR	-	IDR	16,333.33	

Figure 15: "2.2-Equipment input" tab showing the input parameters using the example of the shredder (inside red box); input parameters from floor space to comments.

11. The last step is to assign the equipment to the associated processing unit. If the same equipment is used for various processing unit, try to estimate the % usage per processing unit. E.g. if the shredder would be used half the time for waste treatment and half the time for post-processing, enter 50% in U-W and 50% in U-P -> U-W 100% (in this case the shredder is only used in the waste treatment unit).

Please note:

If you have several equipment that is shared in the BSFL plant, try to be accurate with the allocation to the respective processing unit. Then you will obtain a fairly good estimate about the operational

cost breakdown for the various units and could e.g. see potential for improvements based on the results and so on.

Equipment allocation table

Instructions:									
			Allocation between Op. units						
U-W	U-T	U-H	U-N-Egg	U-N-5DOL	U-N-17DOL	U-P	U-R	SG&A	Total
0%	0%	0%	0%	0%	0%	0%	0%	100%	**100%**
0%	50%	50%	0%	0%	0%	0%	0%	0%	**100%**
10%	40%	40%	0%	0%	0%	10%	0%	0%	**100%**
0%	50%	50%	0%	0%	0%	0%	0%	0%	**100%**
10%	40%	40%	0%	0%	0%	10%	0%	0%	**100%**
100%	0%	0%	0%	0%	0%	0%	0%	0%	**100%**
25%	25%	25%	8%	5%	0%	12%	0%	0%	**100%**
0%	0%	100%	0%	0%	0%	0%	0%	0%	**100%**
0%	0%	100%	0%	0%	0%	0%	0%	0%	**100%**
0%	0%	100%	0%	0%	0%	0%	0%	0%	**100%**
0%	0%	100%	0%	0%	0%	0%	0%	0%	**100%**
0%	0%	0%	100%	0%	0%	0%	0%	0%	**100%**

Figure 16: "2.2-Equipment input" tab showing the input parameters using the example of the shredder (inside red box); input parameters for equipment allocation to processing units.

5.4   Staff input

The staff working at the BSFL plant can be specified in the tab "2.3-Staff input". Figure 17 gives an overview of the first part of the input parameters. Please proceed as followed if you want to enter new staff into the table:

1. Enter the Position of the staff, e.g. worker or manager
2. Chose in the "Position Category" column from the dropdown menu the allocation of staff according to their role at the plant (Figure 17):
   a. If the staff is directly involved in the production chose the first category "Manufacturing Direct Labor", e.g. worker;
   b. if the staff has a supervisory / management role in the production, chose the second category "Manufacturing Overhead";
   c. if the staff is responsible for admin, sales, or transport, chose the last category "SG&A Overhead"
3. Enter the basic salary per month in the next column.
4. Specify benefits per month, e.g. medical or pension allowances.
5. If in the basic input ("1.0-General Input" tab) the automatic calculation for nr of staff required was chosen ("Yes"), no number of employees has to specified manually;
   If the automatic calculation was not chosen, the nr of staff can be entered manually in the respective column

2.3 Advanced input - Staff input table

									Total nr of employees		
											86
									Model Output: Number of employees	Manual input: Number of employees	Chosen Nr: Model or Manual
Position ID	Position	Position Category	Basic salary [per month]	Benefits [per month]	net salary [yr]		net salary conversion [yr]	Employment rate [%]			
pos001	General worker	Manufacturing Direct Labor	140.00	-	1,680.00	IDR	28,000,000.00	100%	47		4
pos002	Nursery staff	Manufacturing Direct Labor	175.00	-	2,100.00	IDR	35,000,000.00	100%	23		2
pos003	Waste units manager	Manufacturing Overhead	280.00	-	3,360.00	IDR	56,000,000.00	100%	3		
pos004	Nursery manager	Manufacturing Overhead	280.00	-	3,360.00	IDR	56,000,000.00	100%	2		
pos005	Site manager	Manufacturing Overhead	420.00	-	5,040.00	IDR	84,000,000.00	100%	3		
pos006	Sales manager	Selling, General & Admin Overhead	350.00	-	4,200.00	IDR	70,000,000.00	100%	4		
pos007	Admin & Accounting	Selling, General & Admin Overhead	175.00	-	2,100.00	IDR	35,000,000.00	100%	4		
pos008	Post-P. worker (Sanitizing)	Manufacturing Direct Labor	210.00	-	2,520.00	IDR	42,000,000.00	100%	0		
pos009	Post-P. worker (Drying & pressing)	Manufacturing Overhead	210.00	-	2,520.00	IDR	42,000,000.00	100%	0		

