



Masters Project:

Design and Implementation of a Web-based System for Certification and LCA of Biofuels

Specification Report

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1 Introduction

A major driver for the current political support of the biofuels market is their supposed environmental benefits. Biofuels appear to be carbon neutral, while decreasing the dependence from oil-producing regions and generating new income for farmers (IEA 2007). However, results from current life-cycle studies demonstrate that greenhouse gas savings of conventional biofuels are usually small due to the carbon intensity of the cultivation and fuel production (Farrell, Plevin et al. 2006; Zah, Hirschier et al. 2007) and the overall balance of environmental impacts like ecotoxicity, eutrophication or biodiversity loss can show unfavourable results for biofuels when compared to fossil fuels (Scharlemann and Laurance 2008). Moreover, the negative effects of biofuels are strongly dominating if carbon and biodiversity loss due to direct (Fargione, Hill et al. 2008) and indirect (Searchinger, Heimlich et al. 2008; Reinhard and Zah 2009) land transformation are considered in the full life cycle of biofuels. Certification schemes could be an efficient approach for ensuring the sustainable production of biofuels by keeping environmental impacts within certain limits (Zah, Faist et al. 2009).

Nowadays, various certification schemes are already implemented or in development such like the Californian Low Carbon Fuel Standard (LCFS) (CARB 2009), the Renewable Fuel Standard (RFS2) (EPA 2010), the UK Renewable Transportation Fuel Obligation (RTFO) (Bauen, Watson et al. 2007; Dehue, Hamelinck et al. 2007), the Swiss mineral oil tax redemption for sustainable biofuels (Leuenberger and Huber-Hotz 2006), the European CEN-standard (TC383 2009), or the voluntary criteria of the Roundtable on Sustainable Biofuels (RSB 2008). In addition to the assessment of sustainability based on Principles & Criteria's those regulations often require calculations of greenhouse gas (GHG) emissions or even of environmental impacts (Swiss regulation) on the basis of Life Cycle Assessment (LCA). In general, environmental impacts occur in all stages of the biofuels value chain, by transforming the land needed, by producing and applying fertilizers and pesticides, by cultivating energy crops, by producing the biofuel, by transporting it to the gauging station and by using it in the car. Consequently, the adequate assessment of environmental impacts along the life cycle is a resource intensive and complex task and even more is the assessment of the overall sustainability (Zah, Faist et al. 2009).

Bearing this in mind the goal of this project was to develop a web-based tool for the interactive evaluation of biofuels sustainability against the standard of the Roundtable on Sustainable Biofuels. In this document we describe the central concepts of the RSB GHG Tool which is one module within the RSB tool. It allows the modular assessment of GHG emissions for numerous biofuel pathways with different methodologies: RSB, EU Renewable Energy Directive (EU RED), Ordinance on mineral oil tax (CH), Low Carbon Fuel Standard (LCFS/USA), and U.S. Renewable Fuel Standard (RFS2/USA).

1.1 Context

The Roundtable on Sustainable Biofuels (RSB) is an international initiative coordinated by the Energy Center at EPFL in Lausanne that brings together farmers, companies, non-governmental organizations, experts,

governments, and inter-governmental agencies concerned with ensuring the sustainability of biofuels production and processing. The RSB has developed a third-party certification system for biofuels sustainability standards, encompassing environmental, social and economic principles and criteria through an open, transparent, and multi-stakeholder process.

The RSB requires a web-based tool to enable an operator to verify his/her compliance with all applicable standards of the RSB certification system and with regulatory requirements in the markets that the biofuel is intended for. This includes performing a self-assessment against

- (i) the RSB Principles & Criteria (P&C),
- (ii) the RSB Risk Assessment and
- (iii) the RSB GHG Assessment.

1.2 Goal

The scope of this master project focuses on the specification and implementation of the RSB GHG Assessment. The goal is to develop a web-based tool to assess the GHG emissions of different operators throughout the supply chain of biofuels according to the certification rules of the RSB on the basis of the Life Cycle Assessment (LCA) framework.

The tool is in part based on the existing Sustainability Quick Check for Biofuels (SQCB) which is a web-based, flexible tool to assess the sustainability of biofuels. The SQCB is designed to check the compliance of biofuels with the environmental and social criteria of the Swiss legislation on mineral-oil tax exemption for biofuels based on a questionnaire to be completed by the user and background data from theecoinvent database.

The main functions of the new GHG tool for the RSB can be summarized as follows:

- (i) stepwise calculations of GHG intensity of a biofuel according to different regulations / schemes,
- (ii) use of default data to complete the fuel chain and
- (iii) possibility of integrating data of other operators.

1.3 Associated Task

The central mission of the master's project is to develop a web-based tool for GHG calculation according to the requirements of the RSB. This includes the following tasks:

- Definition of the requirements in cooperation with the RSB; development of a specification document describing the requirements and a plan for their implementation. The document should address
 - o the general workflow the GHG tool will be based on
 - o the questionnaire configuration and design
 - o the database structure and its connection to the questionnaire
- Implementation of the GHG tool according to the specification document.

1.4 Structure of this document

This document describes the specifications of the RSB GHG tool. It is structured as follows:

Chapter 2 highlights the inception phase of the tool. The chapter provides a first insight to the purpose of the tool and expatiates on intended users, main functions, use cases and architecture of the RSB GHG tool.

The following chapter (3) explains the central principles of the tool, i.e. it explains the most important concepts of the RSB GHG tool and elucidates in a nutshell how it works.

In chapter 4 the detailed specification is explained. Section 4.1 to 4.4 exemplify the specification for each module, while section 4.5 and 4.6 demonstrate how modules are calculated and the results represented.

Chapter 5 provides some details to the implementation of the RSB GHG tool.

The subsequent conclusion (chapter 6) summarises the main features of the tool and elaborates on the insights gained with the development of the RSB GHG tool.

2 Inception

The RSB requires a web-based tool to enable an operator to verify his/her compliance with all applicable standards of the RSB certification system and with regulatory requirements in the markets that the biofuel is intended for. This includes performing a self-assessment against

- (i) the RSB Principles & Criteria (P&C),
- (ii) the RSB Risk Assessment and
- (iii) the RSB GHG Assessment.

2.1 Intended users

Users are participating operators of the RSB certification systems or other interested persons or organisations. Operators are defined in the standard as “individual, company or other legal entity responsible for the implementation of the RSB certification standards, and applying for participation or participating in the RSB certification system.

Participating operators are legal entities or natural persons producing, converting, processing, blending, trading, using or otherwise handling biomass and/or biofuels and participating in the RSB certification systems.

2.2 Main functions

2.2.1 Information function

The tool provides an overview of the RSB certification system. It informs the user about the RSB certification scheme, the possibilities of the RSB tool, and contains links to relevant organisations or information.

2.2.2 Evaluation function

The tool should include the evaluations of the RSB certification scheme (self-risk assessment, self-evaluation according to P&C, GHG calculation), and evaluation according to other regulations (Swiss SQCB, EU RED, LCFS, US RFS).

2.2.2.1 Self-evaluation regarding to the RSB P&Cs

Operator can fill in questionnaire and check if he complies with the RSB P&Cs. To this aim, the criteria of the RSB P&Cs are listed in the online questionnaire.

2.2.2.2 Self-Risk assessment

The tool implements the RSB standard for risk management.

The tool evaluates the risk factors of the operators and allows calculating the risk class.

2.2.2.3 GHG emissions of the biofuel pathway

The tool allows entering data and calculating GHG emissions according to the RSB methodology.

The tool also allows entering data and calculating GHG emissions according to the methodology of intended markets (for example, according to RED).

The tool incorporates the EU RED market access Std that allows evaluation against the EU RED.

The tool incorporates California LCFS GHG pathway GHG intensity data and requirements.

The tool incorporates US RFS GHG pathway GHG intensity data.

2.3 Use cases

2.3.1 General

In general, the tool should answer the question whether a biofuel production steps / pathway comply with the sustainability criteria (see Figure 1). For that reason the user enter the data required by the respective certification scheme into a questionnaire. Based on the specific rules from the certification schemes and background data from the database such data is manipulated, complemented and evaluated against the criteria of the respective certification scheme. The final result shows if the biofuel production complies with the sustainability criteria of the selected certification scheme.

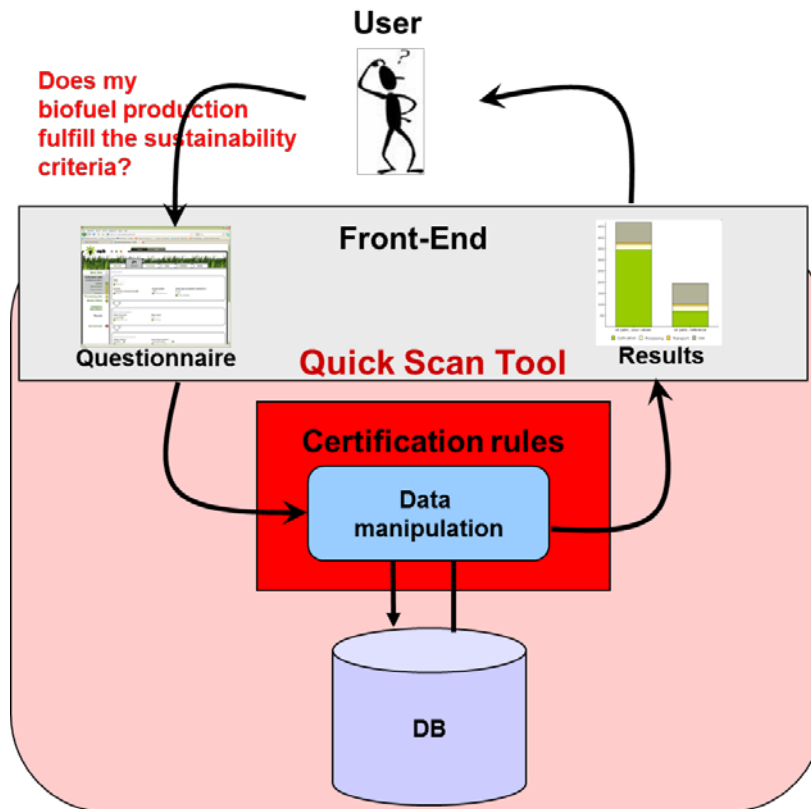


Figure 1. Use case of the RSB tool (source: own depiction).

2.3.2 In the specific context of a biofuel pathway

In general, the RSB GHG calculation is free and open to everyone. However, the calculated GHG intensity become official if the operator takes part in the RSB certification. In this case each user has to include the calculated GHG number with the Chain of Custody (COC) documentation. Figure 2 exemplifies one possible use case where the scope of operation of each user is limited to one processing step.

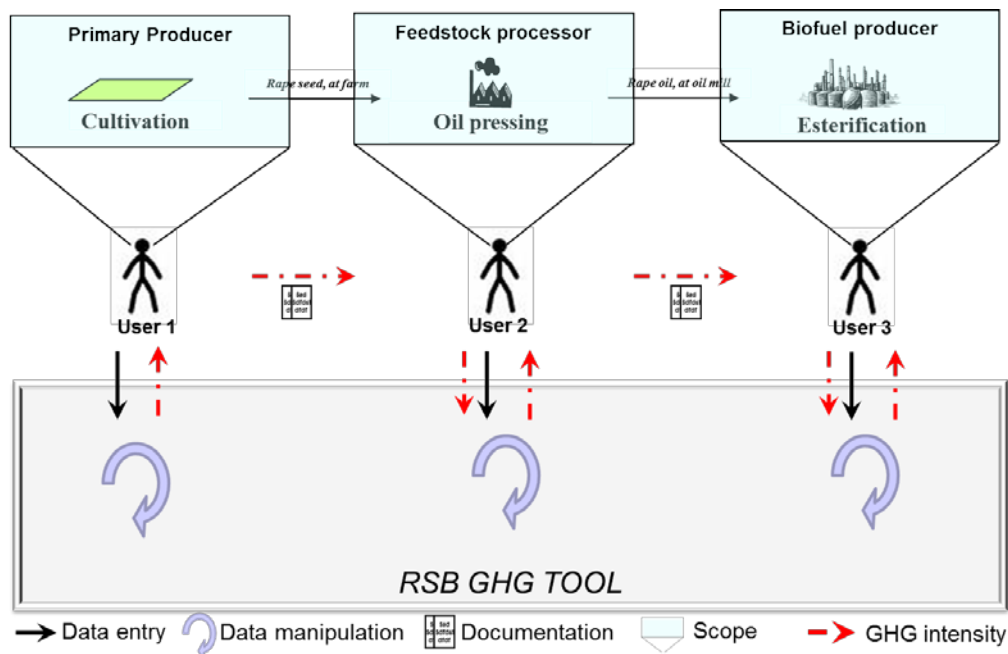


Figure 2. Exemplary Use Case of RSB GHG TOOL (source: own depiction).

In this case user 1 enters his data into the RSB GHG tool and calculates the GHG intensity for his scope of operation, i.e. cultivation step. The resulting GHG intensity is noted in the COC documentation and as such transmitted to the next user in the biofuel pathway. On the basis of the received GHG intensity user 2 is able to calculate the cumulated GHG intensity of the overall pathway, i.e. the GHG intensity associated with the feedstock cultivation plus the GHG intensity of his feedstock processing. In this manner each participating user can calculate the cumulated GHG intensity of the feedstock / biofuel including his scope of operation.

Figure 3 exemplifies another use case where the scope of operation of a user includes more than one processing step.

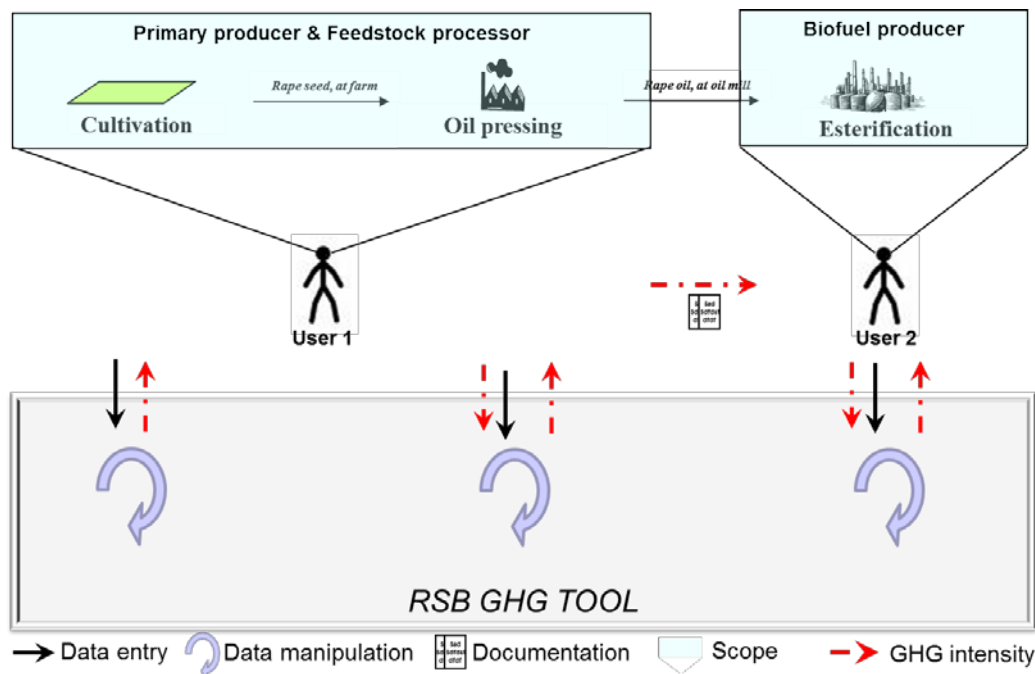


Figure 3. Exemplary Use Case of RSB GHG TOOL (source: own depiction).

In this case user 1 enters both data for cultivation and feedstock processing. However, as indicated by the two manipulation arrows and the red arrows user 1 has to act like two separate users; first he has to calculate the GHG intensity for the cultivation, then he can use the calculated GHG intensity as the basis to calculate the cumulated GHG intensity of the overall scope of operation.

With the upcoming upgrades of the RSB GHG tool it is intended to merge both steps in order to allow the user to immediately calculate the GHG intensity for his overall scope of operation.

2.4 Architecture

Figure 4 shows in the most simplistic fashion the architecture for RSB tool and the prior elaborated use case.

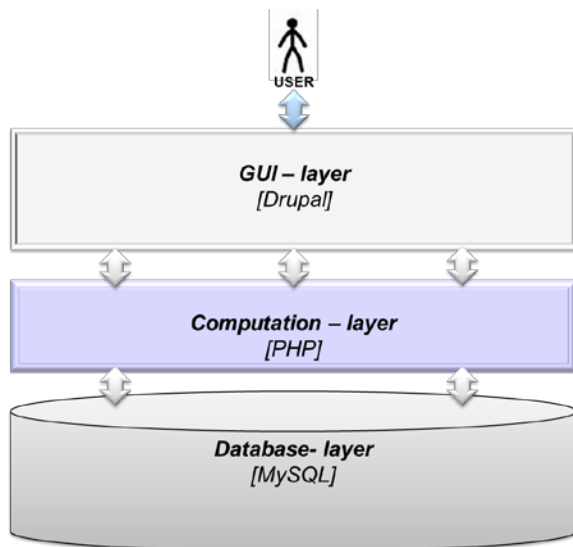


Figure 4. Architecture of the RSB GHG Tool (source: own depiction).

The RSB Tool generally can be divided into three layers; the graphical user interface (GUI), the computation layer and the database layer. The GUI or front end is reflected by a web-browser and is based on Drupal and specifically, Drupal 6. Drupal is a free and open source content management system (CMS) written in PHP. The computation layer which runs in the background is a mix of PHP and drupal-proprietary syntax. The database is based on MySQL, a relational database management system. Given that it is a popular choice of database for use in web applications, we are not going further into detail.

3 Central Principles

3.1 A Workflow based on Life Cycle Assessment

3.1.1 Life Cycle Assessment

It is the Life Cycle Assessment (LCA) framework which provides the basis for the central concepts of the RSB GHG tool. LCA is a technique to assess the environmental impacts of a given product or service over its life cycle, i.e. from cradle-to-grave (Guinée 2001). It comprises the compilation and the evaluation of the inputs, outputs and potential environmental impacts of a products system throughout its life cycle (Guinée 2001). In practice the LCA framework consists of four basic steps (Figure 5).

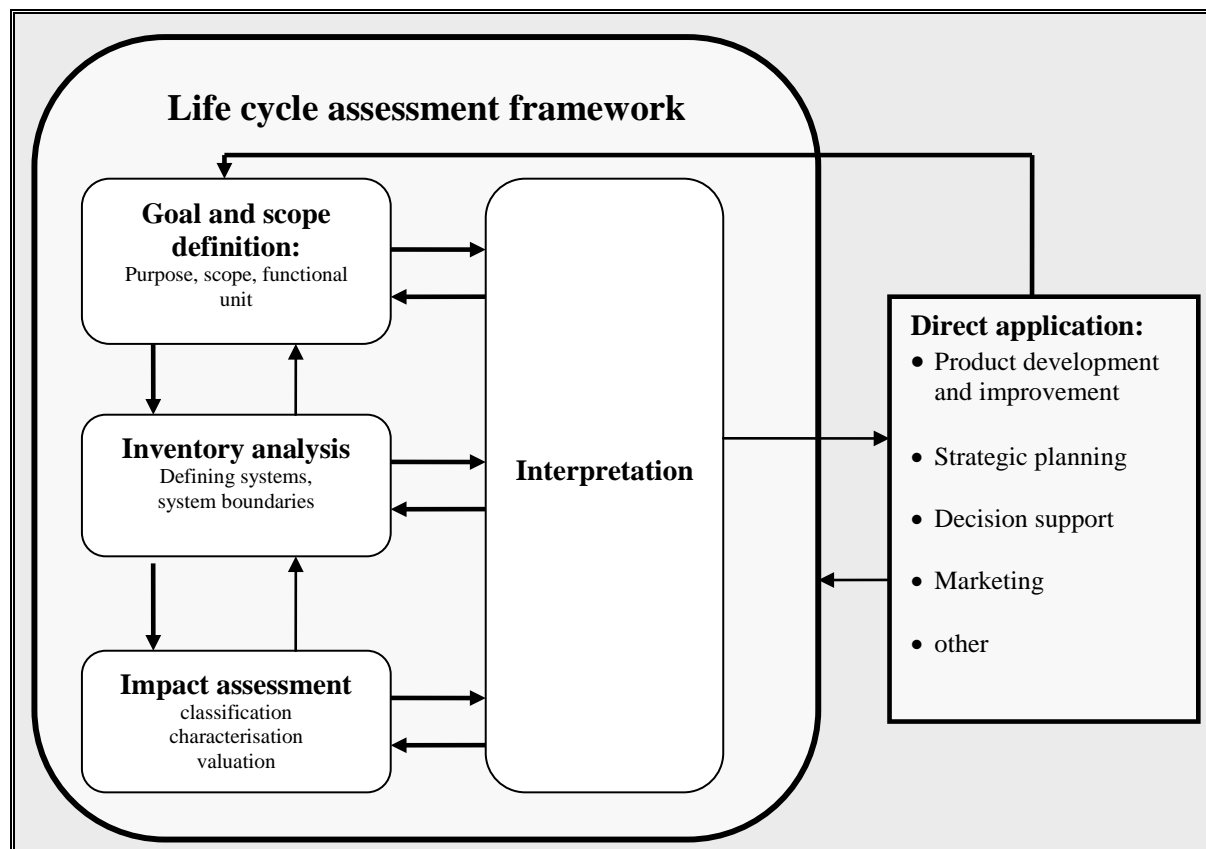


Figure 5. LCA framework (source: according (Guinée 2001, p. 4)).

The first step is the goal definition and scoping. Here the fundamental direction of the LCA is defined including the purpose of the study as well as the general condition. The scoping process links the goal of the LCA with the extent or scope of the study, i.e. the definition of what will or will not be included (Schaltegger

1996). In this regard it provides a description of the product system in terms of the system boundaries and a functional unit. The functional unit is the important basis that enables alternative goods, or services, to be compared and analysed (Rebitzer, Ekvall et al. 2004).

The second step is the Life Cycle Inventory (LCI) Analysis. An LCI can be described as a model of one or more product systems (Rebitzer, Ekvall et al. 2004). A product system is composed of unit processes, which each represents one or several activities, such as production processes, transport, or use (Rebitzer, Ekvall et al. 2004). The LCI Analysis aims at identifying and quantifying all inputs and outputs associated with the product system including materials, energy and residuals (Finnveden, Hauschild et al. 2009).

This compiled LCI table is the basis for third step in the LCA framework, the Life Cycle Impact Assessment (LCIA). LCIA is a quantitative and/or qualitative process to classify and characterize and/or assess the effects of the inputs (resources) and the outputs (emissions) listed in the inventory table (Schaltegger 1996). The LCIA is aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of the studied system (Finnveden, Hauschild et al. 2009).

In the last step, i.e. the interpretation, the results from the previous phases are evaluated in relation to the goal and scope in order to reach conclusions and recommendations (Finnveden, Hauschild et al. 2009).

3.1.2 Workflow

Figure 6 shows how the prior explained LCA framework was transformed into the workflow of the RSB GHG tool.