Figure 17: Overview of input parameters in the tab "2.3-Staff input" from column Position ID to Nr of employees.

6. The last step is to allocate the staff to the processing units in which they are working (Figure 18). If a general worker is e.g. hired to work half the time in the waste treatment and half the time in the nursery unit, enter 50% in the column U-W and 50% in the column U-N.

	Allocation between operating units									
	U-W	U-T	U-H	U-N-Egg	U-N-5DOL	U-N-17DOL	U-P	U-R	SG&A	Total
6	9%	19%	31%	0%	0%	0%	0%	42%	0%	100%
6	0%	0%	0%	90%	10%	0%	0%	0%	0%	100%
1	26%	10%	20%	0%	0%	0%	10%	24%	10%	100%
0	0%	0%	0%	50%	25%	0%	0%	0%	25%	100%
1	10%	10%	10%	10%	5%	0%	10%	10%	35%	100%
1	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%
1	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%
2	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%
1	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%

Figure 18: Overview of input parameters in the tab "2.3-Staff input", allocation of employees.

Please note:

The first 1 – 10 staff positions are as on site at the FORWARD plant in Surabaya. Only the salary and staff nr can be edited. If you wish to enter your own list of staff, switch off the automatic staff nr calculation in the basic input, and enter the new staff in the orange rows below incl. all details (as per steps above).

5.5   Settings Database

In the "4.1-Settings Database" process parameters for the BSFL plant can be adjusted. If you want to use the pre-filled in values described in the Step-by-Step Guide for BSF Biowaste Processing please keep the selection "Step-by-step guide" in the select Database drop down menu (Figure 19). If you have process data from your site, select "Custom data" and fill in the values in the orange column underneath the header "Custom data".

Figure 19: "4.1-Settings Database" tab, selection of database to be used for the process parameters for the model (red box).

Once the "Custom data" database is selected, the process parameters for processing units can be entered in the table. The table is structured as per the processing units. Explanations for some of the inputs are given below:

- Unit-W:
  The parameters here are the efficiencies expressed as amount of waste after the pre-processing step over the amount of waste before the step
- Unit-T:
  The BCR is a calculated value (using the survival rate, nr of 5-DOL added per kg of pre-processed waste, and larvae weight of the 5-DOL and 17-DOL); the waste reduction value can be specified

- Unit-P:
  The efficiencies mentioned for the various products, e.g. dried larvae or larvae meal, are expressed as amount of product produced using fresh larvae (17-DOL) as baseline. The dried larvae process efficiency of 27% means e.g. that of 1 kg 17-DOL, 0.27 kg dried larvae can be produced

If you only want to update some of the process parameters and use the Step-by-Step Guide data for the rest, select "Custom data" as database and copy over the values from the "Step-by-Step Guide" column to the "Custom data" column in the cells that are not updated with own values.

Characteristics of the waste received		Step-by-step guide	Custom data
	Feedstock	Fruit waste	
	Total solids content [%TS]	25%	23%
Waste pre-processing unit (U-W)	Waste sorting yield [%wt]	95%	100%
	Shredding yield [%wt]	98%	98%
	Dewatering yield [%wt]	100%	100%
Waste treatment & Harvesting unites (U-T & U-H)	Retention time in waste treatment process (MRT) in days	12	12
	Larvae survival rate in WT and H units (5DOL->harvested 17DOL) [%]	80%	70%
	5DOL input in WT [#/kg of waste enterring WT unit]	1400	1100
	5DOL weight [g/larva]	2.32E-03	2.32E-03
	harvested 17DOL weight [g/larva]	1.53E-01	1.53E-01
	BCR [%wt]	**17%**	**12%**
	Waste reduction [%wt]	40%	40%
Nursery unit (U-N)	17DOL -> PP [%]	91%	80%
	Larvae Retention time (days)	10	10.00
	PP -> Fly [%]	71%	60%
	Prepupae Retention time (days)	23	23.00
	Eggs per Fly [Nr]	250.00	250.00
	Fly Retention time (days)	4	4.00
	Egg -> 5DOL [%]	60%	60%
	Hatchling Retention time (days)	5	5.00
	Larvae survival rate in Nursery unit (5DOL-> 17DOL) [%]	n/a	n/a
	Days of treatment	12	12.00
	Egg weight [g/egg]	2.91E-05	0.0000291
	nursery 17DOL weight [g/larva]	n/a	n/a
Post-Processing unit (U-P) [%wt of Fresh Larvae]	Pop Larvae yield	26%	31%
	Dried Larvae	26%	26%
	BSFL defatted cake	18%	18%
	BSFL press liquid	7%	9%
	BSF meal defatted	17%	17%
	BSF press cake yield (from dried larvae)	68%	68%
Residue unit (U-R)	Residue conversion efficiency	30%	30%

Figure 20: Overview of input values for the process parameters.

In the next section of the "4.1-Settings Database" tab, the time-motion values can be adjusted. A time-motion study was carried out at the reference site in Indonesia to analyse how much time each processing step requires. The data was then converted to values that reflect the time needed over the kg produced (for each processing step). As an example, it was found out that it requires 0.01 h per kg harvested 17-DOL and residue. Given the amount to be treated and the working hours per week, the amount of staff needed to treat the incoming waste can be calculated.

The time-motion study was done for each processing step and the results are summarised in the database tab. If you want to keep the automatic calculations for staff but want to use your own time-motion values, you can update those in this section (Figure 21).

A study allowance factor was added and set to 10% by default.

Please note:

The time-motion values are only relevant for the automatic calculation of the number of staff required in the tab "2.3-Staff input" and when "Yes" is selected for the Staff numbers category in the basic input section in the "1.0-General input" tab. If you enter the staff number in the "2.3-Staff input" tab manually the time-motion values are not relevant and don't need to be updated.

Time-motion studies

The values below are used for the automatic calculation of nr staff required for the BSFL plant. If you have conducted a time motion study, you can enter your ownd data below in the tabs with orange background.

	Waste Pre-Processing			
	W [hr/kg of pre-processed waste]	T [hr/kg of 17DOL + residue]	H [hr/kg of 17DOL]	Res [hr/kg of residue]
General worker	0.003	0.010	0.115	0.025
General worker [hr/t waste_in]	1.236	2.705	4.512	6.064
Corresponding allocation [%]	8.5%	18.6%	31.1%	41.8%

	Nursery units	
	Egg production [h/kg of egg]	5DOL production [h/kg of 5DOL]
Nursery staff	287	1

Product	Process Step	equipemnt	equipemnt/worker	max input / equipment /da	Post Processing output
Sanitized larvae	Sanitazing	Pot and sieve	1	320	
Dried larvae	Microwave drying	Microwave MAX-30B	3	210	
Dried larvae	Rotary drying	Rotary dryer - custom	3	160	
Press cake from dried larvae	Pressing (dry)	Oilpress - ZX80	2	160	
Larvae meal	Milling	Grinder - AGR-GRP-180	2	135	
Larvae oil	self decanting	-	-	-	
Time-study allowance	10%				

Figure 21: Time-motion studies values in the "4.1-Settings Database" tab.

6 Appendix tabs

The BM has several tabs in the appendix, which serve as additional information. These tabs are however essential for the calculation of the final results in the two results tabs, and can be accessed to obtain further details if needed.

The tab "5.0 Appendix" gives an overview of the tabs in the appendix (Figure 22).