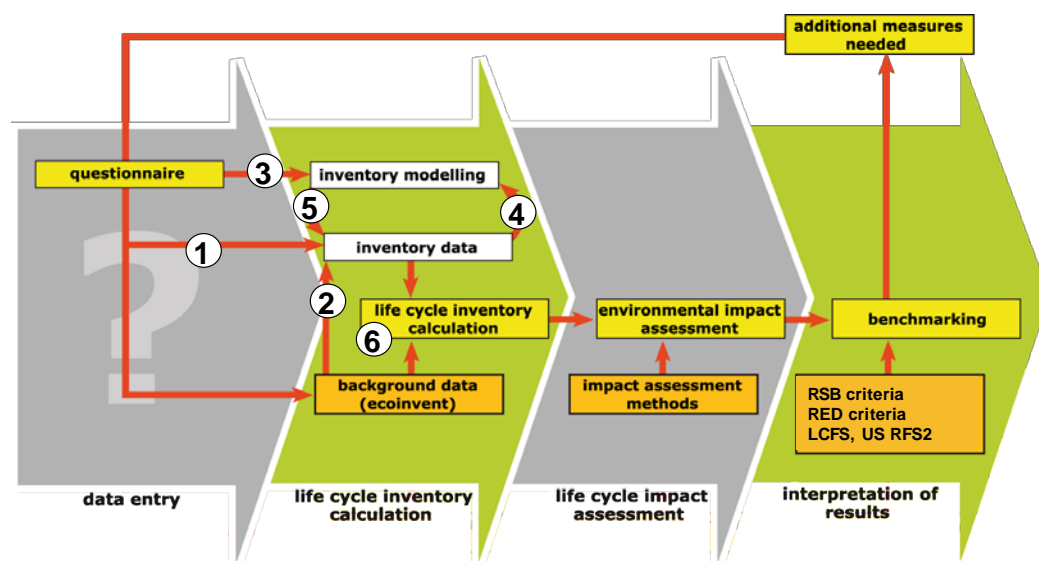


Figure 6. Workflow of environmental impact modeling in the RSB GHG tool (source: own depiction).

As shown by Figure 6, a questionnaire is used to set the scope of the analysis and to gain the data to generate the LCI. The operator can adapt all data directly related to the biofuel pathway, whereas the background data can only be influenced indirectly, i.e. by measures taken in that foreground system.

Different paths for the transformation of questionnaire data into Life Cycle Inventory (LCI) data are used. Some of the data entered by the operator can directly be used as LCI flows (step 1). In general, the LCI can be supplemented (step 5) with data resulting from background models using (i) questionnaire data as input (step 3) or (ii) already determined LCI flows (step 4). Another part of the required data is used by default from the background data, e.g. the transport of auxiliaries and infrastructure such like production facilities (step 2). When all required LCI flows are completed, the LCI is calculated (step 6). In the following, the respective steps are explained in more detail.

3.2 Modular Questionnaire

Data entry is done via a modular questionnaire. The operator can select the module, which correspond to his scope of operation, i.e. the step in the lifecycle production process where he is responsible for. There are modules for cultivation, processing, and blending & transport. In addition, there is the basic data module and two management modules that manage the creation of modules and basic data, and also the interaction of the pathway data. These modules form the basis for the generation of all relevant biofuel pathways.

The basic data module is required to set the scope of operation of the operator, i.e. the system boundaries of the foreground system. The operator chooses raw material, country of operation, and the GHG calculation methodologies he wants to apply – RSB is set, all other methods are facultative. The generic structure of the modules is visualized in Figure 7.

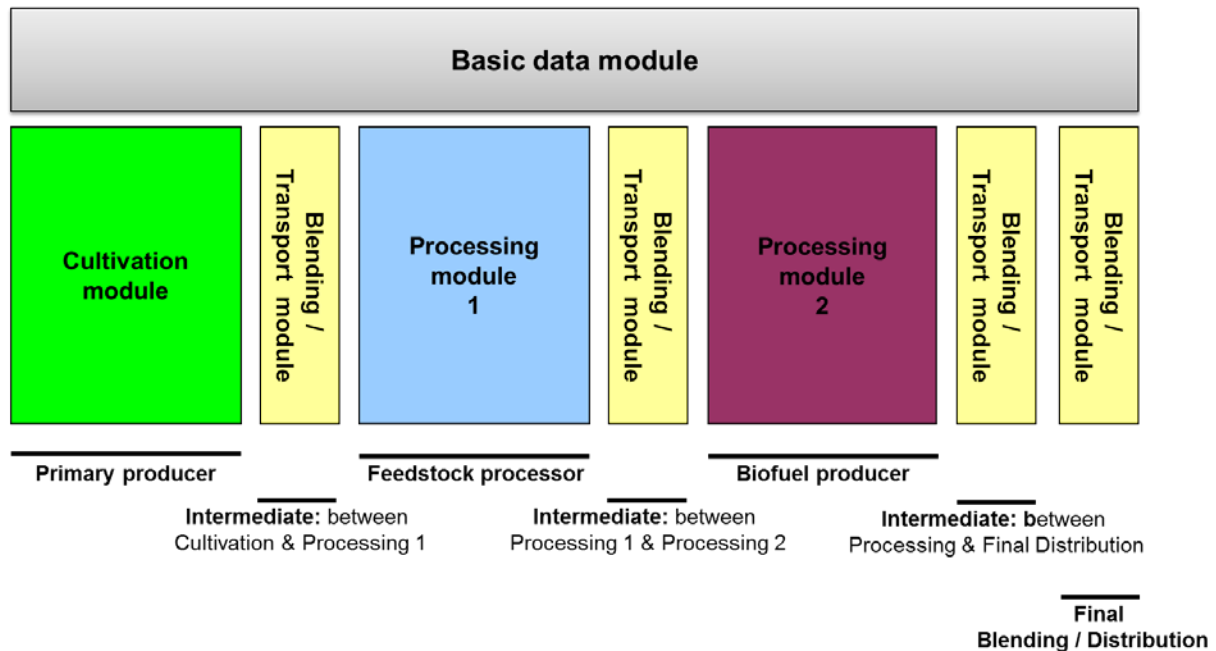


Figure 7: Structure of Questionnaire Modules in the GHG tool (source: own depiction).

The **Cultivation module** asks for all data related to the production of the feedstock. The module is structured into general context information, land use change, mechanical work, mineral fertilizer, organic fertilizer and pesticides.

For process data the tool contains generic questionnaires for **Processing module 1** (feedstock processor) and **Processing module 2** (biofuel producer). The questionnaire asks for all interventions related to the processing of the feedstock/fuel.

The **Blending and Transport modules** are related to the scope of operation of an intermediate distributor/blender and the final distributor/blender. The operator can enter data for the blending (which products are mixed) and / or add transport interventions.

3.3 Life Cycle Inventory Calculation

3.3.1 Foreground & Background System

In LCA the model of a product system is typically seen as a static simulation model, i.e. it is composed of linearly linked unit processes. For each unit process, data are recorded on the inputs of natural resources, energy and material flows and the output of products, emissions and waste flows (Rebitzer, Ekvall et al. 2004). The product system can be separated into a foreground and a background system (Figure 8).

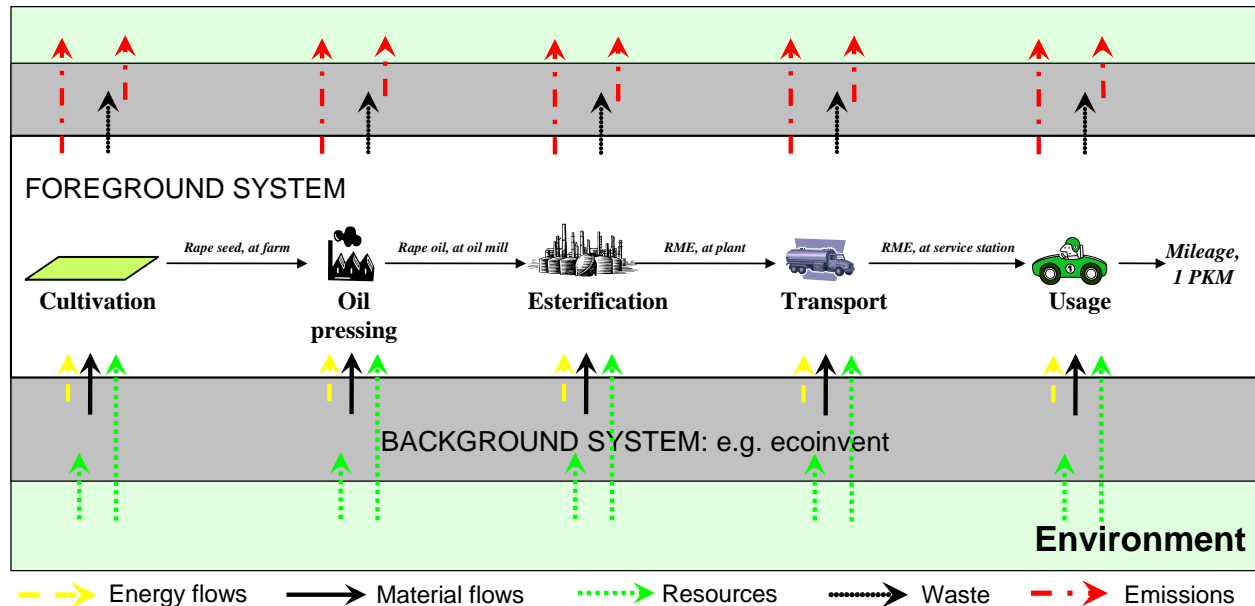


Figure 8. Life Cycle Inventory Analysis (source: own depiction).

The foreground system is the collection of unit processes on which measures may be taken concerning their mode of operation as a result of decisions based on the study (Tillman 2000). The background system consists of all other modeled processes influenced by measures taken in the foreground system (Tillman 2000). This typically implies that material and energy flows are followed systematically upstream assuming that upstream supply is fully elastic. In other words, the induced demand for one unit of a product in the foreground system leads to the production and supply of one unit of product in the background system (Rebitzer, Ekvall et al. 2004). The background system usually reflects the aggregated data from LCI databases such like ecoinvent (Jungbluth, Chudacoff et al. 2007).

The boundary between the background system and the natural environment shown in Figure 8 also reflects the boundary between the techno sphere and the natural environment. In this perspective, the foreground system transforms the direct inputs from the techno sphere (energy and material flows) and the environment (resources) into emissions, waste and product flows. Via the techno sphere the waste and product flows are transformed into emissions or recycled to other product systems. Finally, the product system only consists of flows from (resources) and to (emissions) the natural environment, i.e. elementary flows.

For example, the foreground system of an exemplary biofuel LCA usually encompasses all unit processes directly associated with the production and use of the biofuel, e.g. cultivation of the feedstock, its processing to a biofuel, up to its use (see Figure 8). The background system includes all LCI affected by the measures taken in the foreground system, e.g. the production and provision of the respective amount of fertilizers, pesticides, electricity and machinery which is required for the cultivation of the feedstock.

3.3.2 Inventory Data

“The unit process inventory is an inventory of energy and material flows (inputs and outputs) which are used or emitted by a unit process” (*Jungbluth et al. 2007, p. 5*). In the RSB GHG tool the unit process inventory in the lifecycle production process where the operator is responsible for.

Figure 9 illustrates a selection of inputs and outputs for rape cultivation. Two classes of inputs and outputs are distinguished: techno sphere flows and elementary flows. Techno sphere flows (top of Figure 9) take place between different processes controlled by humans, e.g. the production of fertilizers and their transport to the field. Elementary flows (left and right of Figure 9) in turn, are all resources used (inputs, e.g. land) and substances emitted to the environment (output).

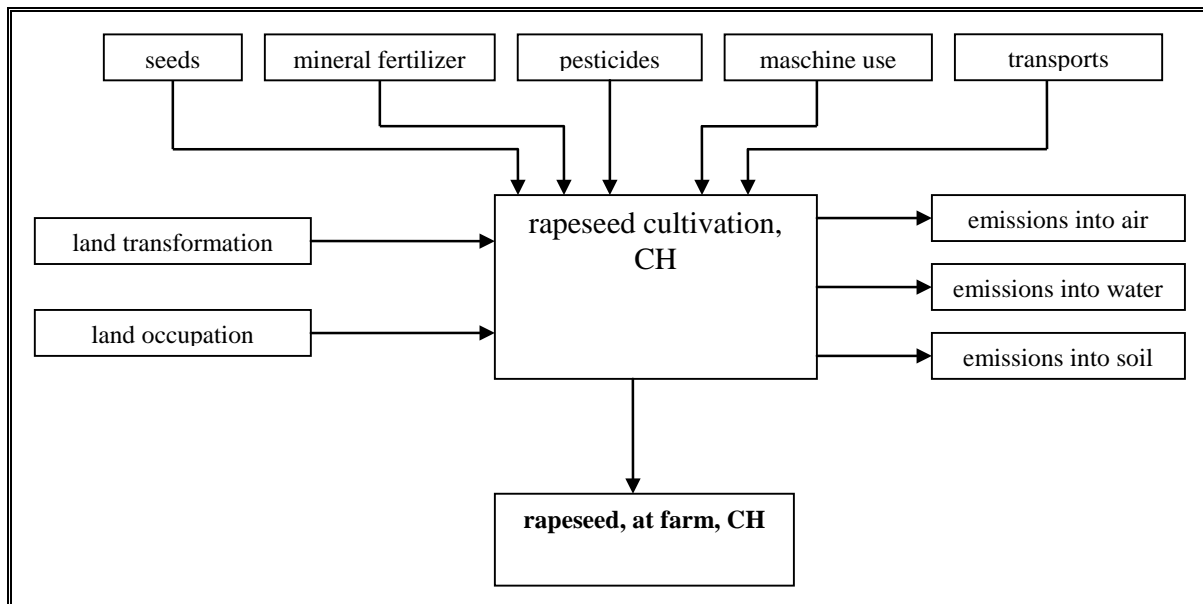


Figure 9. Excerpt of a unit process inventory for the cultivation of rapeseed, CH (source: according to (*Jungbluth, Faist et al. 2007*)).

Rape seeds are the direct inputs, and rape seeds are also the major output (product or reference flow) of this unit process. However, further inputs are related to rape cultivation, e.g. land use, fertilizer, machine use or pesticides and emissions, e.g. nitrate to water or N_2O to air (*Jungbluth et al. 2007, p. 6*).

Figure 9 exemplary shows some unit process raw data for the production of 1 kg rape seed in Switzerland with integrated production technology.

Explanations	Name	Location	Infrastructure- Process	Unit	rape seed, ip, at farm	uncertainty- Type	Standard- Deviation95%
	Location InfrastructureProcess Unit				CH 0 kg		
Technosphere	rape seed IP, at regional storehouse	CH	0	kg	0,021333	1	1,0714
	calcium ammonium nitrate, as N, at regional storehouse	RER	0	kg	0,020077	1	1,0714
	triple superphosphate, as P2O5, at regional storehouse	RER	0	kg	0,0057467	1	1,0714
	potassium chloride, as K2O, at regional storehouse	RER	0	kg	9,81E-05	1	1,0714
	pesticide unspecified, at regional storehouse	RER	0	kg	8,23E-05	1	1,0744
	transport, lorry 3.5-16t, fleet average	RER	0	tkm	0,0003239	1	2,095
resource, biotic	Energy, gross calorific value, in biomass			MJ	15,251	1	1,0714
resource, in air	Carbon dioxide, in air			kg	1,313	1	1,0714
resource, land	Occupation, arable			m2a	1,2222	1	1,113
	Transformation, from arable, non-irrigated			m2	1,3333	1	1,2077
	Transformation, to arable, non-irrigated			m2	1,3333	1	1,2077
water, ground-	Nitrate			kg	0,016674	1	1,5051
	Zinc, ion			kg	1,51E-06	1	1,8042
water, river	Phosphorus			kg	1,69E-05	1	1,5051
air, low population density	Ammonia			kg	0,00048759	1	1,209
	Nitrogen oxides			kg	0,0001335	1	1,4057
	Dinitrogen monoxide			kg	0,00063571	1	1,4057
soil, agricultural	Cadmium			kg	6,43E-07	1	1,5051
	Chromium			kg	5,06E-07	1	1,5051
water, river	Cadmium, ion			kg	3,74E-09	1	1,8042
	Chromium, ion			kg	3,75E-07	1	1,8042
soil, agricultural	Diflufenican			kg	8,33E-06	1	1,209
Outputs	rape seed, ip, at farm	CH	0	kg	1		

Figure 10. Selection of unit process raw data for the production of 1 kg rape seed in Switzerland with integrated production technology. Values have been changed (source: according to (Nemecek, Heil et al. 2004)).

One of the main challenges of the RSB GHG tool is to generate such a unit process inventory data on the basis of simple questionnaire data. This highlights the important role of background inventory modelling.

3.3.3 Inventory Modelling

As will become apparent in section Land use change 4.2.2, the inventory modeling can be very resource intensive because usually, only key factors of the agricultural and technical processes are known and not the environmental flows itself. For example, a farmer knows in detail type and amount of fertilizers he is applying and the respective yield of his cultivation but he does not know the amount of phosphate leaching to the groundwater or the diffusion rate of N₂O from his field to the atmosphere. As shown by Figure 11, therefore the RSB GHG tool asks only for parameters which are known or at least can be determined by the operator.

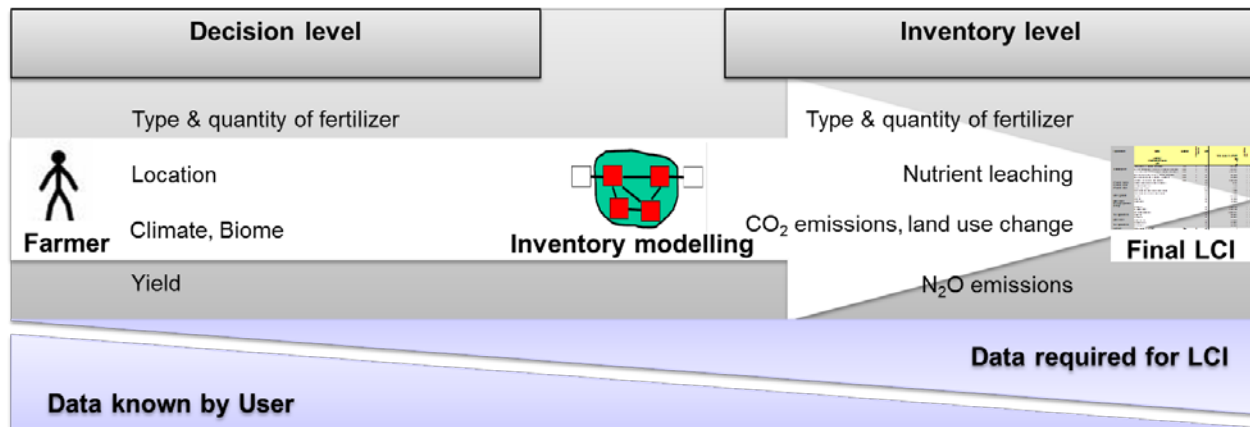


Figure 11. Inventory modelling on the basis of simple data given by the operator (source: own depiction).

There is a gap between the data required for Life Cycle Impact Assessment and the data known by the operator. This emphasizes the importance of background LCI models which combine the specific context of the operator (e.g. Eco zone, soil type, etc.) and his input data (e.g. amount of mineral fertilizer applied) to derive the environmental flows which are not directly accessible. The model applied for the calculation of direct CO₂ emissions caused by land transformation is based on the IPCC-guidelines (IPCC 2007). The calculation of the agricultural emissions on theecoinvent report on bioenergy (Jungbluth, Chudacoff et al. 2007). For nitrate and phosphate leaching, new simplified models have been developed (Faist-Emmenegger, Reinhard et al. 2009). Using such models allows to generate a full LCI on the basis of the input data the operator can provide.

3.3.4 Processing of different certification schemes

In order to enable the parallel processing of different GHG calculation schemes using one questionnaire, the following general concept is applied (Figure 12). It is important to note that the shown figure lack important parts of the computation in order to emphasize some others, namely the parallel computation of different GHG calculation schemes.

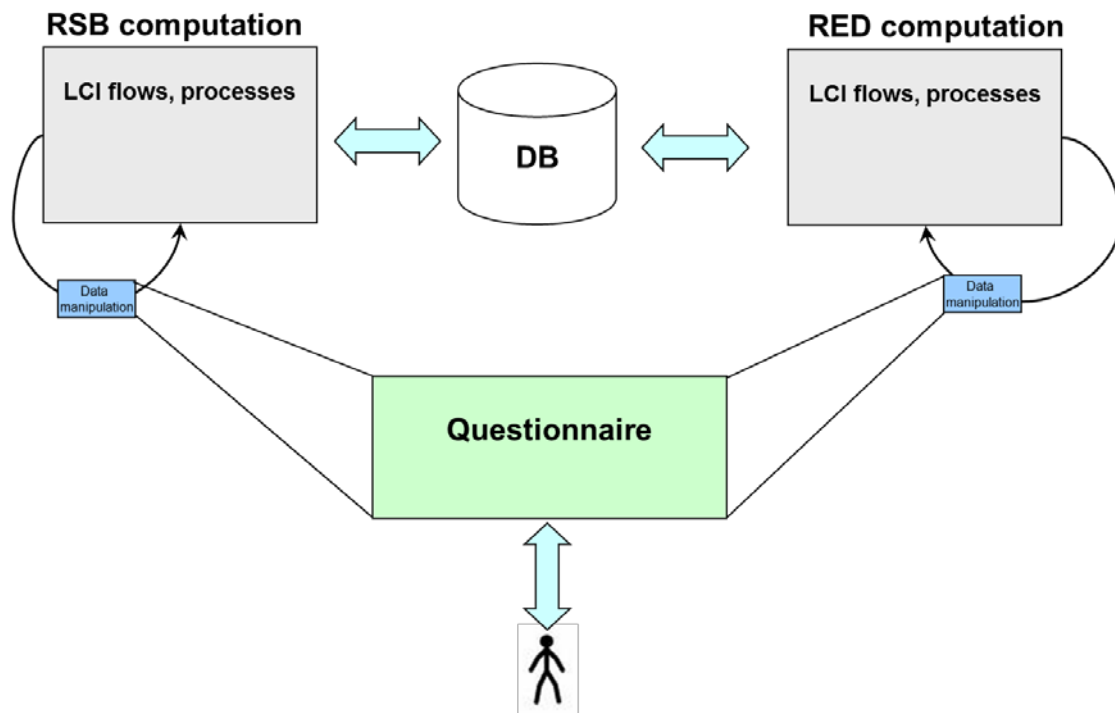


Figure 12. General concept for the parallel computation of different certification schemes (source: own depiction).

In general, the user manipulates the database using the questionnaire. Whenever possible, the data required for the methodologies are asked for with the same question, e.g. when the user enters the type and amount of fertilizer used per hectare, both the LCI flows of the RSB and the RED are computed. However, given the differences between the methodologies this is not possible for all questions, e.g. due to the different allocation in the RSB (economic) and RED (energetic), the user has to enter the price (RSB) and the energy content (RED) of products.

In a simplified perspective, the calculation procedure can be described as follows: According to the questionnaire data entered by the user, first all required LCI flows of the RSB and the RED are loaded from the database into the RSB and the RED computation table. These LCI flows include all resource and commodity flows directly related to the relevant production step, i.e. the selected scope of operation. Subsequently, the data is loaded, manipulated and written back to the computation tables following the structure of the questionnaire. The final unit process inventories represent the basis for the next step in the RSB GHG workflow, i.e. the Life Cycle Impact Assessment.

3.4 Life Cycle Impact Assessment

In order to calculate the environmental impacts of the foreground system (e.g. cultivation step) each exchange listed in the unit process inventory table (LCI) has to be transformed to its respective environmental impact. The RSB GHG tool uses the classification scheme of the ecoinvent database in order

to classify and match both, the LCI exchanges and their associated impacts stored in an impact table. The impact table includes all required environmental impacts for all inventory flows available from ecoinvent classified into (i) exchanges from and to nature and (ii) techno sphere processes.

3.4.1 Assessing exchanges from and to nature

For (i) Table 1 shows how the environmental impacts for different emissions (OutputGroup 4) are stored in the impact table.

Table 1. Excerpt of the impact table showing the environmental impacts of emissions (global warming potential and UBP) for different certification schemes.

Exchange Name	Unit	InputGroup	OutputGroup	MinÖv GWP100 (IPCC 2001)	MinÖv UBP (2006)	RSB GWP100 (ReCiPE)	RED GWP100 (IPCC 2001)
Dinitrogen monoxide	kg	0	4	296	92'000	298	296
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	kg	0	4	1'300	400'000	1'430	0
Methane, fossil	kg	0	4	23	7'100	25	23

For the calculation of the GHG intensity (0.189 kg CO₂ equiv.) associated with the dinitrogen monoxide emissions listed in the unit process inventory of rape seed, CH, the amount (0.0006357 kg, see Figure 10) has to be multiplied with the value listen in the impact table (298 kg).

3.4.2 Assessing techno sphere processes

With regard to (ii) Table 2 shows how the environmental impacts for the techno sphere processes (InputGroup 5) are stored in the impact table.

Table 2. Excerpt of the impact table showing the environmental impacts of techno sphere processes (global warming potential and UBP) for different certification schemes.

Exchange Name	Unit	InputGroup	OutputGroup	MinÖv GWP100 (IPCC 2001)	MinÖv UBP (2006)	RSB GWP100 (ReCiPE)	RED GWP100 (IPCC 2001)
Ammonium nitrate phosphate, as N, at regional storehouse	kg	5	0	5.25	6648	5.2655	4.67
chopping, maize	ha	5	0	325.23	454190	324.83	194.47
combine harvesting	ha	5	0	154.87	220230	154.45	122.38
electricity, low voltage, production CH, at grid	kWh	5	0	0.03	278	0.029754	0.02
transport, lorry 20-28t, fleet average	tkm	5	0	0.19	215	0.19385	0.16

The listed environmental impacts for each of the techno sphere processes reflect the cumulated (upstream) impact associated with its provision. In this regard the RSB GWP100 for the use of 3 kWh “electricity, low voltage, production CH, at grid” can be calculated by multiplying with the corresponding value in the impact

table (~0.03 kg CO₂ equiv.) The exchange flows listed in the impact table for all certification scheme are calculated on the basis of the ecoinvent database (Frischknecht, Jungbluth et al. 2005).

3.4.3 Assessing different certification schemes

As shown by Table 1 and Table 2, each certification scheme is reflected by one column. This structure does not only allow the parallel computation of different certification schemes but also the easy integration of new impact assessment methodologies.

The values for the environmental impacts, e.g. GWP100, differ with regard to the applied certification scheme. The reason for this is that the certification schemes apply different impact assessment methodologies. For example, the GWP100 value associated with the fertilizer production of 1 kg “ammonium nitrate phosphate, as N, at regional storehouse” according to RSB amounts to ~5.27 kg CO₂ equiv. (see Table 2). For the EU RED this value is approx. 11% lower given that the European methodology does not take account of infrastructure (plants, streets, etc.) and the fact that the EU RED uses the GWP100 impacts according to IPCC 2001 (IPCC 2001) – while RSB methodology uses GWP100 according to ReCiPe (Goedkoop, Heijungs et al. 2009).

3.5 Interactive Interpretation

Finally the GHG intensity per module are compared tabular and graphically to the fossil reference system considering (i) the different GHG intensity of the fossil reference system and (ii) the varying thresholds of the different certification schemes. In other words, the results indicate if the greenhouse gas emissions comply to the respective requirements of a certification system. In addition to the GHG intensity associated with the specific module the cumulated GHG intensity of the upstream pathway is shown. On this basis, the operator can determine the importance of his step in the context of prior processing steps.

For all certification schemes, the operator can take a more detailed look at composition and main sources of GHG emissions. On this basis he can easily identify hot spots and adapt data entries in order to get more insight on the key drivers of the GHG emissions.

4 Specification

The specification follows the following procedure: For each module / sub-module of the tool first the graphical specification of the questionnaire is explained, i.e. its graphical user interface. Subsequently, its links / interfaces / interaction to the database are clarified. Finally selected relations and their interactions are elucidated (Figure 13).

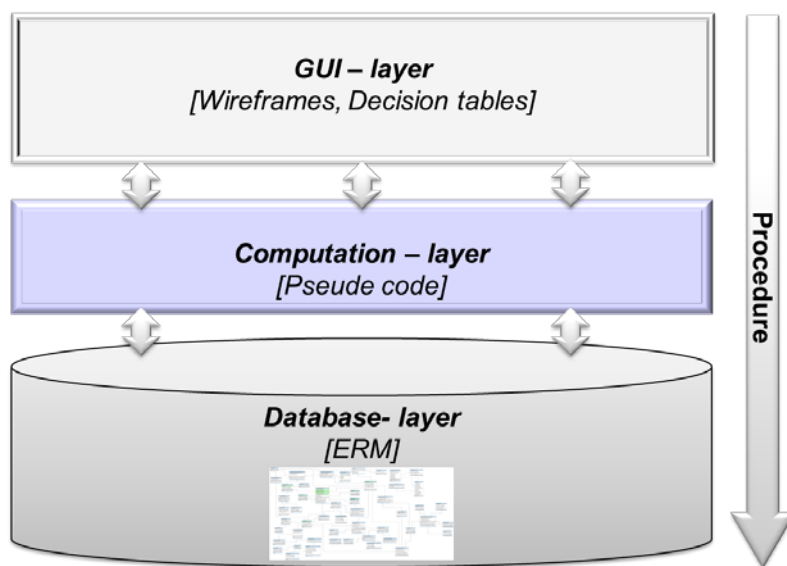


Figure 13. Procedure and tools used for specification (source: own depiction).

The specification of the GUI is done with wireframes drawn in Microsoft Power Point. A wireframe is a visual guide that represents the skeletal framework of a website. It depicts the page layout or arrangement of the websites' content, including interface elements and navigational systems, and how they work together. All three components are of particular importance when it comes to the specification and design of a complex and extensive questionnaire like the one required for RSB GHG tool.

Subsequently, the computation of questionnaire data, i.e. its manipulation and transformation to the database is explained. There were discussions about using the Unified Modeling Language (UML) for this task. However, UML is rather useful for object oriented modelling. Given that we used PHP (a scripting language) for the programming we did not use UML but modelled the interaction between the database and questionnaire using concepts such like pseudo code and decision tables.

The database reflects is implemented as a relation database and consequently was modelled with Entity Relationship Modelling (ERM) using Microsoft Workbench. In this report we are only showing excerpts of the overall database model given that it includes more than 220 relations.

4.1 Basic data module

4.1.1 Concept

A basic data module determines the system boundaries for the calculation process. The user can either create a new module or directly access already existing modules. Figure 14 shows the workflow for the definition of a basic data module.

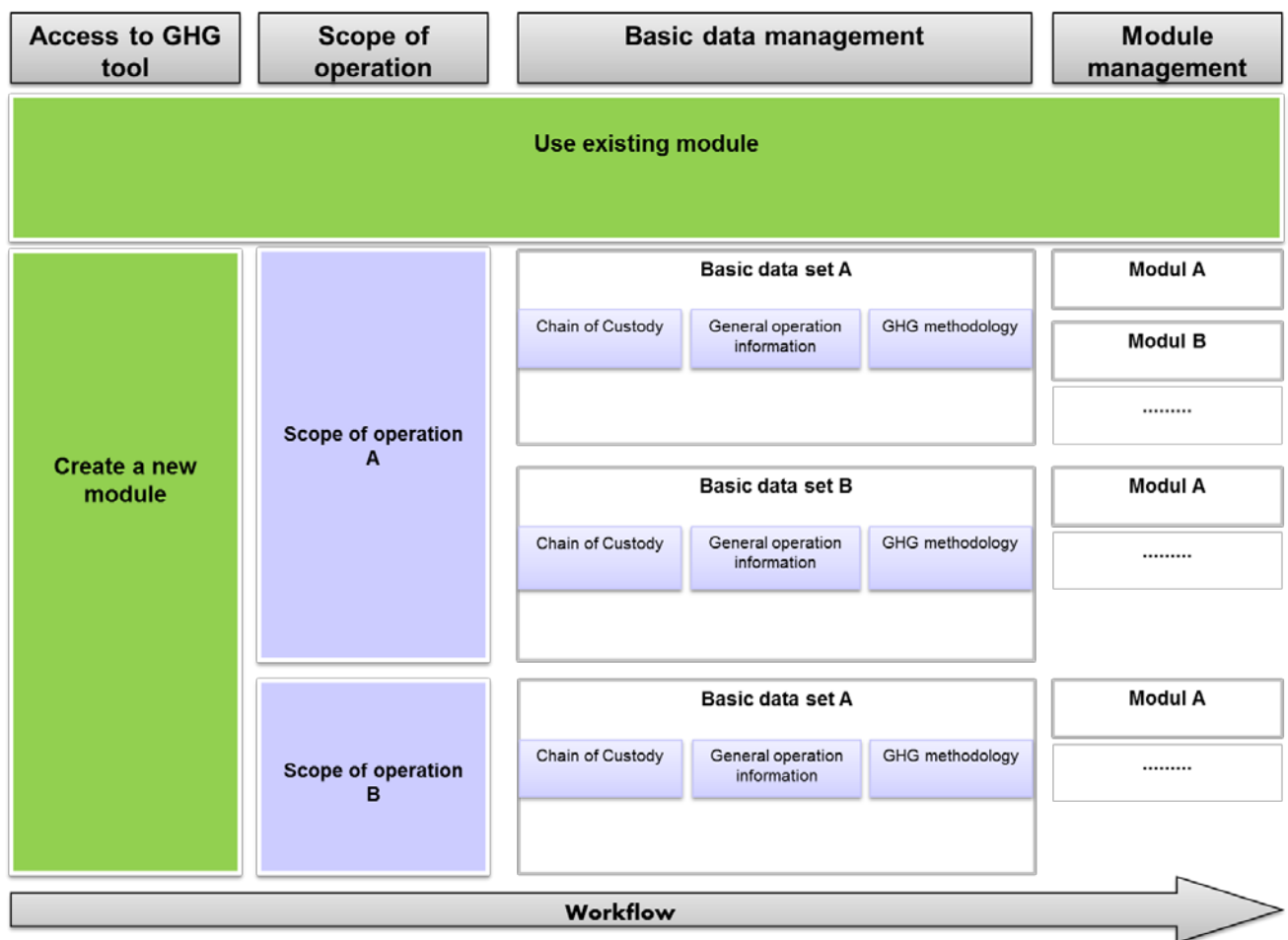


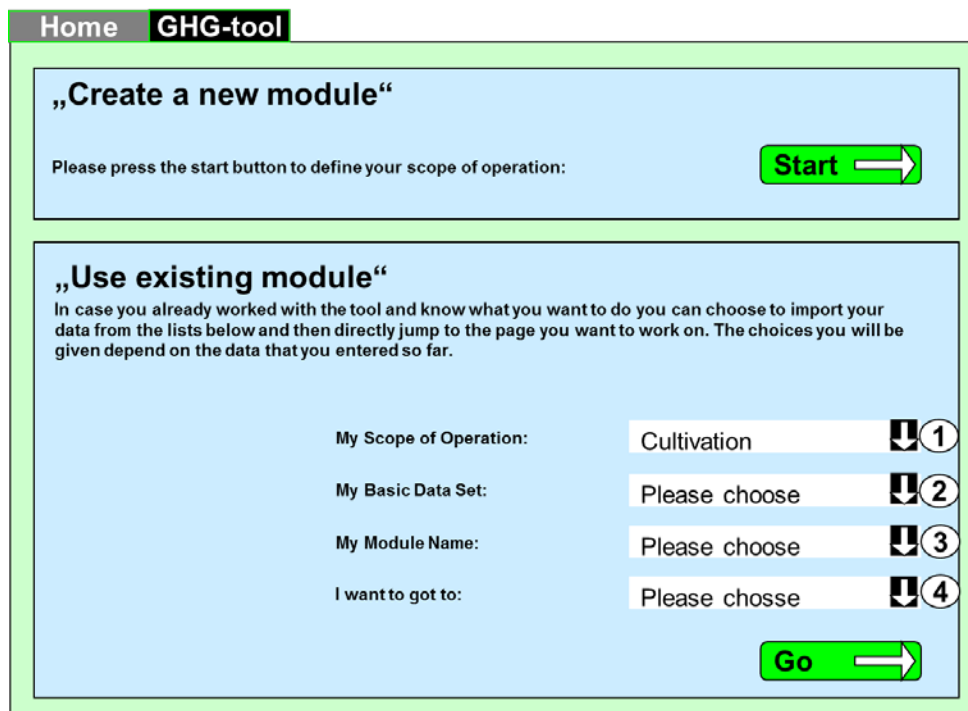
Figure 14. Workflow for the specification of basic data (source: own depiction).

The creation of a new module includes (i) the definition of the scope of operation and its associated basic data as well as (ii) the specification of sub-modules. The scope of operation is the process step relevant for the operator, e.g. cultivation. The associated basic data includes information on the chain of custody, general operation information and GHG methodologies used. For each scope of operation numerous basic data sets can be specified. Once created a basic data set can be the origin for different modules. A module reflects a specific characteristic of a basic data set, i.e. inherits the characteristic of a basic data set.

The use of existing modules allows the quick guide to already defined scope of operations, basic data sets and modules. This minimizes the data input for the operator in particular in case he has to fill out different modules or wants to try out different combinations. For example, a feedstock processor can reuse the data already determined within the basic data module in order to enter data for different facilities, i.e. for one and the same basic data set an operator can define numerous facilities.

4.1.2 Graphical representation

After the operator clicks on “GHG-tool” in the navigation bar he can create a new module or use existing modules (Figure 15).



The screenshot shows the 'GHG-tool' interface. At the top, there is a navigation bar with 'Home' and 'GHG-tool'. Below this, there are two main sections. The first section is titled '„Create a new module“' and contains the text 'Please press the start button to define your scope of operation:' followed by a green 'Start' button with a right-pointing arrow. The second section is titled '„Use existing module“' and contains the text 'In case you already worked with the tool and know what you want to do you can choose to import your data from the lists below and then directly jump to the page you want to work on. The choices you will be given depend on the data that you entered so far.' Below this text are four input fields, each with a dropdown menu and a numbered circle to its right: 'My Scope of Operation:' with 'Cultivation' selected (1), 'My Basic Data Set:' with 'Please choose' selected (2), 'My Module Name:' with 'Please choose' selected (3), and 'I want to go to:' with 'Please choose' selected (4). At the bottom right of this section is a green 'Go' button with a right-pointing arrow.

Figure 15. First page of the tool (source: own depiction).

If the operator has already created a module he can directly jump to any step within such a module. The following input fields are required for a quick guide to a specific step within an existing module:

1. My Scope of Operation: Shows the general scope of operations (Table 3).
2. My Basic Data Set: Shows the already created basic data sets for the select scope of operation.
3. My Module Name: Shows the modules already defined for the selected basic data set.
4. I want to go to: Shows the available steps in the workflow.

If the operator accesses the GHG tool the first time he can proceed with the “Start” button. As shown in Figure 16, first the tool asks for the scope of operation of the operator. The pull down expresses the values listed in (Table 3).

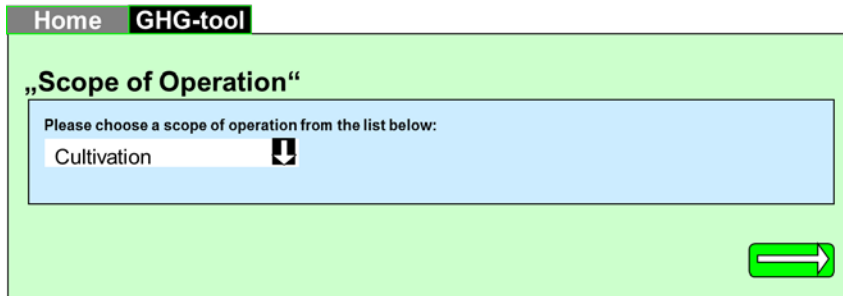


Figure 16. Choice of scope of operation for the calculation (source: own depiction).

The next page allows the operator to manage his basic data to the selected scope of operation (Figure 17). He can choose to copy, adapt or delete existing calculation modules.

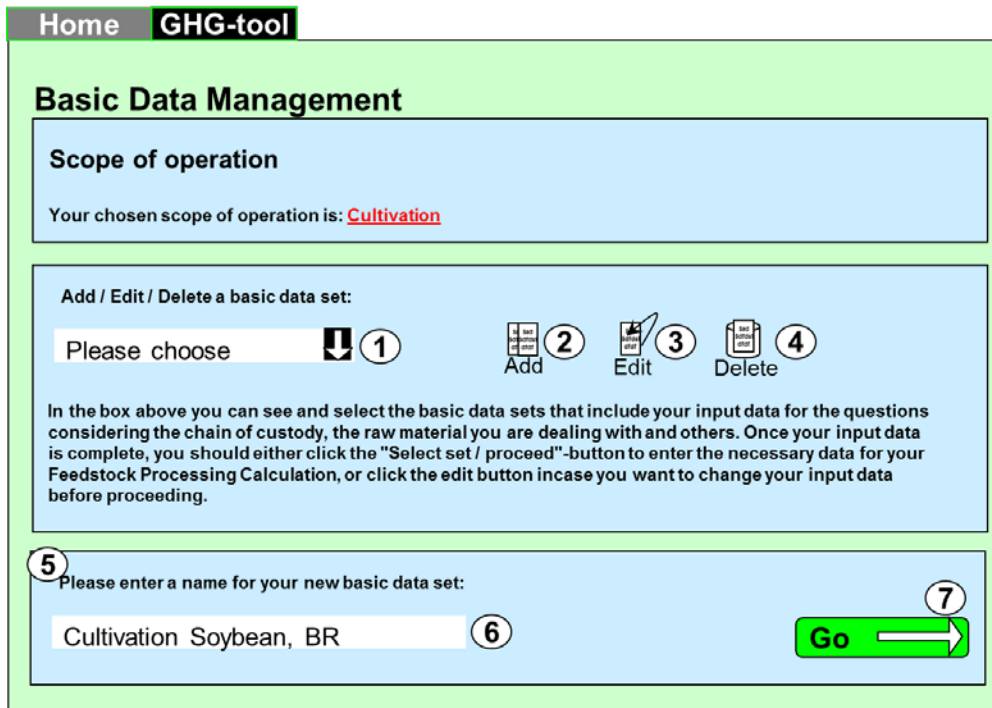


Figure 17. Basic data management (source: own depiction).

The page provides the following functionality:

1. Pull-down: If the operator wants to edit or delete an already created basic data set, he can select it here.
2. Add: Allows creating a new basic data set, i.e. fades-in context field 5.
3. Edit: Allows editing an existing basic data set, i.e. the one selected in 1.
4. Delete: Allows deleting an existing basic data set, i.e. the one selected in 1.
5. Context field: Is faded in if the operator presses “add”.
6. Name of basic data set: Allows the operator to specify any name for his new basic data set.
7. “Go” Button: Navigates to the next page.

If the operator adds or edits a basic data set, he is navigated to the basic data editing page (Figure 18).

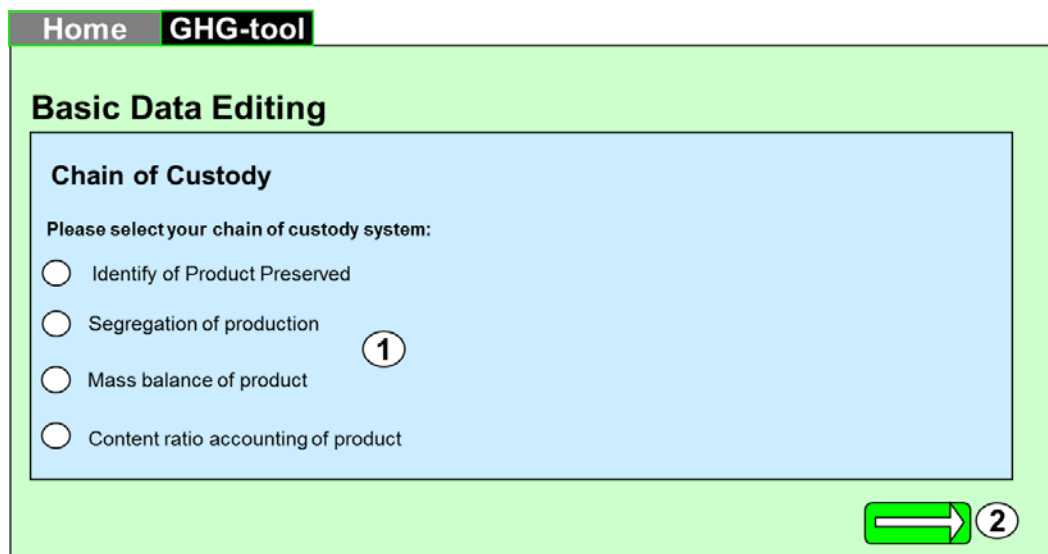


Figure 18. Basic Data Editing- Chain of Custody (source: own depiction).

The page provides the following functionality:

1. Radio buttons: Selection of Chain of Custody system. The selection is not related to any further functionality, i.e. it is the responsibility of the operator to enter his data according to the selected chain of custody system.
2. Button: Navigation to next page.

The next page allows the operator to specify his general operation information (Figure 19).

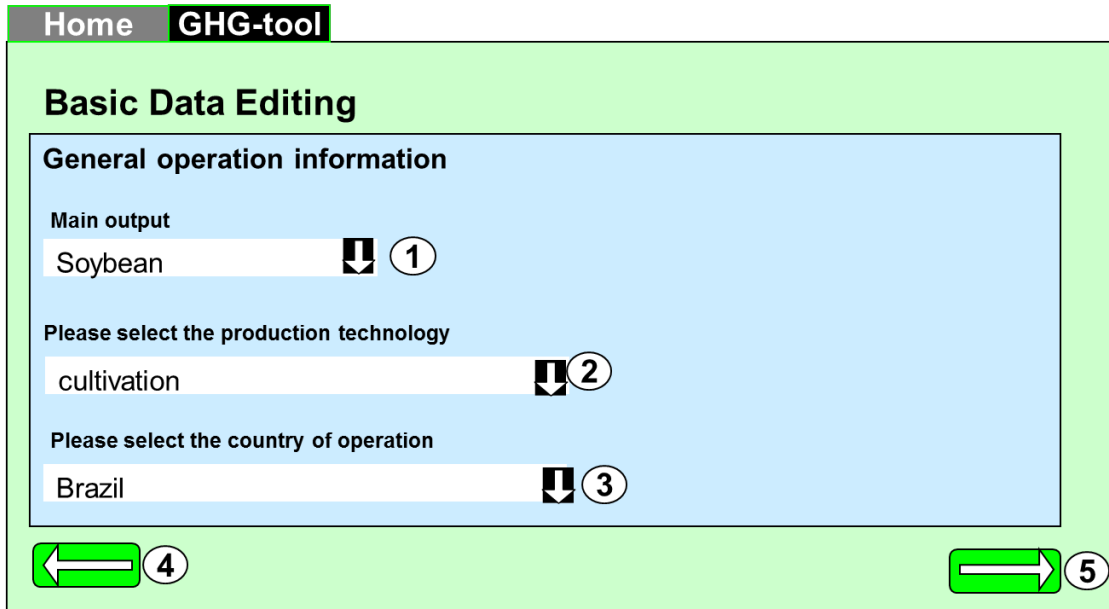


Figure 19. Basic Data Editing – General operation information (source: own depiction).

The sequence of the input fields refers to their dependencies, e.g. when a feedstock processor selects rape seed as an feedstock, the selection of the production technology is limited to the variants available (cold pressing or hexane extraction) and excludes impossible constellations (e.g. fermentation of rape seed). Both, i.e. main output and production technology, is required to distinctly define the archetype used later as shell for the population with life cycle inventory data.

The page provides the following functionality.

1. Pulldown: Selection of the main process output (see Table 4 for an excerpt of available main outputs).
2. Pulldown: Selection of production technology (Table 5).
3. Pulldown: Selection of the country of operation. The ecoinvent country list is used as basis for the selection.
4. Button: Allows the operator to navigate back to the Chain of Custody page.
5. Button: Allows the operator to navigate to the next page.

On the next page, the operator chooses the methods he wants to use to calculate GHG additionally to RSB methodology, i.e. RSB methodology is set mandatory (Figure 20).

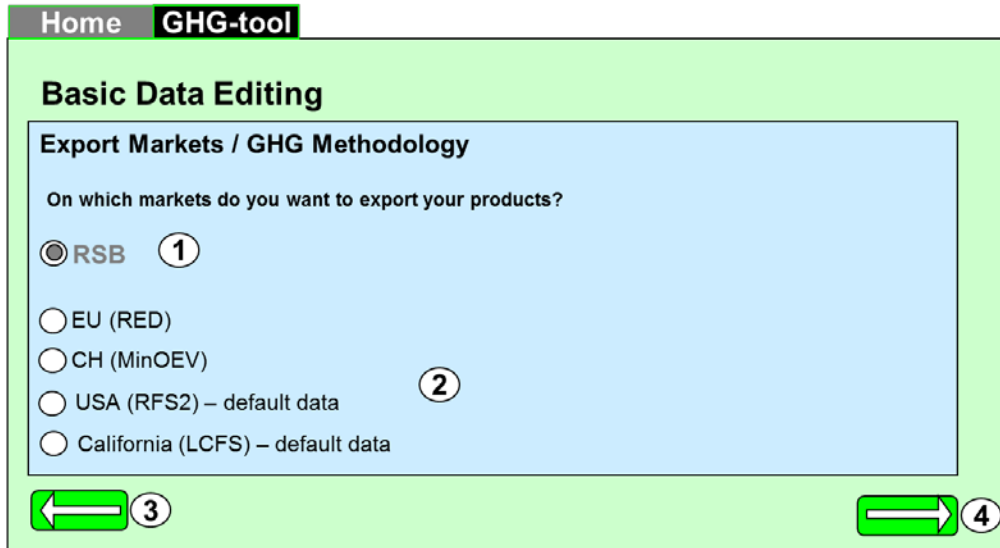


Figure 20. Basic Data Editing – Choice of calculation methodology (source: own depiction).

If the operator ticks the EU RED and/or the CH (MinÖV) methodologies, the calculations with these methods are performed additionally to the RSB method. If the user ticks the RFS2 or LCFS methodology, the default results for these methods will show in the results page. The page provides the following functionality.

1. Radio button: Cannot be adapted by the operator.
2. Radio buttons: The operator can select additional calculation methodologies optionally.
3. Button: Allows the operator to navigate back to the General operation information page.
4. Button: Allows the operator to navigate to the next page.

On the next page the operator can create and manage (edit, delete) modules for the prior specified basic data set (Figure 21).

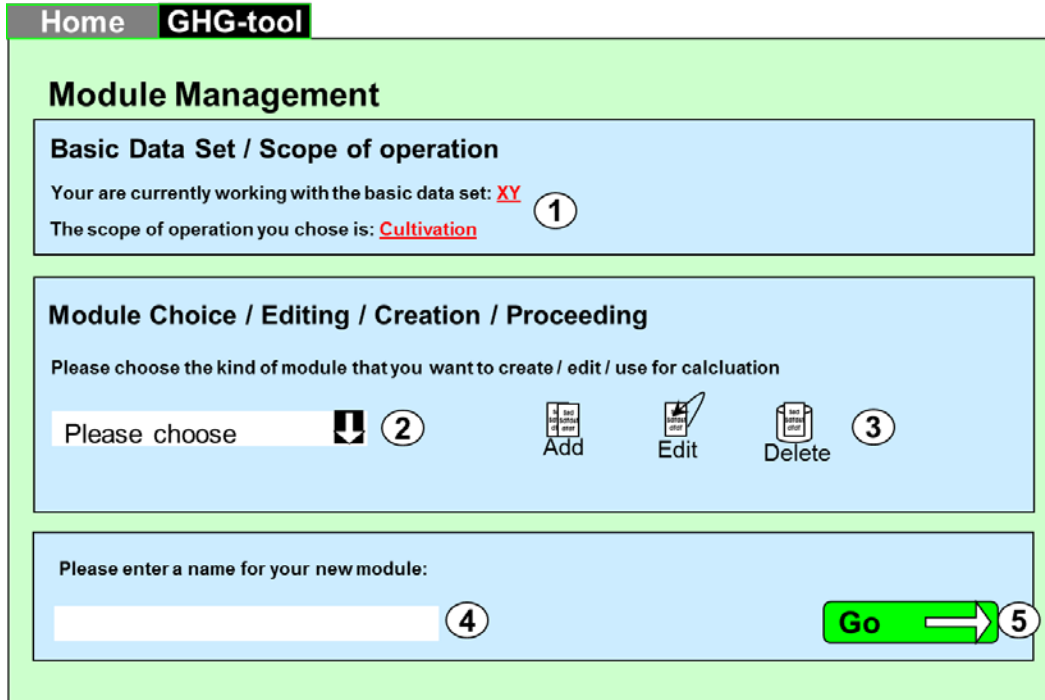


Figure 21. Module management – Module Choice / Editing / Creating (source: own depiction).

The page provides the following functionality:

1. It shows the scope of operation and the name of the created basic data set.
2. Pull-down: Allows the operator to select existing modules. The pull-down is empty if now module is available.
3. Manage modules: Allows the operator to add new modules and edit or delete existing modules, respectively.
4. Input field: Allows the operator to determine a name for a new module – only relevant if an new module is added.
5. Button: Allows the operator to navigate to the next page.

The next page informs the operator about his selected scope of operation and the steps required for data entry (Figure 22).

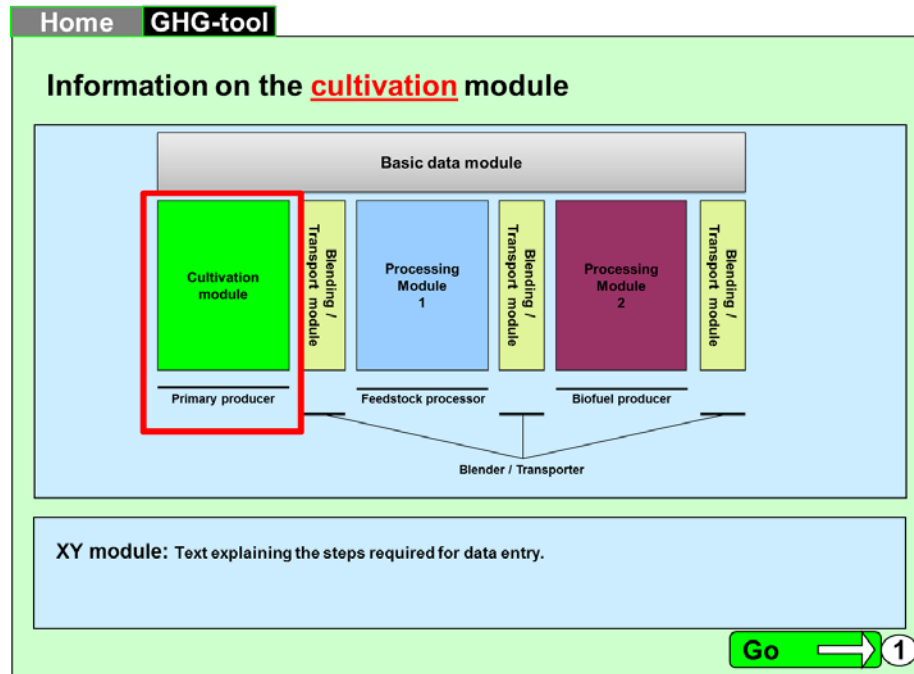


Figure 22. Information on the selected module (source: own depiction).

The page provides the following functionality:

1. Button: Allows the operator to navigate to the selected step in the pathway and start with the data entry.

4.1.3 Computation

It is the specification of main output and technology which allows the distinct identification of the relevant LCI under manipulation, while the definition of the relevant GHG methodologies allows the appropriate selection of questionnaire design and impact assessment methods.

In detail, the following computation is applied:

1. **Select** Process_ID_Ecoinvent from Table 4 (Relation Main output) where the output name entered by the operator matches the Process_ID_Ecoinvent.
2. **Select** all inventory flows from the LCI table. For each relevant Process_ID_Ecoinvent the LCI includes all LCI flows.
3. **Write** the selected LCI flows to Step N.

4.1.4 Tables

Table 3 to Table 5 show selected relations used in the context of the basic data module.

Table 3. Relation for Scope of operation.

Step_id	Step_name
1	cultivation
2	TransportBlending_Cultivation_to_Processing
3	Feedstock processor
4	TransportBlending_Processing_to_Processing
5	Biofuel producer
6	Transport_Processing_to_Final Transport
7	TransportBlending_Final

Table 4. Excerpt of the relation „Main output”.

Step_by_Step_id	Step_id	Process_id	Process_name	Country_ID	Process_ID_Ecoinvent	Output_id_1	Output_name_pulldown	Technology_ID	Factor_id
1	0	0	n.a.	n.a.	0	0	not specified	0	18
2	1	1	Rape seed cultivation	CH	1971	1	rape seed	10	4
3	1	2	Sunflower cultivation	RER	2801	2	sunflower seed	10	4
4	1	3	Soybean cultivation	US	32025	3	soybeans	10	4
5	1	4	Oil Palm cultivation	MY	33066	4	palm fruit bunches	10	6
6	1	5	Jatropha cultivation	IN	n.a.	5	jatropha seed	10	4
7	1	6	Wheat seed cultivation	CH	3672	6	wheat grains	10	4
8	1	7	Wheat straw cultivation	CH	1987	7	wheat straw	10	4
22	3	21	extraction, rape oil	RER	6813	21	rape oil	2	18
23	3	22	extraction, sunflower oil	RER	6813	22	sunflower oil	2	18
24	3	23	extraction, soybean oil	US	32027	23	soybean oil	2	18

Table 5. Relation for the selection of technology.

Technology_ID	Technology name
0	not relevant
1	cold pressing
2	solvent extraction
3	fermentation
4	fermetnation (BTL)
5	esterification
6	distillation
7	gasificaiton

For the detailed relations please see the Excel “Relations_MastersProject.”

4.2 Cultivation Module

The cultivation model asks for all data related to the production of the feedstock. Given the relevance of the cultivation for the total GHG intensity of a biofuel pathway it is not surprising that most of the questions of the questionnaire associated with this production step. Moreover, due to its direct exchange to nature most of the inventory models are associated with this production step.

In order to allow a structured data entry, the questions related to the cultivation are subdivided into 6 sections, i.e. context information, land use change, mechanical work, mineral fertilizer, organic fertilizer and pesticides. The specification is explained for each section separately. For the detailed computation of phos-

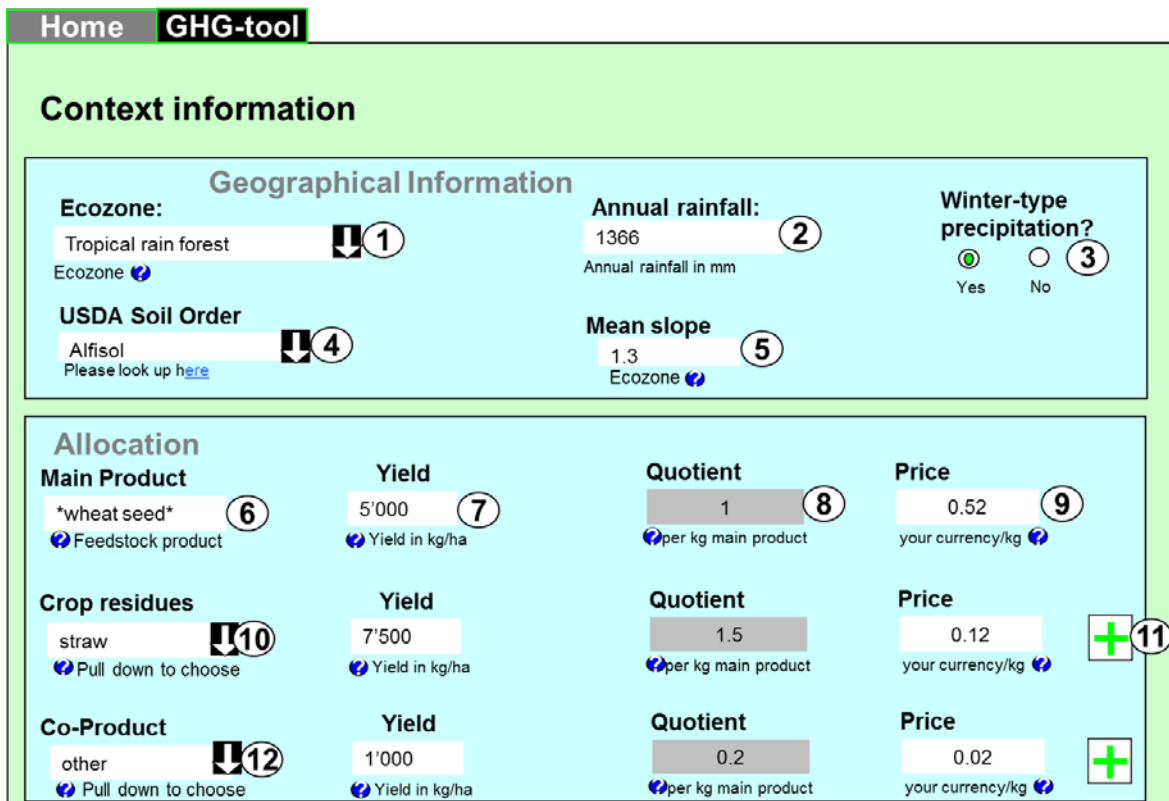
phorus, nitrate, ammonia, dinitrogen monoxide and further emissions such like heavy metals please refer to (Faist-Emmenegger, Reinhard et al. 2009).

4.2.1 Context information

The context information section determines the geographical and climatically context the crop is cultivated in. In addition, this section asks for the yield of the main crop and possible co-product in order to determine the allocation factors for the life cycle inventory (LCI-) flows.

4.2.1.1 Graphical representation

Figure 23 shows the graphical representation of the context information page.



Home **GHG-tool**

Context information

Geographical Information

Ecozone: Tropical rain forest ①
Ecozone

Annual rainfall: 1366 ②
Annual rainfall in mm

Winter-type precipitation? ☒ Yes ☐ No ③

USDA Soil Order: Alfisol ④
Please look up [here](#)

Mean slope: 1.3 ⑤
Ecozone

Allocation

	Yield	Quotient	Price
Main Product			
wheat seed ⑥ Feedstock product	5'000 ⑦ Yield in kg/ha	1 ⑧ per kg main product	0.52 ⑨ your currency/kg
Crop residues			
straw <input type="button" value="↓"/> ⑩ Pull down to choose	7'500 Yield in kg/ha	1.5 per kg main product	0.12 your currency/kg <input type="button" value="+"/> ⑪
Co-Product			
other <input type="button" value="↓"/> ⑫ Pull down to choose	1'000 Yield in kg/ha	0.2 per kg main product	0.02 your currency/kg <input type="button" value="+"/>

Figure 23. Concept showing the graphical implementation of the allocation box. Grey boxes cannot be manipulated by the user, whereas white boxes can be used for data entry.

The page provides the following functionality:

1. Ecozone: The operator has to select the ecozone where cultivation takes place. The available list is already limited on the basis of the selected country, i.e. only ecozones in a selected country are

available. Please refer to (Faist-Emmenegger, Reinhard et al. 2009), i.e. the SQCB background report, for the detailed specification.

2. Annual rainfall: The operator has to enter the annual rainfall. Please refer to (Faist-Emmenegger, Reinhard et al. 2009), i.e. the SQCB background report, for the detailed specification.
3. Winter-type precipitation: The operator has to check whether his climate refers to winter-type precipitation. Please refer to (Faist-Emmenegger, Reinhard et al. 2009), i.e. the SQCB background report, for the detailed specification.
4. USDA-Soil order: The operator has to select the USDA-soil order. Please refer to (Faist-Emmenegger, Reinhard et al. 2009), i.e. the SQCB background report, for the detailed specification.
5. Mean Slope: The operator has to enter the mean slope of his cultivation area. Please refer to (Faist-Emmenegger, Reinhard et al. 2009), i.e. the SQCB background report, for the detailed specification
6. Main product: The main product selected by the operator on the scope of operation page (see Figure 19).
7. Yield: The operator has to enter the yield of the main product in kg per hectare.
8. Quotient: Based on the yield for main and co-product, the quotient is calculated automatically in order to show the operator the ratio between the main and co-product.
9. Price: The operator has to enter the price per kg main product. The yield and price of the main and co-products is used for economic allocation.
10. Crop-Residues: The pulldown list for agricultural crop residues is generated on the basis of Table 6 by selecting all names referring to co-product category 1.
11. Plus-Button: Via the plus button the operator can add further Crop-Residues.
12. Co-Products: The pulldown list for other co-products, in turn, is generated by selecting all names referring to co-product category 2.

4.2.1.2 Computation

The geographical information is required as an input for the inventory modeling. For example, it is used as one important input for the modeling of emission from land use change (see 4.2.2 Land use change). Its detailed use of other inventory models such like the computation of phosphorus, nitrate, ammonia, dinitrogen monoxide and further emissions is explained in detail in (Faist-Emmenegger, Reinhard et al. 2009).

With regard to allocation, the quotients (grey boxes) of the co-products and agricultural crop residues are calculated automatically using Equation 1. The quotient of the main product is always one, i.e. one kg main product per kg main product.

Equation 1: Computation of the co-product product output per kg main product.

$$O_{Cp} = \frac{Y_{Cp}}{Y_{Mp}}$$

O_{Cp} = Output co-product in kg/kg main product;

Y_{Cp} = Yield co-product in kg. For each additional co-product equation (2) is applied.

Y_{Mp} = Yield of the main product in kg, is always set to 1 kg.

The values entered by the user are used to calculate the factors for the allocation of all Life Cycle Inventory (LCI) flows related to the cultivation. To calculate the allocation factors, the following procedure is applied¹.

1. **Select** the relevant allocation factor from table ‘SQCB_Allocation’ by comparing the ID of the main product with the ID of the allocation factor.
2. **Divide** all flows by the allocation factor relevant for the process (Recalculate the allocation applied in order to apply new allocation factors).
3. **Calculate** new allocation factors using the amount and the price or lower heating value (LHV) of the main and co-product(s).
4. **Multiply** all LCI flows values by the allocation factor applied for the main product (e.g. $1 \cdot 0.8 = 0.8$).

If only one co-product is produced with one unit of the main product, the formula to calculate the allocation factor of the main product is determined as shown in Equation 2.

¹ REMARK: In the RSB tool we use allocated LCIs. The first step of the following procedure excludes the allocation related to the LCI flows.

Equation 2: Calculation of the allocation factor of the main product.

$$Af_{Mp} = \frac{F_{Mp}}{F_{Mp} + F_{Cp}}$$

Af_{Mp} = Allocation factor main product; dimensionless.

F_{Mp} = Fraction main product; dimensionless.

F_{Cp} = Fraction co-product; dimensionless.

Equation 3: Calculation of the fraction of the main product.

$$F_{Mp} = A_{Mp} * X_{Mp}$$

A_{Mp} = Amount of the main product;

X_{Mp} = Price or LHV of the main product (depending on the respective calculation scheme;

Equation 4: Calculation of the allocation factor of the main product if more than one co-product is produced.

$$F_{Cp} = A_{Cp} * X_{Cp}$$

A_{Cp} = Amount of the co-product produced with one kg of the main product;

X_{Cp} = Price or LHV of the co-product.

However, if more than one co-product is produced with a unit of the main product the following formula should be applied.

Equation 5: Calculation of the fraction of the co-product.

$$Af_{Mp} = \frac{F_{Mp}}{F_{Mp} + \sum F_{Cp}}$$

After all data related to the agricultural step is processed and stored, all flows in the processing table have to be multiplied (except the output of the main product) with the calculated allocation factor of the main product.

4.2.1.3 Tables

Table 6. Co-product.

Co-product_ID	Category_ID	Name
1	1	straw
2	2	sweet sorgum stems
3	1	nut shells
4	1	bagasse
5	1	husks
6	1	cobs
7	1	others
8	2	others

Table 7. Co-product categorie.

Category_ID	Name
1	Agricultural crop residues
2	Other co-products

4.2.2 Land use change

In this section we specify the procedure to determine the emissions associated with possible land use changes, i.e. emissions associated with the transformation of the former land use at the reference date (01.01.2009) to the current land use.

4.2.2.1 Graphical representation

Figure 24 shows the concept for graphical implementation.

Home
GHG-tool

LUC – Former Land Use

Land use change

Land use at reference date
Grassland 1
Type of land use on the 1st of January 2009

Managed? 2
☒ Yes ☐ No

Acreage 3
100%
% of total acreage

Vegetation

Vegetation 4
Steppe/Tundra
Type of vegetation

Maturity 5
>20years
How old is the forest?

Canopy Cover 6
Broadleaf
Type of Canopy

Species Type 7
Broadleaf
Type of Species

Cultivation practice

Land use 8
Perennial/tree crop
Land use

Input: 9
Medium (Default)
Input

Tillage: 10
Low
Tillage

Fires

Was Fire used for land clearing? 11
☒ Yes ☐ No

What was burned? 12
Tropical rain forest
Type of vegetation burned

Subcategory 13
Primary open forest
Specify in detail from list.

Season 14
Early dry season
Specify in detail from list.

+ 15

Figure 24. Concept for the graphical representation of Land Use Change (source: own depiction).

First, data directly associated with the land use at reference date has to be entered.

1. Pull-down: The operator has to select the land use at reference data (see Table 15 for the pull down list).
2. Radio-button: The operator has to indicate if the land use at reference data was managed or not.
3. Input-field: The operator has to enter the percentage of land referring to the land use at reference data. Using the plus button (15), the operator can determine.

Next, the operator has to specify context information for the vegetation.

4. Pull-down: The operator has to select the vegetation type for the land use at reference date (see section Tables 4.2.2.3 for further details).
5. Pull-down: The operator has to select the maturity for the land use at reference date (see section Tables 4.2.2.3 for further details).

6. Pull-down: The operator has to select the canopy cover for the land use at reference date (see section Tables 4.2.2.3 for further details).
7. Pull-down: The operator has to select the species type for the land use at reference date (see section Tables 4.2.2.3 for further details).

Now, the cultivation practice has to be indicated.

8. Pull-down: The operator has to specify in more detail the land use at reference date (see section Tables 4.2.2.3 for further details).
9. Pull-down: The operator has to select the applied input (see section Tables 4.2.2.3 for further details).
10. Pull-down: The operator has to select the applied tillage for the land use at reference date (see section Tables 4.2.2.3 for further details).

Finally, the operator has to indicate if fires were used for the clearing of the land use at reference date.

11. Radio-button: The operator has to specify if fires were used for land clearing.
12. Pull-down: The operator has to specify in detail what was burned (see section Tables 4.2.2.3 for further details).
13. Pull-down: The operator has to specify in detail the subcategory (see section Tables 4.2.2.3 for further details).
14. Pull-down: The operator has to specify in detail the season of the fire (see section Tables 4.2.2.3 for further details).
15. Plus-button: Using the plus button he can determine not only one type of land use at the reference but represent mixes between different land use types. For example, 20% of the land use at the reference data might have been grassland, 70% cropland and 10% forest land. It is important to note, that if the user enter more than one land use at the reference date such as 50% grassland and 50% cropland all context boxes including the subsequent input fields are shown twice, i.e. once for the data related to grassland, once for the data related to cropland.

In order to enhance usability the inputs fields are dynamic meaning that they adapt in accordance with the already entered user data. This means only the input fields required are shown.

The interaction between the input fields is quite complex. Table 8 to Table 13 shows the dependencies using the concept of a decision table. For example, Table 8 shows for the selection of forest land that if the operator ticks “No” for both input field 2 and input field 11, only input field 5 and input field 6 are shown while all other input field are hidden.

Table 8. Decision table showing the interaction of the GUI if the land use at reference data is Forest land (source: own depiction).

DT: Land use = Forest Land	R1	R2	R3	R4
<i>Conditions</i>				
Input field 2 (Managed)	N	Y	Y	N
Input field 11 (Land clearing with fires?)	N	N	Y	Y
<i>Actions</i>				
Show input field 4 (Vegetation)				
Show input field 5 (Maturity)	x	x	x	x
Show input field 6 (Canopy Cover)	x			x
Show input field 7 (Species Type)		x	x	
Show input field 8 (Land use)		x	x	
Show input field 9 (Input)				
Show input field 10 (Tillage)				
Show input field 12 (What was burned)			x	x
Show input field 13 (Subcategory)			x	x
Show input field 14 (Season)				

Table 9. Decision table showing the interaction of the GUI if the land use at reference data is Grassland (source: own depiction). Non sequitur combinations are not shown.

DT: Land use = Grassland	R1	R2	R3	R4	R5
<i>Conditions</i>					
Input field 2 (Managed)	N	Y	Y	N	N
Input field 11 (Land clearing with fires?)	N	N	Y	Y	Y
What was burned = Savanna woodland / Savanna Grassland	N	N	Y	Y	N
<i>Actions</i>					
Show input field 4 (Vegetation)	x	x	x	x	x
Show input field 5 (Maturity)					
Show input field 6 (Canopy Cover)					
Show input field 7 (Species Type)					
Show input field 8 (Land use)		x	x		
Show input field 9 (Input)		x	x		
Show input field 10 (Tillage)					
Show input field 12 (What was burned)			x	x	x
Show input field 13 (Subcategory)			x	x	x
Show input field 14 (Season)			x	x	

Table 10. Decision table showing the interaction of the GUI if the land use at reference data is Cropland (source: own depiction).

DT: Land use = Cropland	R1	R2	R3	R4
<i>Conditions</i>				
Input field 2 (Managed)	N	Y	Y	N
Input field 11 (Land clearing with fires?)	N	N	Y	Y
<i>Actions</i>				
Show input field 4 (Vegetation)		x	x	
Show input field 5 (Maturity)				
Show input field 6 (Canopy Cover)				
Show input field 7 (Species Type)				
Show input field 8 (Land use)		x	x	
Show input field 9 (Input)		x	x	
Show input field 10 (Tillage)		x	x	
Show input field 12 (What was burned)			x	x
Show input field 13 (Subcategory)			x	x
Show input field 14 (Season)				

Table 11. Decision table showing the interaction of the GUI if the land use at reference data is Wetlands (source: own depiction).

DT: Land use = Wetlands	R1	R2	R3	R4
<i>Conditions</i>				
Input field 2 (Managed)	N	Y	Y	N
Input field 11 (Land clearing with fires?)	N	N	Y	Y
<i>Actions</i>				
Show input field 4 (Vegetation)				
Show input field 5 (Maturity)				
Show input field 6 (Canopy Cover)				
Show input field 7 (Species Type)				
Show input field 8 (Land use)		x	x	
Show input field 9 (Input)		x	x	
Show input field 10 (Tillage)		x	x	
Show input field 12 (What was burned)			x	x
Show input field 13 (Subcategory)			x	x
Show input field 14 (Season)				

Table 12. Decision table showing the interaction of the GUI if the land use at reference data is Settlement (source: own depiction).

DT: Land use = Settlement	R1	R2	R3	R4
<i>Conditions</i>				
Input field 2 (Managed)	N	Y	Y	N
Input field 11 (Land clearing with fires?)	N	N	Y	Y
<i>Actions</i>				
Show input field 4 (Vegetation)				
Show input field 5 (Maturity)				
Show input field 6 (Canopy Cover)				
Show input field 7 (Species Type)				
Show input field 8 (Land use)				
Show input field 9 (Input)				
Show input field 10 (Tillage)				
Show input field 12 (What was burned)				
Show input field 13 (Subcategory)				
Show input field 14 (Season)				

Table 13. Decision table showing the interaction of the GUI if the land use at reference data is Other land (source: own depiction).

DT: Land use = Other Land	R1	R2	R3	R4
<i>Conditions</i>				
Input field 2 (Managed)	N	Y	Y	N
Input field 11 (Land clearing with fires?)	N	N	Y	Y
<i>Actions</i>				
Show input field 4 (Vegetation)				
Show input field 5 (Maturity)				
Show input field 6 (Canopy Cover)				
Show input field 7 (Species Type)				
Show input field 8 (Land use)		x	x	
Show input field 9 (Input)		x	x	
Show input field 10 (Tillage)		x	x	
Show input field 12 (What was burned)			x	x
Show input field 13 (Subcategory)			x	x
Show input field 14 (Season)				

Based on this input, the fraction of the above ground biomass burned and the associated emissions can be determined. Figure 25 shows the continuation of the Land Use Change page.

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LUC – Current Land Use

Soil Information

Soil type?

☒ mineral
☐ organic

1

Mineral

WRB Soil Classification

Alfisol

2

Please look up [here](#)

Organic

Peat land

3

Please look up [here](#)

Cultivation practice – on current land use

Input:

Medium (Default)

4

Please look up [here](#)

Tillage:

Low

5

Tillage

Tillage method:

Mulch tillage

6

Tillage method

Anti-erosion practice

Cross slope

7

Anti-erosion practice

Annual irrigation:

8

Please look up [here](#)

Conventional drainage?

☒ Yes ☐ No

9

Apply
10

Figure 25. Concept for the graphical representation of Land Use Change (continuation) (source: own depiction).

First the operator has to specify the soil information.

1. Radio-button: A soil is either a mineral or an organic soil. This means, if the soil type is mineral, the input field for organic is not shown and vice versa. Table 14 shows the interaction.
2. Pull-down: If the soil type is mineral, the operator has to select the soil classification according to WRB (see Table 16 for the pull down list).
3. Pull-down: If the soil type is organic, the operator has to classify the organic soil.

Table 14. Decision table showing the interaction of the GUI in dependence on the selected soil type (source: own depiction).

DT: Land use = Other Land	R1	R2
Conditions		
Input field 1 (Soil type = mineral)	Y	N
Actions		
Show input field 2 (Mineral)	X	
Show input field 3 (Organic)		X

Subsequently, the operator has to specify the cultivation practice of the current land use

4. Pull-down: The operator has to select the applied input (see section Tables 4.2.2.3 for further details).
5. Pull-down: The operator has to select the applied tillage for the current land use (see section Tables 4.2.2.3 for further details).
6. Pull-down: The operator has to select the detailed tillage method (see section Tables 4.2.2.3 for further details).
7. Pull-down: The operator has to select from possible anti erosion practices (see section Tables 4.2.2.3 for further details).
8. Pull-down: The operator has to enter the amount of annual irrigation in m³ per year.
9. Pull-down: The operator has to indicate if conventional drainage is applied.

All of this information is required as a basis to determine the leaching of nitrate (which indirectly affects N₂O – emissions) and the emissions associated with changes in soil organic carbon induced by the land use change. In this context the tool also requires the cultivation practice of the current land use.

After all information was entered the computation can be executed by the operator. The results for selected parameters are directly shown to the operator using the following graphical representation (Figure 26).

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LUC – Results

Land use state at reference date

Above Ground Biomass 128 In tons C per ha-1	Below Ground Biomass 24 In tons C per ha-1	Dead organic matter 1 In tons C per ha-1
Share Burned 0.4 Ratio of AGB and DOM burned		
Mineral soil – natural 64 In tons C per ha-1	Mineral soil - reference 64 In tons C per ha-1	Organic soil - emission 0 In tons C per ha-1y-1

Projected land use state

Above Ground Biomass 0 In tons C per ha-1	Below Ground Biomass 0 In tons C per ha-1	Dead organic matter 0 In tons C per ha-1
Gains 4 In tons C per ha-1y-1	Losses 4 In tons C per ha-1y-1	SOC - biofuel 23 In tons C per ha-1y-1

Change
Accept

Figure 26. Concept for showing the results associated with the land use change (source: own depiction).

In order to proceed, the operation can press the accept button. To enter own data / adapt the shown data the operator can change the calculated data.

The operator can't change all input fields. If the soil is a mineral soil, the operator cannot enter data for organic soil emissions. If the soil type is an organic soil, the operator can't enter data for the different mineral soil states. The results associated with AGB, BGB and DOM of the projected land use cannot be changed, i.e. they are always zero. They are only shown to underline this assumption. The possible re-growth of biomass during the cultivation of the projected land use can be determined by adapting gains and losses accordingly.

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LUC – Results

Land use state at reference date

Above Ground Biomass
128
In tons C per ha-1

1

Below Ground Biomass
24
In tons C per ha-1

2

Dead organic matter
1
In tons C per ha-1

3

Share Burned
0.4
Ratio of AGB and DOM burned

4

Mineral soil – natural
64
In tons C per ha-1

5

Mineral soil - reference
64
In tons C per ha-1

6

Organic soil - emission
0
In tons C per ha-1y-1

Projected land use state

Above Ground Biomass
0
In tons C per ha-1

Below Ground Biomass
0
In tons C per ha-1

Dead organic matter
0
In tons C per ha-1

Gains
4
In tons C per ha-1y-1

8

Losses
4
In tons C per ha-1y-1

9

SOC - biofuel
23
In tons C per ha-1y-1

10

Accept

Figure 27. Concept for changing the results associated with the land use change (source: own depiction).

The matching of the input fields with the calculated values is explained in the following. For the context box “Land use state at reference date” the input fields refer to:

1. $AGB = AGB_{Total}$, see Equation 6.
2. $BGB = BGB_{Total}$ see Equation 6.
3. $DOM = DOM_{Total}$ see Equation 6.
4. Share burned = Combustion factor (CF), see Equation 7 and Equation 8.
5. Mineral soil - natural = $SOC_{(0-T)}$ in Equation 13.
6. Mineral soil - reference = $SOC_{0\text{ projected } - \text{ nochange}}$ in Equation 13.
7. Organic soil – emissions = $L_{Organic}$ in Equation 12.

For the context box “Projected land use – state at the end of the inventory period” the input fields refer to:

8. AGB = AGBNet in Equation 9
9. BGB = BGBNet in Equation 9
10. SOC – biofuel = $SOC_{0projected - biofuel}$ in Equation 13 (only when soil = mineral soil) otherwise = zero.

Any changes done by the user are incorporated into the mentioned equations. Subsequently the GWP from land use change is calculated with the adapted values using the detailed framework elaborated in the following.

4.2.2.2 Computation

In the following, the computation is explained in detailed; structured into the calculation of emissions associated with (i) ΔC_B , and L_{fire} which includes the emissions from above ground biomass (AGB), below ground biomass (BGB), foregone sequestration, dead organic matter (DOM) and fires and (ii) ΔC_{SOILS} , i.e. losses in soil organic carbon.

Figure 28 shows the tables and input boxes required for the computation of (i).

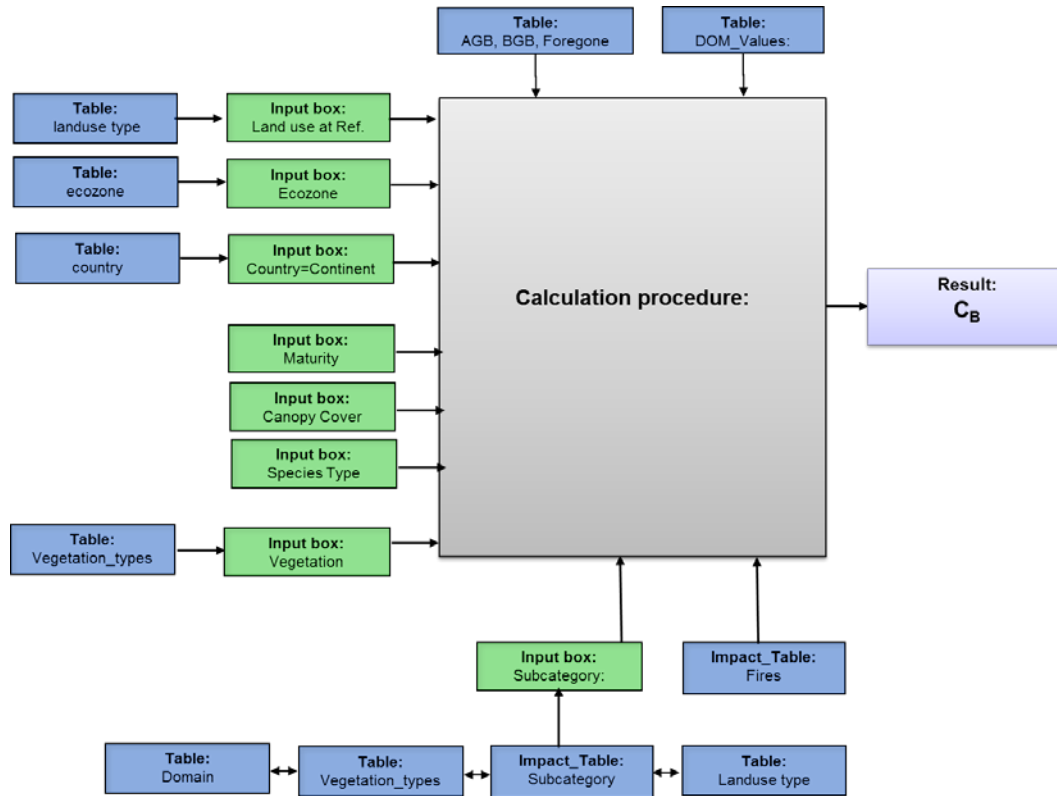


Figure 28. Directly required tables, input boxes and conditions for the calculation of Above and Below Ground Bio-mass (AGB & BGB), Foregone sequestration, Dead organic matter (DOM) and Fires.

The calculation procedure can be described as follows. The tables and selections required for each step are described in the respective equation.

Calculation associated with the land use at the reference date:

1. **Select** the value for AGB_{Total} from table “Table_AGB_BGB_Foregone” and **assign** it to Equation 6 and Equation 8. If no value is available set AGB_{Total} to zero.
2. **Select** the value for BGB_{Total} from table “Table_AGB_BGB_Foregone” and **assign** it to Equation 6 and Equation 8.. If no value is available set BGB_{Total} to zero.
3. **Select** the value for DOM_{Total} from table “Table_DOM_values” and **assign** it to Equation 6 and Equation 8. .If no value is available set DOM_{Total} . to zero.
4. **If** “no” is selected for land clearing with fires.
 - a. **Set** B_{fire} (Equation 6) and L_{fire} (Equation 16) to zero and proceed with point 5.

5. **Otherwise** (i.e. “yes” is selected for land clearing with fires):

- b. **Select** the fraction of the biomass burned (C_f) from Table_Subcategory and **assign** it to Equation 8
- c. **Select** the emissions factors (G_{ef}) of fires from the table “Impact_Table_Fires” and **assign** it to Equation 8.
- d. **Select** the impact factor of the respective greenhouse gas (I_f) and **assign** it to Equation 8.
- e. **Calculate** the GHG emissions associated with the fraction of the AGB and DOM burned. Use Equation 8.
- f. **Save** the calculated GHG emission as L_{fire} and assign it to Equation 16.
- g. **Calculate** B_{fire} , i.e. the amount of carbon in biomass burned. Use Equation 7. **Assign** the result to B_{fire} in Equation 6.

6. **Select** the avoided carbon accumulation (foregone sequestration) from table “Table_AGB_BGB_Foregone” and assign it to $C_{Foregone}$ in Equation 6.

Calculation associated with the projected land use

7. **Select** the value for AGB_{Total} from table “Table_AGB_BGB_Foregone” and **assign** it to Equation 9. If no value is available set AGB_{Total} to zero.
8. **Select** the value for BGB_{Total} from table “Table_AGB_BGB_Foregone” and **assign** it to Equation 9. If no value is available set AGB_{Total} to zero.
9. **Calculate** the net carbon accumulation of the projected land use, i.e. C_{G_n} with Equation 9 and **assign** the result to C_{G_n} in Equation 6.
10. **Calculate** GHG emissions associated with the loss in biomass (ΔC_B) with Equation 6. **Assign** the results to ΔC_B in Equation 16

Equation 6. Calculation of greenhouse gas emissions from biomass (source: adapted from (IPCC 2006), p. 2.20.)

$$\Delta C_B = \left[\left[AGB_{Total} + BGB_{Total} + DOM_{Total} + C_{Foregone} \right] - B_{fire} \right] - \left[C_{G_n} \right]$$

Where:



ΔC_B = change in carbon stocks in biomass on land converted to other land-use category, in tonnes C per year.

AGB_{Total} = total carbon content of AGB per ha-1 in tons C. Determine AGB value of the former land use from table “Table_AGB_BGB_Foregone” using the land use at ref. date, the ecozone, the LUC classification (which is determined by the relationship between the country of operation and the continent, and the continent and the LUC classification) and depending on the land use selected, the age (maturity for forests) or the vegetation (for grasslands). If no AGB is found set AGB to zero.

BGB_{Total} = total carbon content of below ground biomass (BGB) per ha-1 in tons C. Determine BGB value of the former land use from table “Table_AGB_BGB_Foregone” using the land use at ref. date, the ecozone, the LUC classification (which is determined by the relationship between the country of operation and the continent, and the continent and the LUC classification) and depending on the land use selected, the age (maturity for forests) or the vegetation (for grasslands). If NO BGB is found set it to zero.

DOM_{Total} = total carbon content of dead organic matter (DOM) per ha-1 in tons C. If the former land use was forest land, determine the DOM value from the table “DOM_values”. Use the following input fields for a distinct identification of the DOM value: ecozone and DOM types. If the former land use was not forest land, excluded DOM_{Total} . If NO DOM is found set it to zero.

$C_{Foregone}$ = annual carbon sequestration avoided by the land use change, i.e. foregone sequestration in tonnes C ha-1. Use the ecozone, the age and the LUC classification to select the respective value from the table “Table_AGB_BGB_Foregone”. If NO Foregone is found set it to zero.

B_{fire} = biomass carbon losses due to fire in tonnes C per ha-1. Use Equation 7.

C_{Gn} = mean net increase in biomass carbon stocks due to biomass growth by vegetation type and climatic zone, tonne C per ha-1.

Equation 7. Calculation of carbon losses induced by fires (source: adapted from IPCC (2006).

$$B_{fire} = [AGB_{Total} * C_f] + [DOM_{Total} * C_f]$$

Equation 8. Calculation of greenhouse gas emissions from fire (source: adapted from IPCC (2006).

$$L_{fire} = \sum_i If_i * [(AGB_{Total} + DOM_{Total}) * C_f] * (G_{ef} * 10^{-3})_i$$

Where:

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of all GHG in kg CO₂ equiv. per ha-1;

If = impact factor of the fuel in terms of CO₂ equiv.; Use the domain and the land use type for the distinct identification of the impact factor (If) of fires from the table “Impact_Table_Fires”.

AGB_{Total} = carbon content of above ground biomass

DOM_{Total} = carbon content of dead organic matter;

C_f = combustion factor; use the vegetation_type and the subcategory to determine the fraction of the AGB burned (Cf) from the table “Subcategory has vegetation”, e.g. 0.43 for crown fire in boreal forests.

G_{ef} = emission factor, g per kg-1 dry matter burnt; Use the domain and the land use type for the distinct identification of the emissions factors (Gef) of fires from the table “Impact_Table_Fires”.

i = the respective greenhouse gas, e.g. methane.

The calculation in the brackets is done for each GHG separately, e.g., CH₄, N₂O, etc.

Equation 9. Annual net increase in biomass carbon stocks due to biomass increment in the projected land use (source: adapted from (IPCC 2006)).

$$C_{Gn} = AGB_{Net} + BGB_{Net}$$

C_{Gn} = mean net increase in biomass carbon stocks due to biomass growth by vegetation type and climatic zone, tonne C per ha-1.

AGB_{Net} = carbon content of above ground biomass. For the mean net AGB carbon accumulation of sugarcane, miscanthus, generic or specific perennial crops use the default values given in “Table_AGB_BGB_Foregone”.

BGB_{Net} = carbon content of above ground biomass. For the mean net BGB carbon accumulation of sugarcane, miscanthus, generic or specific perennial crops use the default values given in “Table_AGB_BGB_Foregone”.

Equation 10. Annual gross increase in biomass carbon stocks due to biomass increment in the projected land use (source: adapted from (IPCC 2006)).

$$C_{GTotal} = C_{Gn} + C_L$$

Where:

C_{GTotal} = mean gross increase in biomass carbon stocks due to biomass growth over the given accounting period, tonne C per ha-1. For annual crops C_{GTotal} is assumed to be equal to C_L , i.e. C_{Gn} , the net increase in biomass carbon stocks is zero.

C_{Gn} = mean net increase in biomass carbon stocks due to biomass growth by vegetation type and climatic zone, tonne C per ha-1.

C_L = biomass carbon loss due to biofuel harvest over the assessed time period, tonne carbon ha-1 over the accounting period.

Equation 11: Annual carbon loss in biomass of biofuel removals (source: adapted from (IPCC 2006), p. 2.15).

$$C_L = t(Y_{Biofuel} * CF)$$

Where:

$L_{biofuel}$ = annual biomass carbon loss due to biofuel harvest, tonnes carbon.

$Y_{Biofuel}$ = yield of the biofuel harvested, tonnes d. m. ha-1 yr-1. Use the yield entered by the operator.

CF = carbon fraction of dry matter, tonne C per tonne d.m.. Use the crop_id and the croptype_id related to the crop selected by the operator to select the crop specific carbon fraction from table “RSB_crop”.

t = time, use 20 years as default.

Figure 29 shows the tables and inputs field required for the calculation of emissions from losses in soil organic carbon, i.e. C_{SOILS} .

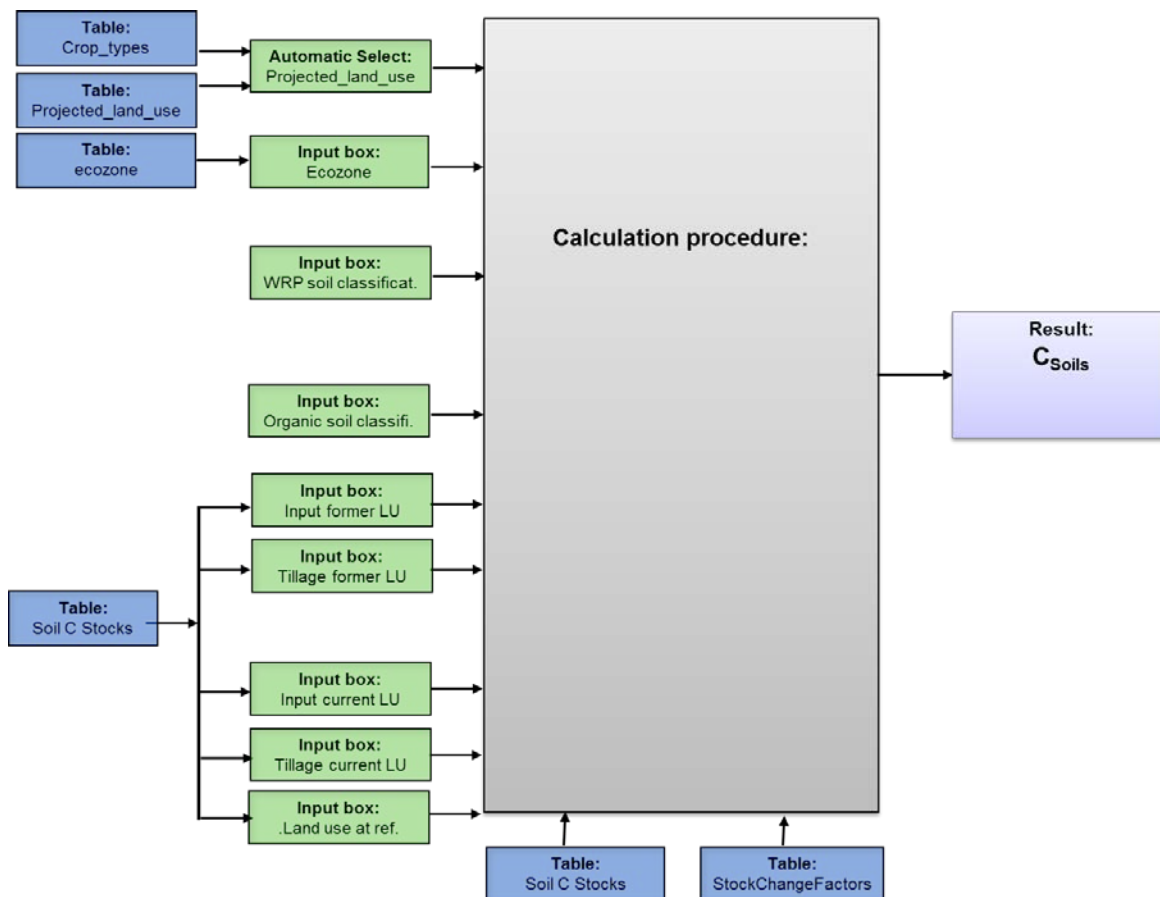


Figure 29. Directly required tables, input boxes, conditions and automatic selections for the determination of the losses in soil organic carbon.

The calculation procedure can be described as follows:

1. **Check** the soil type entered by the user, i.e. mineral or organic.
2. **If** the soil is a mineral soil apply the following procedure:

- a. **Select** the value for the soil organic reference carbon stock from table “Table_Soil_C_Stocks” and **assign** it to (both) $SOC_{(0-T)}$ in Equation 13.
- i. **If** the operator selected “yes” for managed **and** the land use at reference date is forest land, grassland or cropland.
1. **Select** the value for the land use at ref. date from table “Table_LU_Change_Terms” and **assign** it to $F_{LU_{c,s,i}}$ in Equation 13.
 2. **Select** the value for the input of the former land use from table “Table_LU_Change_Terms” and **assign** it to $F_{I_{c,s,i}}$ in Equation 13.
 3. **Select** the value for the tillage of former land use from table “Table_LU_Change_Terms” and **assign** it to $F_{MG_{s,s,i}}$ in Equation 13.
 4. **Multiply** the reference carbon stock with the factor for the projected land use, the input and the tillage, i.e. apply Equation 13. Assign the result to $SOC_{0projected_nochange}$ in Equation 13.
- ii. **Otherwise** (the operator selected “no” for managed) **or** the land use at reference date is other land, wetland.
1. **Set** $SOC_{0projected_nochange} = SOC_{(0-T)}$
- b. **Select** the value for the projected land use from table “Table_LU_Change_Terms” and **assign** it to $F_{LU_{c,s,i}}$ in Equation 13.
- c. **Select** the value for the input of the projected land use from table “Table_LU_Change_Terms” and **assign** it to $F_{I_{c,s,i}}$ in Equation 13.
- d. **Select** the value for the tillage of projected land use from table “Table_LU_Change_Terms” and **assign** it to $F_{MG_{s,s,i}}$ in Equation 13.
- e. **Multiply** the reference carbon stock with the factor for the projected land use, input and the tillage, i.e. apply Equation 13. Assign the result to $SOC_{0projected_biofuel}$ in Equation 13.



- f. **Calculate** $\Delta C_{Mineral}$ (Equation 13) and **assign** the result to $\Delta C_{Mineral}$ in Equation 12 and Equation 14.
 - g. **If** the land use at ref. date was grassland or forest land
 - i. **Set** R (Equation 14) to 15.
 - h. **Otherwise**
 - i. **Set** R (Equation 14) to 10.
 - i. **Calculate** $SOC_{N_2O_mineral}$ (Equation 14) and **assign** the result to $SOC_{N_2O_mineral}$ in Equation 12.
3. **Otherwise** (i.e. the soil is organic), apply the following procedure.
- a. **Select** the value for the soil organic reference carbon stock from table “Table_Soil_C_Stocks” and **assign** it to $L_{Organic}$ in Equation 12 (the selected value should be 469).
 - b. **Select** value for EF2 and assign it to Equation 15.
 - c. **Calculate** $L_{N_2O_organic}$ (Equation 15) and assign it to $L_{N_2O_organic}$ in Equation 12.
4. **Calculate** ΔC_{Soils} (Equation 12) and assign the result to ΔC_{Soils} in Equation 16.

Equation 12. Annual change in carbon stocks in soil organic carbon (source: adapted from IPCC (2006)).

$$C_{Soils} = \left[\Delta C_{Mineral} + L_{N_2O_mineral} - (L_{Organic} + L_{N_2O_organic}) \right]$$

Where

C_{Soils} = change in carbon stocks in soils, tonnes C per ha-1 in 30 cm depth.

$\Delta C_{Mineral}$ = change in organic carbon stocks in mineral soils, tonnes C per ha-1, use Equation 13.

$L_{N_2O_mineral}$ = loss of carbon stemming from N₂O emission, in tons C per ha-1, use Equation 14.

$L_{Organic}$ = annual loss of carbon stocks from drained organic soils, tonnes C per ha-1 yr-1. Use the Ecozone, the Land use, the Soil type and the soil characteristic to determine $L_{Organic}$ from table “SoilC_Stocks”.

$L_{N_2O_organic}$ = annual loss of N₂O emission expressed in tonnes C per ha-1 yr-1, use Equation 15.

Equation 13. Annual change in organic carbon stocks in mineral soils (source: adapted from IPCC (2006)).

$$\Delta C_{Mineral} = \left[(SOC_{(0-T)} - SOC_{0\ projected_nochange}) - (SOC_{(0-T)} - SOC_{0\ projected_biofuel}) \right]$$

$$SOC = SOC_{REF_{c,s,i}} * F_{LU_{c,s,i}} * F_{MG_{s,s,i}} * F_{I_{c,s,i}}$$

Where:

$\Delta C_{Mineral}$ = annual change in carbon stocks in mineral soils, tonnes C.

$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time period, tonnes C ha-1.
Use the ecozone, the land use, the soil type and the soil characteristic to determine $SOC_{(0-T)}$ from table “SoilC_Stocks”.

SOC_0 = soil organic carbon stock in the last year of the time period, tonnes C ha-1.

$SOC_{0\ projected_unchanged}$ = soil organic carbon stock in the last year of the time period in tonnes C ha-1, if no land use change would have occurred (Note: equivalent to $SOC_{REF_{c,s,i}}$ if the reference land use is Forest land).

$SOC_{0\ projected_biofuel}$ = soil organic carbon stock in the last year of the time period in tonnes C ha-1, if the land use change to the biofuel system has occurred.

c = represents the climate zones, s the soil types, and i the set of management systems that are present.

$SOC_{REF_{c,s,i}}$ = the reference soil organic carbon stock, tonnes C ha-1, i.e. equivalent to $SOC_{(0-T)}$.

$F_{LU_{c,s,i}}$ = stock change factor for land-use systems or sub-system for a particular land-use, dimensionless. Use the Land use, the ecozone, the influence factor and the soil factor to determine $F_{LU_{c,s,i}}$ from table „Table_LU_Change_Terms”

$F_{MG_{s,i}}$ = stock change factor for management regime, dimensionless. Use the Land use, the ecozone, the influence factor and the soil factor to determine $F_{MG_{s,i}}$ from table „Table_LU_Change_Terms“.

$F_{I_{c,s,i}}$ = stock change factor for input of organic matter, dimensionless. Use the Land use, the ecozone, the influence factor and the soil factor to determine $F_{I_{c,s,i}}$ from table „Table_LU_Change_Terms“.

Equation 14. Carbon emissions associated with N mineralised in mineral soils as a results of loss of soil c through change in lad use or management (source: adapted from (IPCC 2007).

$$SOC_{N_2O_mineral} = \frac{If * \left[Ef1 * \left(\Delta C_{Mineral} * \frac{1}{R} \right) \right]}{\left(\frac{44}{12} \right)}$$

Where:

$SOC_{N_2O_mineral}$ = N₂O emission expressed in tons C per ha-1.

If = impact factor of N₂O in terms of CO₂ equiv., use 298 as a default (Goedkoop, Heijungs et al. 2009).

$Ef1$ = emission factor N mineralised from mineral soil as a result of loss of soil carbon in kg N₂O–N (kg N)–1. Use 0.01 as default.

$\Delta C_{Mineral}$ = annual change in carbon stocks in mineral soils, tonnes C. Use $\Delta C_{Mineral}$ from Equation 13.

R = C:N ratio of the soil organic matter. Determine R according to the land use at ref. date. If land use at ref. was forest or grassland set R =15, otherwise set R = 10.

$\frac{44}{12}$ = transformation factor from CO₂ to C.

Equation 15. Carbon emissions associated with N emitted by organic soils (source: adapted from (IPCC 2007).



$$L_{N_2O_organic} = \frac{If * \left(Ef2 * \frac{44}{28} \right)}{\left(\frac{44}{12} \right)}$$

Where:

$L_{N_2O_organic}$ = N₂O emission expressed in tons C per ha-1 y-1.

If = impact factor of N₂O in terms of CO₂ equiv., use 298 as a default (Goedkoop, Heijungs et al. 2009).

$Ef2$ = emission factor for N emitted by managed organic soils, in kg N₂O-N (kg N)⁻¹. Use the ecozone and the projected land use to determine $Ef2$ from table “Ef2”.

$\frac{44}{28}$ = transformation factor from N to N₂O.

The calculation procedure for the final computation can be described as follows:

1. **Select** the annual yield entered by the operator and **assign** it to Y_{PLUC} in Equation 16.
2. **Set** t (Equation 16) to 20.
3. **Calculate** Equation 16 and **write** the result to the life cycle inventory of the crop cultivated.

Equation 16. Equation for the computation of the annual CO₂ emissions from LUC in g CO₂ per kg crop (source: adapted from (IPCC 2007)).

$$\Delta CO_{2LUC_kgcrop} = \left[\frac{\left\{ (\Delta C_B + C_{SOILS}) * \left(\frac{44}{12} \right) * 1000 \right\} + L_{fire}}{(Y_{PLUC} * t)} \right] * 1000$$

Where

ΔCO_{2LUC_kgcrop} = annual CO₂ emissions from LUC in **g CO₂ per kg crop** at farm gate.



ΔC_B = change in carbon stocks in biomass on land converted to other land-use category, in tonnes C ha⁻¹ (use Equation 6 to determine ΔC_B).

C_{SOILS} = change in carbon stock in soil organic carbon, in tonnes C ha⁻¹.

$\left(\frac{44}{12}\right)$ = Transformation of carbon to CO₂.

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of all GHG in kg CO₂ equiv. ha⁻¹ (see).

Y_{PLUC} = annual yield of the projected land use, in kg ha⁻¹.

t = 20 years

4.2.2.3 Tables

Figure 30 shows the ERM-model for the whole land use change section.

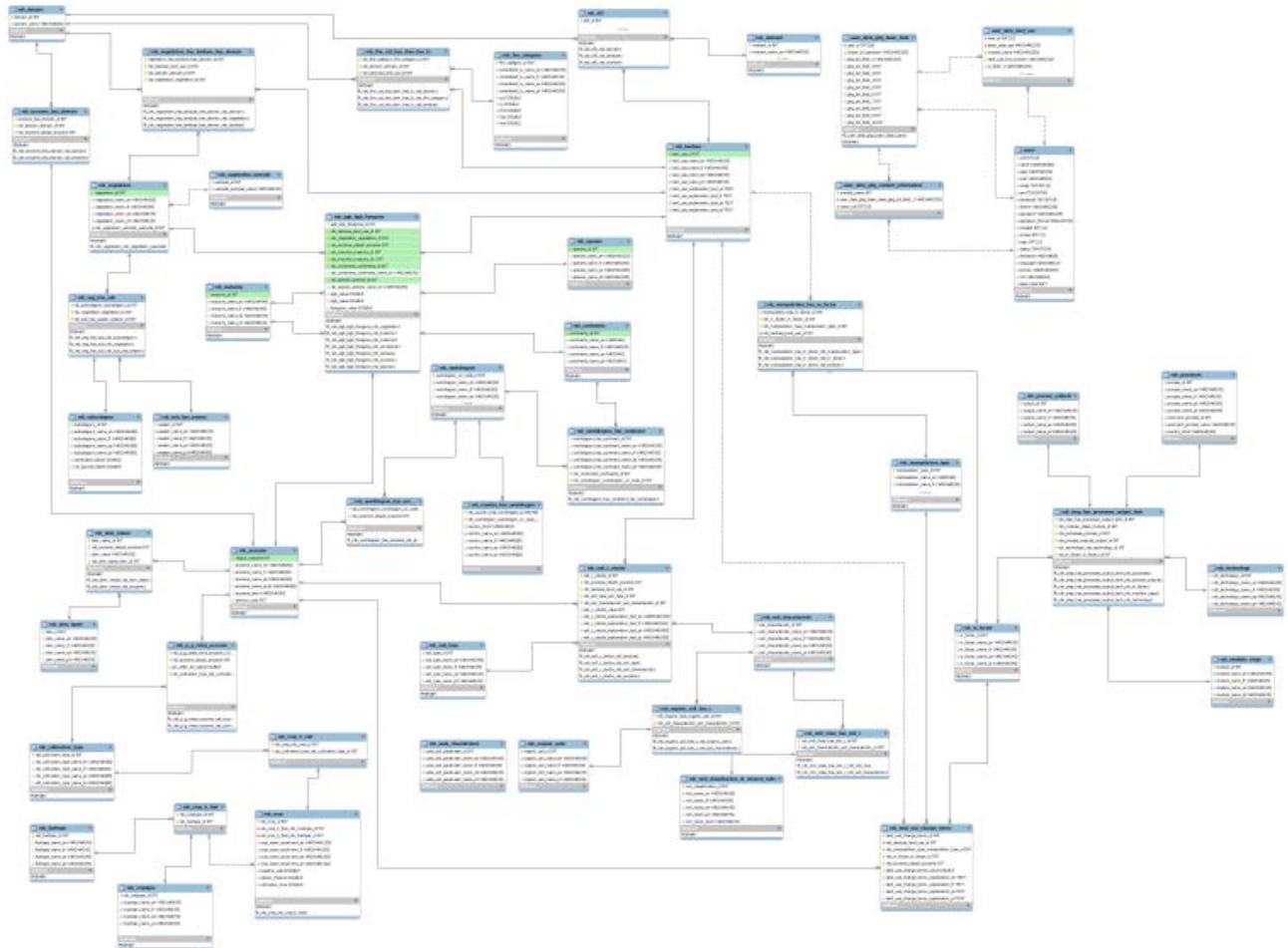


Figure 30. ERM diagram for Land use change. For a detailed vie, please use the MySQL Workbench file provided with this report (ERM_DB_Model_LUC.mwb (source: own depiction).

Table 15. Relation Land use types (source: own depiction).

LU_code	Name_Landuse
1	Forest Land
2	Cropland
3	Grassland
4	Wetlands
5	Settlements
6	Other Land

Table 16. Relation WRB soil classification (source: own depiction).

RSB_WRB_Code	Name_long	Name_short
1	Acrisol	AC
2	Albeluvisol	AB
3	Alisol	AL
4	Andosol	AN
5	Anthrosol	AT
6	Arenosol	AR
7	Calcisol	CL
8	Cambisol	CM
9	Chernozem	CH
10	Cryosol	CR
11	Durisol	DU
12	Ferralsol	FR
13	Fluvisol	FL
14	Gleysol	GL
15	Gypsisol	GY
16	Histosol	HS
17	Kastanozem	KS
18	Leptosol	LP
19	Lixisol	LX
20	Luvisol	LV
21	Nitisol	NT
22	Phaeozem	PH
23	Planosol	PL
24	Plinthosol	PT
25	Podzol	PZ
26	Regosol	RG
27	Solonchak	SC
28	Solonetz	SN
29	Stagnosol	ST
30	Technosol	TC
31	Umbrisol	UM
32	Vertisol	VR

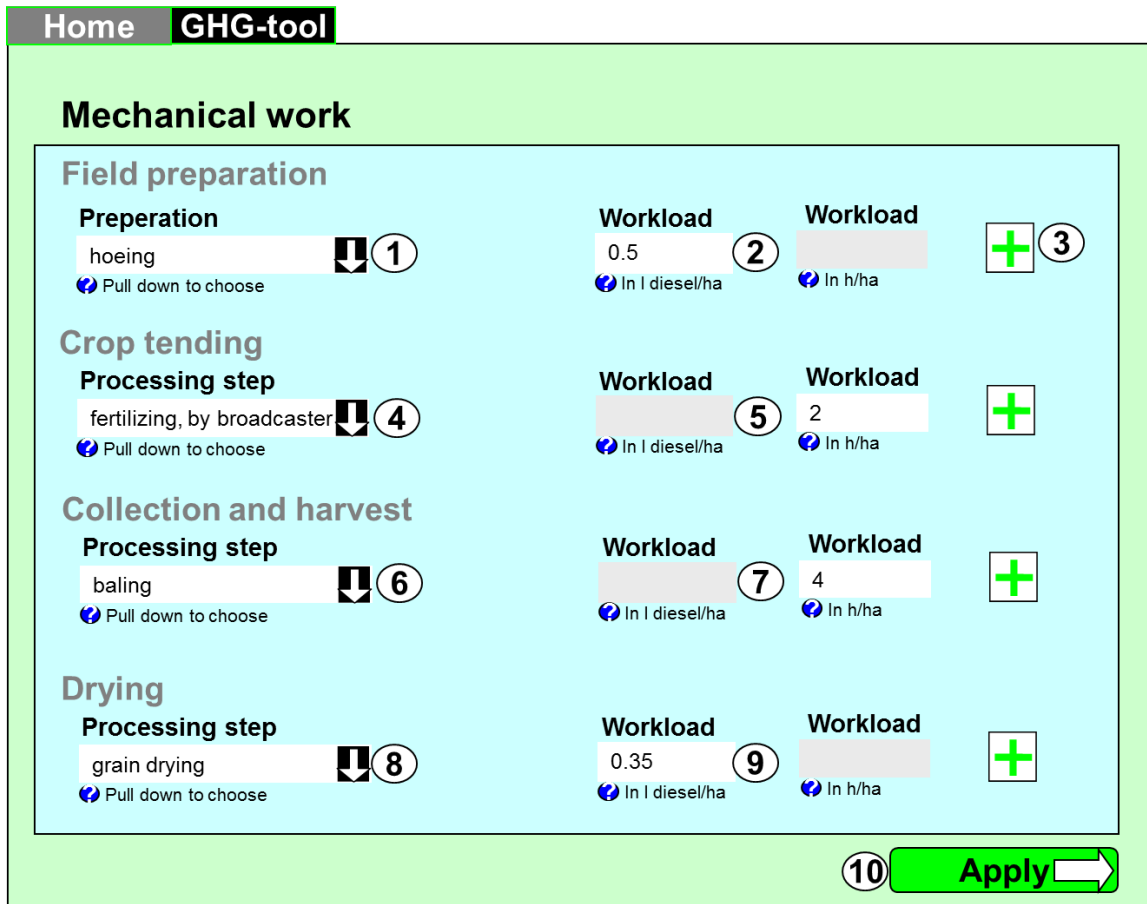
For the detailed relations please see Excel Database_MastersProject.

4.2.3 Mechanical work

According to the RSB methodology, the emissions from the extraction of raw materials shall include emissions from the extraction or cultivation process itself; from the collection of raw materials, etc. The operator has to enter data reflecting the mechanical work done during the cultivation. The question for mechanical work are implemented on an own page namely “Mechanical work” which is located between “Land use” and “Mineral fertilizer”.

4.2.3.1 Graphical representation

Figure 31 shows the wireframe for the mechanical work page.



The wireframe for the mechanical work page is structured as follows:

- Navigation:** Home | **GHG-tool**
- Mechanical work**
 - Field preparation**
 - Preparation** (1)
 - hoeing (2)
 - Workload: 0.5 (3) In l diesel/ha
 - Workload: (4) In h/ha
 - Crop tending**
 - Processing step** (4)
 - fertilizing, by broadcaster (5)
 - Workload: (6) In l diesel/ha
 - Workload: 2 (7) In h/ha
 - Collection and harvest**
 - Processing step** (6)
 - baling (7)
 - Workload: (8) In l diesel/ha
 - Workload: 4 (9) In h/ha
 - Drying**
 - Processing step** (8)
 - grain drying (9)
 - Workload: 0.35 (10) In l diesel/ha
 - Workload: (11) In h/ha

- Apply** (10)

Figure 31. Concept for data entry for mechanical work (source: own depiction).

Using the pulldown menu the operator can determine the type of the mechanical work and the related work load: the latter either by giving the amount of diesel in litre required or the work time required per hectare. For example, when the user enters data for the amount of diesel required he cannot enter data the time load for the same mechanical work type, i.e. the input field “in h/ha” gets grey when the user enters data in the “in l diesel/ha” input field and vice versa.

In detail, the page provides the following functionality:

Pull-down: The operator has to select the type of field preparation (see Table 17 for the detailed list).

Input fields: The operator either enters the workload in l diesel per hectare or in hours per hectare.

Pull-down: The operator has to select the processing type used for crop tending (see Table 17 for the detailed list).

Input fields: The operator either enters the workload in l diesel per hectare or in hours per hectare.

Pull-down: The operator has to select the harvesting method applied (see Table 17 for the detailed list).

Input fields: The operator either enters the workload in l diesel per hectare or in hours per hectare.

Pull-down: The operator has to select the type of grain drying applied (see Table 17 for the detailed list).

Input fields: The operator has to enter the type of drying and the moisture content of the harvested feedstock before and after the drying process.

If the user chooses “wood chopping, mobile chopper, in forest” or “diesel, burned in splitting machine (forestry)” from the drop down, he can only enter the workload in the unit l diesel /ha. The cell “workload h/ha” is deactivated and greyed out in this case.

For the selection of the respective processes use the category_id listed in Table 17. For example, to show all mechanical work which is related to ‘Field preparation’ select all names tagged with 1, 0 and 5 in the category_id. The unallocated mechanical work type ‘transport tractor and trailer’ is selected and shown for ‘Field preparation’, ‘Crop tending’ and ‘Harvest’. It is not relevant for ‘Drying’. For all four data entry fields, give the user the possibility to select ‘not applied’, i.e. always select the name related to category_id 5.

4.2.3.2 Computation

After the user entered all relevant data, apply the following procedure.

1. **Load** all LCI flows related to the step n (where $n = 1$).
2. **Delete** all flows tagged as “work processes” in the SubCategory field.
3. **Transform** the amount (either diesel in l/ha or h/ha) to the functional unit. Use **Table 17** and the equations determined below.
4. **Write** the data entered by the user to the LCI and **tag** the LCI flows as work processes in the Sub-Category field.

Detailed steps for 3:



1. For category 1, 2, and 3 and for each mechanical work type entered, **check** which unit/field was entered by the user.

- a. **If** the unit/field entered is ‘in l diesel/ha’ use the following equation:

Equation 17: Computation of mechanical work per functional unit.

$$MW_{FU} = \frac{(LD_{ha} * 0.84)}{FCkg_{FU}} * \frac{1}{Y_{ha}}$$

with

MW_{FU} = Mechanical work per functional unit, i.e. the output of one kg of the crop;

LD_{ha} = Liter diesel per hectare; 0.84 = kg diesel/l diesel;

$FCkg_{FU}$ = Fuel consumption in kg per functional unit;

$\frac{1}{Y_{ha}}$ = normalization to one kg output with the yield per hectare.

- b. **If** the unit/field entered is ‘in h/ha’ use the following equation

Equation 18: Computation of mechanical work per functional unit.

$$MW_{FU} = \frac{OT_{ha}}{OT_{FU}} * \frac{1}{Y_{ha}}$$

with

OT_{ha} = Operation time per hectare;

OT_{FU} = Operation time per functional unit.

2. **For** the processing of the flows related to category 4 use the following equation:

Equation 19: Computation of mechanical work per functional unit.

$$MW_{FU} = M_b - M_a$$



with

M_b = Moisture before drying;

M_a = Moisture after drying.

4.2.3.3 Tables

Table 17. Excerpt of relation mechanical work (source: own depiction).

ID	Ecoinvent_ID	Name	Category_ID	FU	Location	Input Group	kg/FU	h/FU
1	152	application of plant protection products, by field sprayer	2	ha	CH	5	1.76	0.7000
2	153	baling	3	unit	CH	5	0.17	0.0299
3	154	chopping, maize	3	ha	CH	5	52.75	1.0000
4	155	combine harvesting	3	ha	CH	5	33.31	1.3000
5	156	fertilising, by broadcaster	2	ha	CH	5	5.29	1.5000
6	157	fodder loading, by self-loading trailer	3	m3	CH	5	0.11	0.0200
7	161	harvesting, by complete harvester, beets	3	ha	CH	5	103.49	8.0000
8	162	harvesting, by complete harvester, potatoes	3	ha	CH	5	28.14	13.4000
9	163	haymaking, by rotary tedder	3	ha	CH	5	1.92	0.6000
10	164	hoeing	1	ha	CH	5	3.28	1.0000

Table 18. Relation category_id (source: own depiction).

Category_ID	Name
1	Field preparation
2	Crop tending
3	Harvest
4	Drying
5	not applied
0	Unallocated

For the detailed relations please see Excel Database_MastersProject, Tab Mechanical_work.

4.2.4 Mineral fertilizer

4.2.4.1 Graphical representation

Figure 32 shows the graphical concept for the mineral fertilizer page. In general the data entry is separated into N, P and K fertilizer.

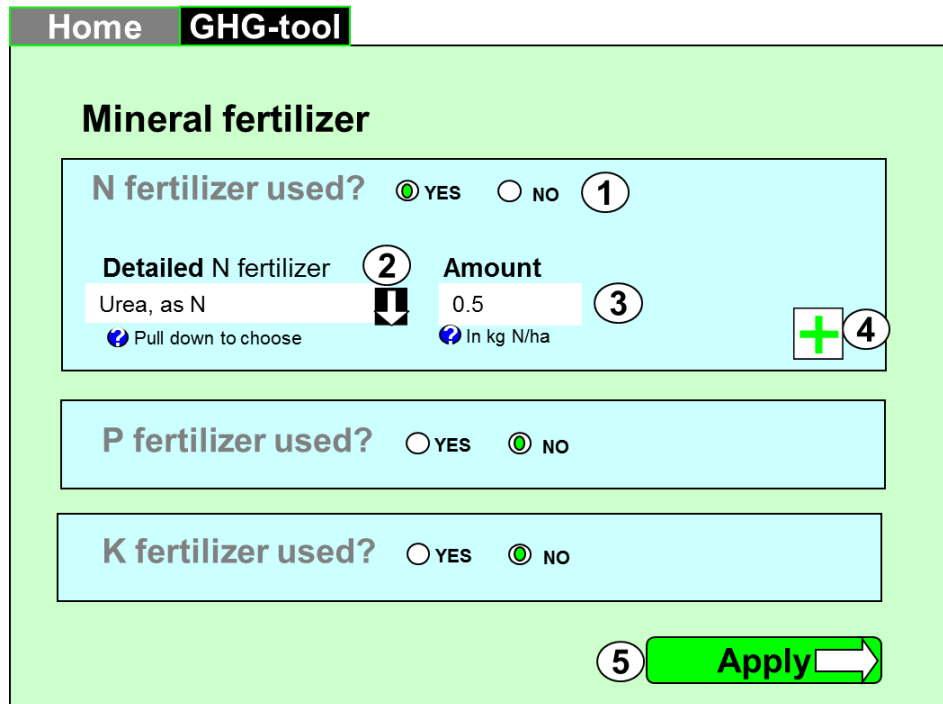


Figure 32. Concept for data entry for mineral fertilizer (source: own depiction).

The page provides the following functionality:

1. Radio-button: For each type of fertilizer (N, P and K) the operator has to determine if it is used. When the operator accesses the page “No” is selected by default. If “No” is selected, input field 2 & 3 are not shown. If the operator selects “yes”, he can enter the detailed data for each fertilizer, i.e. the type and the associated amount.
2. Pull-down: The operator has to select the type of fertilizer applied.
3. Input field: The operator has to enter the amount in kg / ha.
4. Plus-button: The operator can add additional fertilizer types by pressing the plus button.
5. Apply-button: The operator navigates to the next page, i.e. the data entry for organic fertilizers.

4.2.4.2 Computation

All of the computation is described in the SQCB background report ((Faist-Emmenegger, Reinhard et al. 2009). Please note that the use of default data is not allowed in the RSB GHG tool.

4.2.4.3 Tables

Please refer to the SQCB background report ((Faist-Emmenegger, Reinhard et al. 2009) for the detailed tables.

4.2.5 Organic fertilizer

4.2.5.1 Graphical representation

Figure 33 shows the graphical concept for the organic fertilizer page. In general data entry is separate into solid manure and liquid manure.

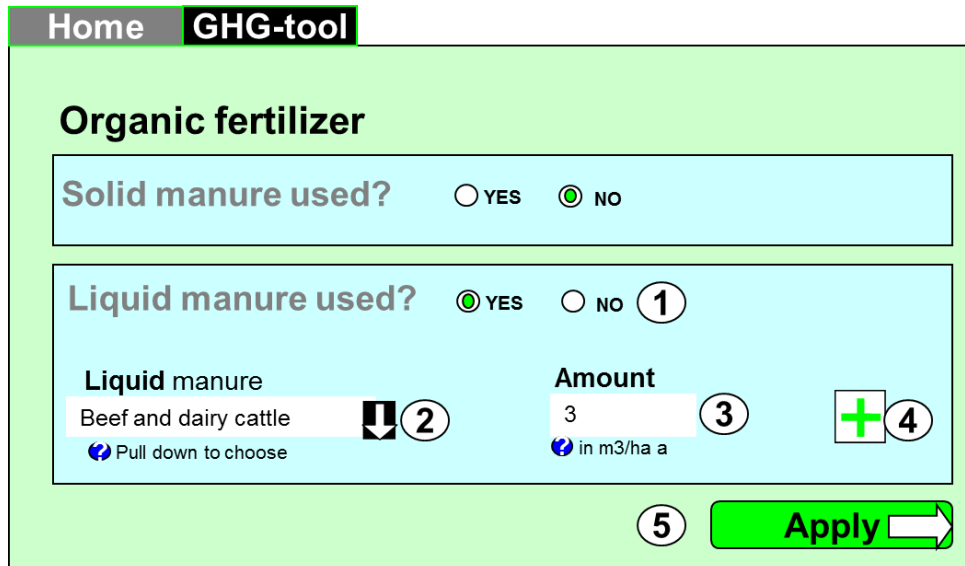


Figure 33. Concept for data entry for organic fertilizers (source: own depiction).

The page provides the following functionality:

1. Radio-button: For each type of organic fertilizer (solid and liquid) the operator has to determine if it is used. When the operator accesses the page “No” is selected by default. If the operator selects “Yes” the input fields expands
2. Pull-down: The operator has to select the type of fertilizer applied.
3. Input field: The operator has to enter the amount in m3 / ha and year.
4. Plus-button: The operator can add additional fertilizer types by pressing the plus button.
5. Apply-button: The operator navigates to the next page, i.e. the data entry for organic fertilizers.

4.2.5.2 Computation

The computation of the solid manure is described in the SQCB background report (Faist-Emmenegger, Reinhard et al. 2009). Please note that the use of default data is not allowed in the RSB GHG tool.

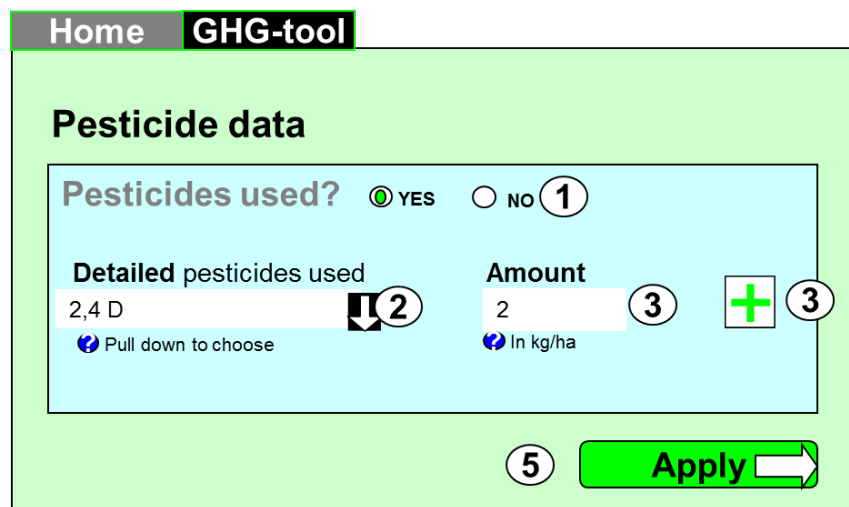
4.2.5.3 Tables

Please refer to the SQCB background report ((Faist-Emmenegger, Reinhard et al. 2009) for the detailed tables.

4.2.6 Pesticides

4.2.6.1 Graphical representation

Figure 34 shows the graphical concept for the pesticide data.



Home GHG-tool

Pesticide data

Pesticides used? ☒ YES ☐ NO ①

Detailed pesticides used ②

2,4 D
Pull down to choose

Amount ③

2
ln kg/ha

③

⑤ **Apply** ➔

Figure 34. Concept for data entry for pesticides (source: own depiction).

The page is structured similar to the mineral fertilizer page and provides the equivalent functionality:

1. Radio-button: The operator has to determine if pesticides are applied. When the operator accesses the page “No” is selected by default. If the operator selects “Yes” the input fields expands
2. Pull-down: The operator has to select the type of pesticide applied.
3. Input field: The operator has to enter the amount in kg / ha.
4. Plus-button: The operator can add additional pesticides.

5. Apply-button: The operator navigates to the next page, i.e. the data entry for organic fertilizers.

The drop-down shows only the pesticides that are relevant for the methodology. The relevant pesticides are listed in the table (1=relevant for the method, 0=not relevant which is equal to “do not show”). If the CH method is chosen, the drop down shows all possible pesticides.

4.2.6.2 Computation

With regard to the RSB methodology, after the user entered all relevant data, apply the following procedure.

1. **Load** all LCI flows related to the step n (where n = 1).
2. **Delete** all flows tagged as “pesticide” in the SubCategory field.
3. **Write** the data entered by the user to the LCI and **tag** the LCI flows as pesticide in the SubCategory field. (pesticide production / pesticide emission)

For MinOeV calculation, use the computation of the SQCB report (Faist-Emmenegger, Reinhard et al. 2009). If the pesticide category “other” is chosen, no emissions flows are written to the database; only pesticide production (dataset “pesticides, unspecified”).

For further details please refer to the SQCB background report (Faist-Emmenegger, Reinhard et al. 2009).

4.2.6.3 Tables

Please refer to the SQCB background report ((Faist-Emmenegger, Reinhard et al. 2009) for the detailed tables.

4.3 Processing Module 1 & 2

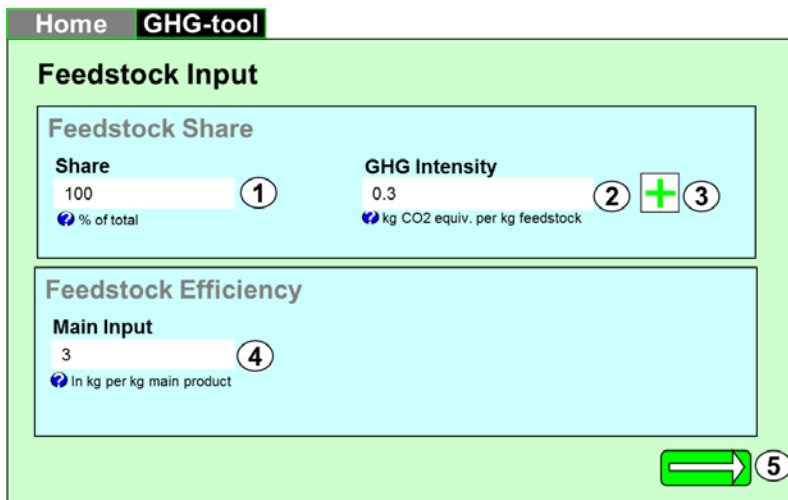
Both modules processing 1 & 2 are equal with regard to their concept and hence addressed with one specification. In other words, they are not differentiated due to their conceptual difference but rather because of user friendliness, i.e. to allow each operator a clear classification of his scope of operation.

All inputs and outputs associated with processing are related to one kg per main-product output. In order to allow a structured data entry, the questions related to the cultivation are subdivided into 5 sections, i.e. feed-stock input, energy input, chemicals and water, main output and co-products. The specification is explained for each section separately.

4.3.1 Graphical representation

4.3.1.1 Feedstock input

The feedstock input reflects the interface to the upstream pathway. In essence the operator can (i) add / mix different feedstock's with different GHG intensities and indicate their respective share and (ii) determine the feedstock efficiency, i.e. the amount of feedstock's required per kg main product produced. Figure 35 shows the graphical concept for the processing page.



The interface is titled "GHG-tool" and "Feedstock Input". It contains two main sections: "Feedstock Share" and "Feedstock Efficiency".

Feedstock Share

- Share**: Input field with value 100, labeled 1. Below it: % of total.
- GHG Intensity**: Input field with value 0.3, labeled 2. Below it: kg CO2 equiv. per kg feedstock.
- Plus button**: A green square button with a white plus sign, labeled 3.

Feedstock Efficiency

- Main Input**: Input field with value 3, labeled 4. Below it: In kg per kg main product.
- Apply button**: A green rectangular button with a white right-pointing arrow, labeled 5.

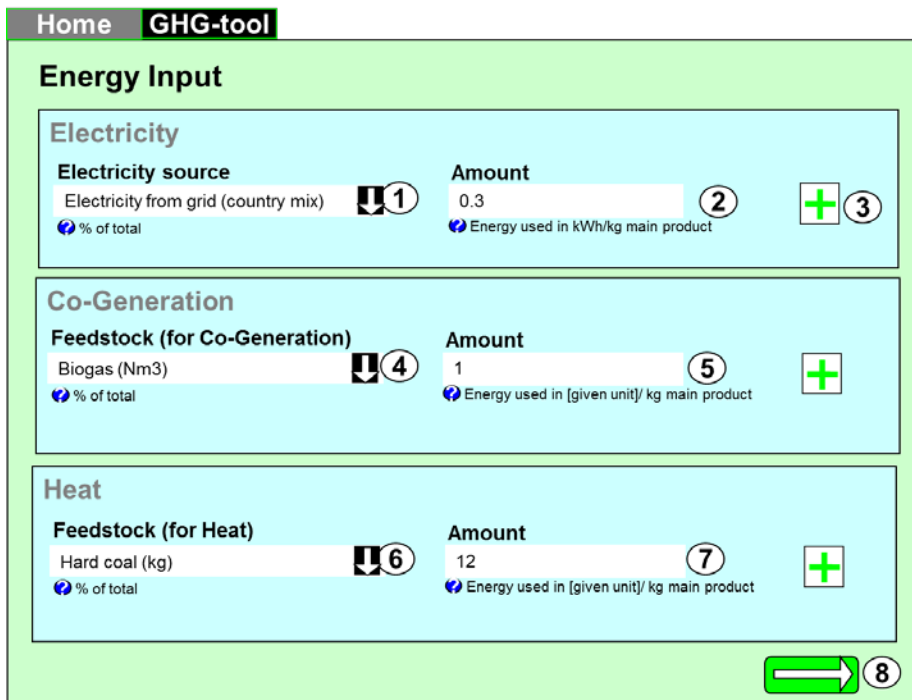
Figure 35. Concept for feedstock input for processing (source: own depiction).

The page provides the following functionality:

1. **Input field:** The operator has to enter the share of the feedstock – 100% if only one feedstock is used as an input.
2. **Input field:** The operator has to enter the GHG intensity of the feedstock. The GHG intensity is available from the COC documentation.
3. **Plus-button:** The operator can add additional feedstocks.
4. **Input field:** The operator has to enter the amount of the feedstock required per kg co-product.
5. **Apply-button:** The operator navigates to the next page, i.e. the energy input.

4.3.1.2 Energy Input

In this questionnaire sub-module the operator can enter all types of energy which are required for the processing. Figure 36 show the graphical concept for the energy input.



The figure shows a web-based interface for energy input. At the top, there are tabs for 'Home' and 'GHG-tool'. Below is a section titled 'Energy Input'. It contains three main input areas:

- Electricity:** A pull-down menu (1) shows 'Electricity from grid (country mix)'. An input field (2) contains '0.3'. A plus button (3) is to the right. Below the input field, it says 'Energy used in kWh/kg main product'.
- Co-Generation:** A pull-down menu (4) shows 'Biogas (Nm3)'. An input field (5) contains '1'. A plus button is to the right. Below the input field, it says 'Energy used in [given unit]/ kg main product'.
- Heat:** A pull-down menu (6) shows 'Hard coal (kg)'. An input field (7) contains '12'. A plus button is to the right. Below the input field, it says 'Energy used in [given unit]/ kg main product'.

At the bottom right of the 'Energy Input' section, there is a green arrow button (8) pointing to the right.

Figure 36. Concept for energy input for processing (source: own depiction).

The page provides the following functionality:

1. **Pull-down:** In general, the operator can open the pull down menu and select his country mix. When no specific country mix is available, the operator can determine his own electricity mix.
2. **Input field:** The operator has to enter the amount of electricity used in kWh per kg main product.
3. **Plus-button:** The operator can create his own electricity mix (e.g. hard coal, nuclear, hydro, etc.) by using the plus button.
4. **Pull-down:** Given its relevance in the context of biofuel production, the operator can enter data for electricity produced by co-generation. The input field is directly related to the input field for heat from co-generation, i.e. if the operator determines wood as the feedstock used for co-generation of electricity, consequently wood is also used in the co-generation of heat. In addition to the feedstock used for co-generation the operator has to enter the amount burned in “unit of the feedstock” (kg, m3) per kg main-product output.

5. Input field: The operator has to enter the amount of energy used in the [given unit] per kg main product.
6. Pull-down: If relevant, the operator can choose the feedstock used for heat production and the amount required. Pressing the plus button, he can determine more than one feedstock source.
7. Input field: The operator has to enter the amount of energy used in the [given unit] per kg main product.
8. Apply-button: The operator navigates to the next page, i.e. to the chemicals and water page.

4.3.1.3 Chemicals and water page

In this questionnaire sub-module the operator can enter chemicals, water, materials, fertilizer and emissions associated with his processing step. The available data entry possibilities are limited only by the LCIs available from ecoinvent. Figure 37 show the graphical concept for the chemicals & water page.

Home
GHG-tool

Chemicals & Water

Chemicals

Chemicals

Ammonium carbonate

Type of chemical

CAS no.:

Amount

0.3

In kg / kg

+

Water

Water

Tab, water

Type of water

Amount

1

In kg / kg

+

Materials

Materials

Limestone

Type of material

Amount

0.12

In kg / kg

+

Fertilizer

Fertilizer

Ammonia, liquid, as N

Type of fertilizer

Amount

0.1

In kg / kg

+

Emissions

Emissions

Methane

Type of emission

Amount

0.22

In kg / kg

+

➡

Figure 37. Concept for energy input for processing (source: own depiction).

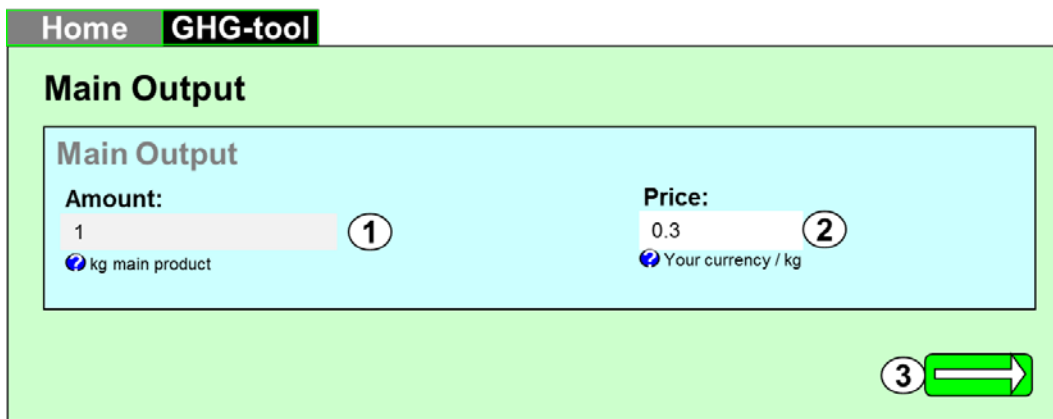
The page provides the following functionality:

1. Pull-down: Here the operator can choose the chemicals required for processing (tagged with CAS-number) and enter the respective amount. Again, the plus button can be used to enter data for more than one chemical.
2. Information field: If available, the operator is shown the CAS-number which corresponds to the selected chemical type.
3. Input field: The operator has to enter the amount of the respective chemical in kg per kg main product.
4. Pull-down: Here the operator can choose the water type required for processing. Again, the plus button can be used to enter data for more than one type of water (e.g. tap water / cooling water).
5. Input field: The operator has to enter the respective amount of water in kg per kg main product.
6. Pull-down: This pulldown contains further substances (materials) which are not included in the "chemicals" box.).
7. Input field: The operator has to enter the amount of energy used in the [given unit] per kg main product.
8. Pull-down: The operator can chose between different types of fertilizer used. This is useful for algae/lemna pathway, where the production of the biomass is calculated with the feedstock processing module.
9. Input field: The operator has to enter the amount of energy used in the [given unit] per kg main product.
10. Pull-down: If relevant, the operator can choose the type of emissions caused by the processing step. Pressing the plus button, he can determine more than one feedstock source.
11. Input field: The operator has to enter the amount of energy used in the [given unit] per kg main product.
12. Plus-button: The operator can create his own electricity mix (e.g. hard coal, nuclear, hydro, etc.) by using the plus button.

13. Apply-button: The operator navigates to the next page, i.e. to the main output page.

4.3.1.4 Main Output

In this questionnaire sub-module the operator can enter the price for the main product. This information is required for the calculation of allocation factors. Figure 38 show the graphical concept for the main output.



The figure shows a web interface for the 'Main Output' page. At the top, there are two tabs: 'Home' and 'GHG-tool', with 'GHG-tool' being the active tab. Below the tabs, the page title 'Main Output' is displayed. The main content area is a light blue box containing two input fields. The first field is labeled 'Amount:' and contains the value '1' with a circled '1' next to it. Below the value is a small icon of a globe and the text 'kg main product'. The second field is labeled 'Price:' and contains the value '0.3' with a circled '2' next to it. Below the value is a small icon of a globe and the text 'Your currency / kg'. At the bottom right of the light blue box, there is a green arrow button with a circled '3' next to it.

Figure 38. Concept for main output page (source: own depiction).

The page provides the following functionality:

1. Information field: The operator is shown amount of main product output, i.e. always 1 kg.
2. Input field: The operator has to determine the price per kg main product.
3. Apply-button: The operator navigates to the next page, i.e. to the co-products page.

4.3.1.5 Co-Product

In this questionnaire sub-module the operator can enter the amount and price for the co-product. This information is required for the calculation of allocation factors. Figure 39 show the graphical concept for the co-products.

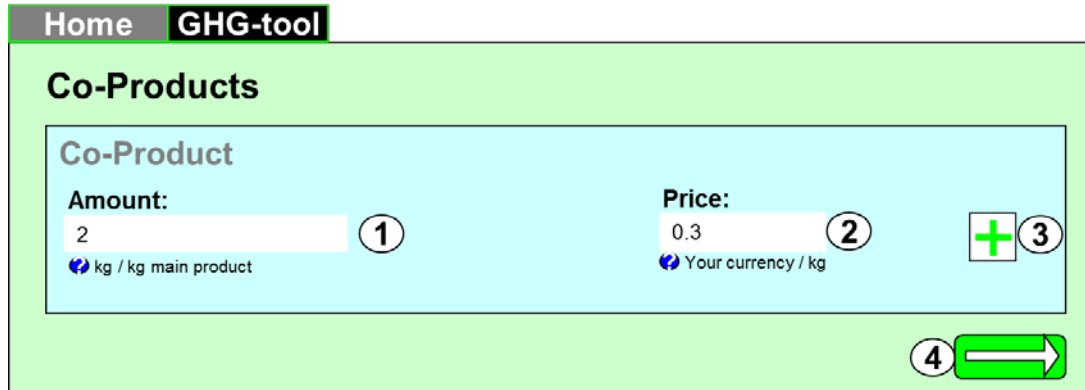


Figure 39. Concept for the co-product page (source: own depiction).

The page provides the following functionality:

1. Input field: The operator has to enter the amount of co-product produced per kg main product.
2. Input field: The operator has to enter the price per kg co-product.
3. Plus-button: The operator can add additional co-products by using the plus button.
4. Apply-button: The operator navigates to the next page, i.e. to the co-products page.

4.3.2 Computation

The detailed calculation procedure can be described as follows:

1. **Load** the main input flow of process n, i.e. step 3 or step 5, and **replace** the amount with the feedstock input entered by the operator.
2. **Delete** all LCI flows **except where infrastructure = 1**. Given that all other data has to be entered by the operator we can delete all LCI flows except the default one, i.e. infrastructure plant.
3. **If** the operator entered data for *electricity source*
 - a. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.
4. **Otherwise** proceed to the next step
5. **If** the operator entered data for the *feedstock (for Co-Gen)*



- a. **Calculate** the amount of heat resulting for each feedstock input (coal in kg, wood in m³) entered by the operator. Use Equation 20.
 - b. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.
6. **Otherwise** proceed to the next step
7. **If** the operator entered data for the *feedstock (in furnace)*
 - a. **Calculate** the amount of heat resulting for each feedstock input (coal in kg, wood in m³) entered by the operator. Use Equation 21 .
 - b. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.
8. **Otherwise** proceed to the next step
9. **If** the operator entered data for *emissions*
 - a. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.
10. **If** the operator entered data for *chemicals*
 - a. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.
11. **If** the operator entered data for *fertilizer*
 - a. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.
12. **If** the operator enter data for *materials*
 - a. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.
13. **If** the operator entered data for *water*
 - a. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.



14. Select the relevant allocation factor for each LCI flow tagged as “default data”

15. Divide all amounts related to the LCI flows by the respective allocation factor (Recalculate the allocation applied in order to apply new allocation factors).

16. Calculate new allocation factors.

a. If only one co-product is produced with one unit of the main product use Equation 22.

b. Otherwise use Equation 23.

17. Multiply the amount of all LCI flows with the allocation factor main product.

Equation 20: Calculation of the energy content of the input in MJ (source: own depiction).

$$E_{MJ} = I_{Operator} * I_{Inventory}$$

E_{MJ} = Energy content of input in MJ,

$I_{Operator}$ = amount of feedstock input entered by the operator,

$I_{Inventory}$ = Input required per functional unit of the inventory.

Equation 21: Calculation of the energy content of the input in MJ (source: own depiction).

$$E_{MJ} = I_{Operator} * \frac{1}{I_{Inventory}}$$

E_{MJ} = Energy content of input in MJ,

$I_{Operator}$ = amount of feedstock input entered by the operator,

$I_{Inventory}$ = Input required per functional unit of the inventory, e.g. 0.25 kg wood per MJ input. Use the table conversion efficiency to determine $I_{Inventory}$ in dependence on the type of feedstock input used to produce heat.



Equation 22: Calculation of the allocation factor of the main product for exactly one co-product (source: own depiction).

$$Af_{Mp} = \frac{F_{Mp}}{F_{Mp} + F_{Cp}}$$

Af_{Mp} = Allocation factor main product;

F_{Mp} = Fraction main product;

F_{Cp} = Fraction co-product.

Equation 23: Calculation of allocation factor of the main product for more than one co-product (source: own depiction).

$$Af_{Mp} = \frac{F_{Mp}}{F_{Mp} + \sum F_{Cp}}$$

Equation 24: Calculation of fraction main and co-product (source: own depiction).

$$F_{Mp} = A_{Mp} * X_{Mp} \text{ and}$$

$$F_{Cp} = A_{Cp} * X_{Cp}$$

F_{Mp} = Fraction main product;

A_{Mp} = Amount of the main product;

X_{Mp} = Price of the main product;

F_{Cp} = Fraction co-product;

A_{Cp} = Amount of the co-product produced with one kg of the main product;

X_{Cp} = Price of the co-product.

4.3.3 Tables

For the detailed relations please see Excel Database_MastersProject Tab Processing_xy.

4.4 Blender / Transport

4.4.1 Graphical representation

The Blender / Transport module is representative for two possible scope of operations: Blending and / or Transport between the main processing steps (cultivation, processing 1 and processing 2) . consist of two tabs, i.e. the ‘Blending tab’ and the ‘Transport Downstream tab.’ The module can be used to (i) enter blending interventions only, (ii) enter transport interventions only or to enter both. Both interventions are written into one and the same LCI process.

4.4.1.1 Blender tab

Within the blending module, the operator can mix several feedstocks resp. biofuels which have different GHG intensities and can add energy requirements for temporary storage (Figure 40).

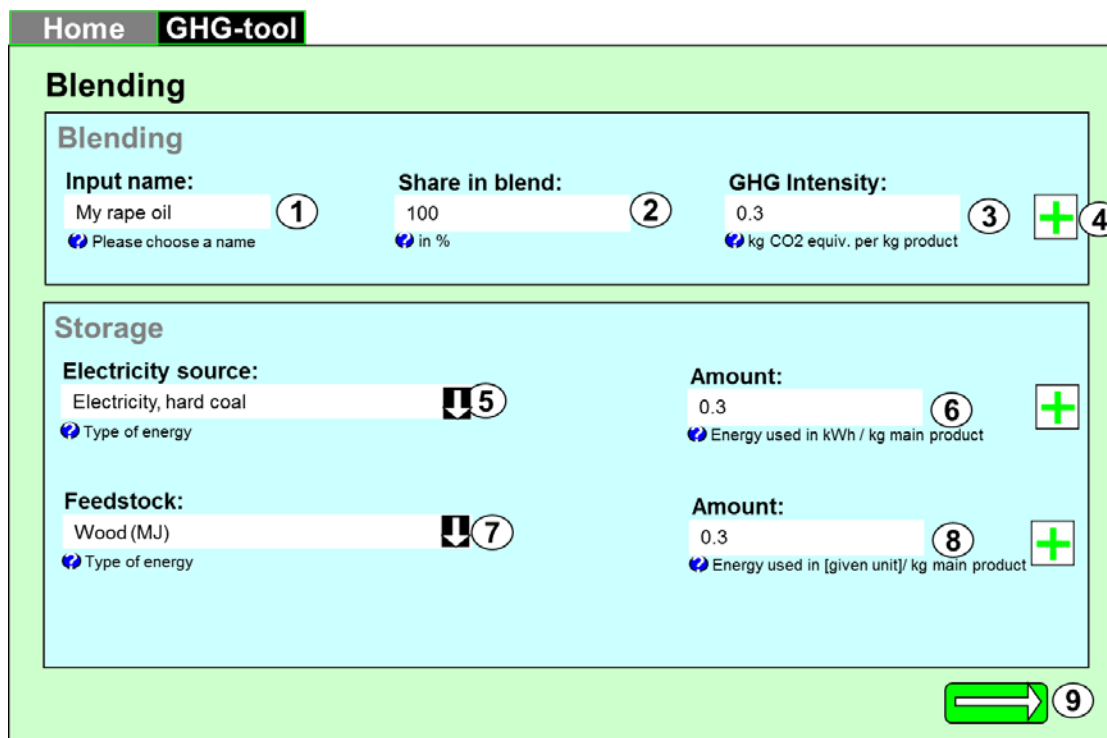


Figure 40. Graphical concept for the implementation of blending data (source: own depiction).

The page provides the following functionality:

1. Input field: The operator has to enter an arbitrary chosen name for his input.

2. Input field: The operator has to enter the share of the input in the blend – 100% indicates that no blending is applied.
3. Input field: The operator has to enter the GHG intensity of the feedstock. The GHG intensity is available from the COC documentation.
4. Plus-button: The operator can create his own electricity mix (e.g. hard coal, nuclear, hydro, etc.) by using the plus button.
5. Pull-down: If required, the operator can enter the type and amount of electricity required by storage. In general, the operator can open the pull down menu and chose country mix. When no specific country mix is available, the operator can chose the European country mix as a proxy (in which case the user gets a warning).
6. Input field: The operator has to enter the amount of electricity used in kWh per kg main product.
7. Pull-down: If relevant, the operator can select a feedstock used for heat production.
8. Input field: The operator has to enter the amount of feedstock used in the [given unit] per kg main product.
9. Apply-button: The operator navigates to the next page, i.e. to the transport tab.

4.4.1.2 Transport tab

In the transport tab the operator can specify transport interventions / modes and associated losses. Figure 41 shows the graphical concept for the transport tab.

Home
GHG-tool

Transport

Transport responsibility

☒ Yes, I am responsible for the further transport of my main product ①
☐ No, I am not responsible for the further transport of my main product.

Transport from point of origin to

Point of delivery ②
Select the point of delivery

Please choose your transportation device ③
Transport, lorry >32 t
Pull down to choose

Distance ④
in km

+ ⑤

Transport losses

Losses ⑥
2
in % of the main output

➡ ⑦

Figure 41. Graphical concept for the implementation of transport data (source: own depiction).

The page provides the following functionality:

1. Radio-button: The operator has select if he is responsible for the further transport or not. If he select “Yes”, fields 2 – 6 are faded in.
2. Pull-down: The operator has to select if he transports the product to the next processing step or the final destination. This information is not used for computation but should help the operator to understand which data he actually enters.
3. Pull-down: The operator has to select the type of transport (see Table 19 for the pull down list).
4. Input field: The operator has to enter the distance in km.
5. Plus-button: The operator can define his own transport mode by using the plus button.
6. Input field: The operator can enter the losses associated with his transport. Losses are accounted for by asking for the percentage of losses. They refer to the original amount transported, i.e. answer the question how much of the original amount transported is lost.
7. Apply-button: The operator computes the environmental impacts.

4.4.2 Computation

Figure 42 shows the general concept for computation.

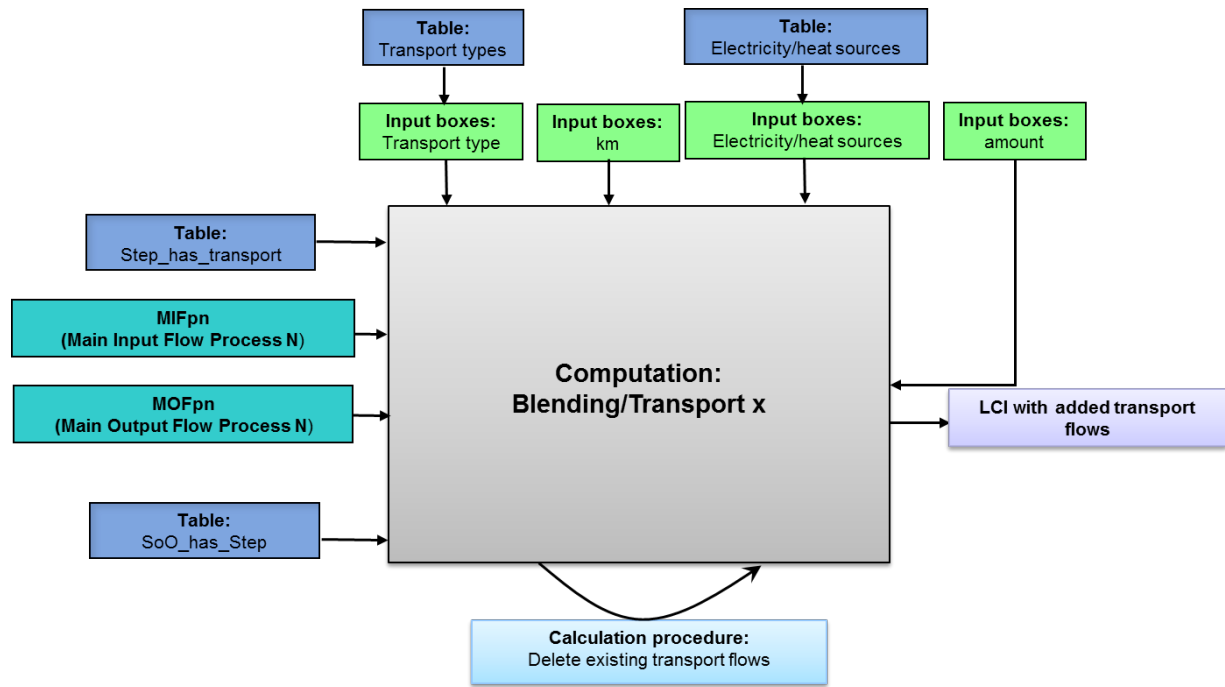


Figure 42. Schema reflecting the computation of the Blending & Transport modules (source: own depiction).

The procedure to calculate the interventions related to blending and transport can be described as follows:

1. **Determine** the process step of the transport process in the pathway.
2. Apply the following procedure:
 - i. **Set** n = current LCI process, i.e. 2, 4 or 6.
 - ii. **Set** the main output flow of process $n = 1$, i.e. $MOF_{PN} = 1$
 - iii. **Calculate** all main input flows of process n on the basis of the input data enter by the user. Use Equation 24.
 - iv. **Write** the main input flow(s) into process n .
 - v. **Multiply** the GHG intensity entered for each input in the blending tab with the respective main input flow. Use the following equation: $GHG_{FU} = GHG_i * MIFi_{PN}$

- vi. **Write** the resulting GHG value into process n.
- vii. **Transform** the km entered by the user into tkm (ton kilometre). Use Equation 25.
- viii. **Write** the transport types and the related tkm of the questionnaire to the LCI.

2. If the operator entered data for *electricity source*

- i. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.

3. If the operator entered data for the *feedstock (in furnace)*

- i. **Calculate** the amount of heat resulting for each feedstock input (coal in kg, wood in m³) entered by the operator. Use Equation 20.
- ii. **Write** the ecoinvent name(s) and the amount(s) to the LCI of process n and tag them as “operator specific data”.

Equation 25: Calculation of the main input flows of all Blending / Transport process (source: own depiction).

$$MIFi_{PN} = \left[\frac{MOF_{PN}}{(1 - LOSS)} \right] * S_i$$

$MIFi_{PN}$ = Main input flow of process n;

MOF_{PN} = Main output flow of process n;

LOSS = the transport losses entered by the user divided by 100, i.e. transformed to a share, e.g. from 30% to 0.3;

S_i = share in blend entered by the user divided by 100 e.g. from 40% to 0.4.

Equation 26: Calculation of the ton km (source: own depiction).

$$Tkm_{FU} = \frac{km}{1000} * \left[\frac{MOF_{PN}}{(1 - LOSS)} \right]_{PN}$$

The second part of the equations considers that e.g. 1.1 kg had to be transported to provide one kg at the service station. This means the loss in transport is taken into account.

4.4.3 Tables

Table 19. Relation Transport types

ID_Trans	ID_Ecoinvent	Pulldown Transport	Unit	Country	Category	Subcategory
1	1892	transport, aircraft, freight	tkm	RER	transport systems	airplane
2	1893	transport, aircraft, freight, Europe	tkm	RER	transport systems	airplane
3	1894	transport, aircraft, freight, intercontinental	tkm	RER	transport systems	airplane
4	1966	transport, barge	tkm	RER	transport systems	ship
5	1967	transport, barge tanker	tkm	RER	transport systems	ship
6	1983	transport, freight, rail	tkm	RER	transport systems	train
7	1968	transport, transoceanic freight ship	tkm	OCE	transport systems	ship
8	1969	transport, transoceanic tanker	tkm	OCE	transport systems	ship
9	1947	transport, van <3.5t	tkm	RER	transport systems	road
10	10758	transport, lorry 3.5-7.5t	tkm	RER	transport systems	road
11	7300	transport, lorry 7.5-16t	tkm	RER	transport systems	road
12	7303	transport, lorry 16-32t	tkm	RER	transport systems	road
13	7306	transport, lorry >32t	tkm	RER	transport systems	road

4.5 Module calculation & impact assessment

For each scope of operation all inventory flows entered by the operator refer to the functional unit of 1 kg output (Figure 43).

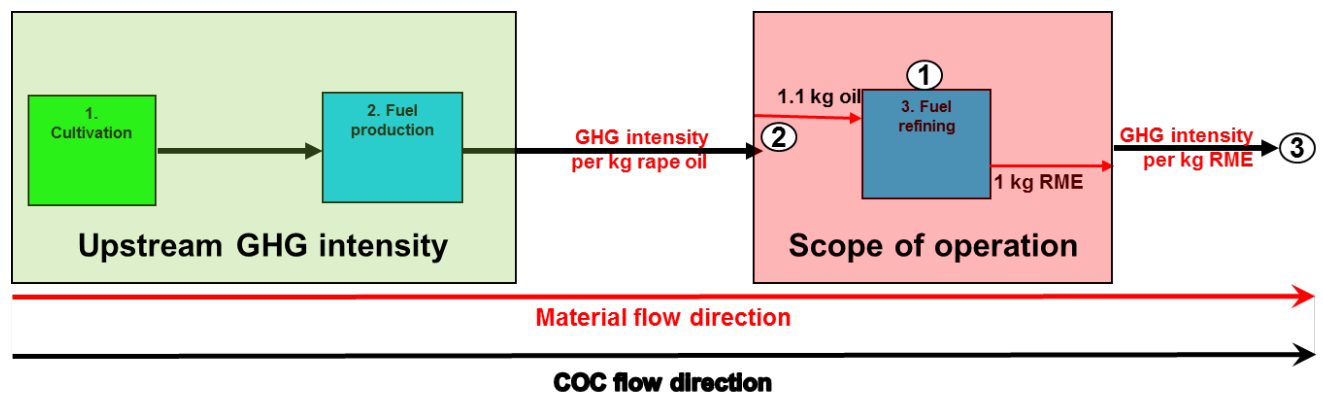


Figure 43. Life Cycle stages of RME with the exemplary calculation to normalize all inventory flows to the functional unit of one MJ fuel, at service station (source: own depiction).

As shown in Figure 43, in order to assess the overall GHG intensity of the product leaving the scope of operation of the operator (3) the interventions related to the scope of operation must be assessed (1) and linked to the GHG intensities of upstream processes outside the scope of operation (2). The definite procedure can be described as follows:

1. **Determine** the scope of operation of the operator, i.e. the step in pathway the operator is responsible for.

2. **Count** number of steps included in the scope of operation.
3. **If** scope of operation = Cultivation
 - i. **Select** all LCI flows included in the LCI flow table and **write** them into LCI flow table_1.
 - ii. **Multiply** the value of each flow with the corresponding impact value, i.e. for the RSB with column Recipe, GWP100a where where Flow_id.LCI_flow_table = Flow_id.RSB_impact_table.
 - iii. **Write** results, i.e. all flow attributes to the result table, i.e. RSB_Results_table.
 - iv