For details on the financial analysis, such as revenue streams, direct and indirect costs per processing unit and so on, can be found in the tab "5.2 Financial Analysis".

The data underlying the cost-break down graphs in the results dashboard are accessible in the tab "5.2 Cost Breakdown Analysis".

The model calculates for each processing unit the detailed costs (direct material costs, utility costs, direct and indirect labor costs, equipment costs, depreciation and capital costs per year). Each processing unit, e.g. Unit-W, is represented with its own tab in the appendix. If you want to have a cost overview with more details for a specific processing unit, please select the corresponding processing unit tab, e.g. "5.3-Unit W", in the 5.3 section in the appendix.

Please note:

None of the cells can be modified in the appendix, all sheets serve for additional information purposes only.

Appendix		
Number	**Name**	**Description**
5.1	Financial Analysis	Shows the detailed financial calculations of COGS, SG&A, cashflow and various parameters
5.2	Cost Breakdown Analysis	Shows the calculation for the cost break down of the operational costs per COGS and processing unit, SG&A contribution etc.
5.3	Process Units	One tab for each process unit; calculates overview of operational costs per unit for financial analysis and capital costs for cashflow

Figure 22: Overview of the tabs in the appendix given in the tab "5.0 Appendix"

In Figure 23 an excerpt from the overview of Unit-W in the appendix is given. These overviews can be helpful if you would like to study the cost items for each unit detail. Also the financial analysis in the appendix can be useful, if one would like to compare the calculated results or extract them for customised graphs.

Unit W: Waste pre-processing

Technical process description

Unit W

Output product	quantity produced (e.g. [t/yr])		Considered as product to be sold
Pre-processed Waste	804.8		

Input materials

Input materials cost [IDR/yr]:	USD	-

pulling data from "Material input table"

Unit	U-W

Material Code	Material Name	kg/kg of pproc waste_o	Unit cost [IDR/kg]	Total cost per kg output
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	
N/A	N/A	N/A	N/A	

Total input materials cost: [IDR/kg pre-processed Waste_out]	USD	-

Utilities

Untilities cost [IDR/yr]:	USD	1,215.06

pulling data from "Equipment Inventory table" (below) & "Sales,Utility&Rental tab"

	Total use per day	Unit	Total cost per day		Total cost per year	
Water	0.85	m3/d	USD	0.36	USD	132.00
Electricity	3.97	kWh/d	USD	0.84	USD	307.69
Fuel	6.00	L/d	USD	2.12	USD	775.37

Total utility cost per day: [IDR/d]		USD	3.33	USD	1,215.06

Direct labor

Direct labor cost [IDR/yr]:	USD	2,315.92

pulling data from "Staff input table"

Note: If # of staff > 20, please manually insert lines and pull the cells (A:C containing the dynamic cells) down.

staff category	Manufacturing Direct Labor
Unit	U-W

Position ID	Position	Net Salary		Number of employ	Allocation	Labor cost [IDR/yr]	
pos001	General worker	USD	1,699.45	16	9%	USD	2,315.92
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			
N/A	N/A	N/A		N/A			

Manufacturing overhead labor

Manufacturing overhead labor cost [IDR/yr]:	USD	1,393.55

pulling data from "Staff input table"

Note: If # of staff > 20, please manually insert lines and pull the cells (A:C containing the dynamic cells) down.

staff category	Manufacturing Overhead
Unit	U-W

Position ID	Position	Net Salary		Number of employ	Allocation	Labor cost [IDR/yr]	
pos003	Waste units manager	USD	3,398.90	1	26%	USD	883.71
pos005	Site manager	USD	5,098.35	1	10%	USD	509.83
N/A	N/A	N/A		N/A			

Figure 23: Excerpt from the process unit cost overview from the Unit-W in the appendix.

7 References

Diener, S., et al. (2015). Opportunities and constraints for medium-scale organic waste treatment with fly larvae composting.

Dortmans, B. M. A., et al. (2017). Black Soldier Fly Biowaste Processing - A Step-by-Step Guide, Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland.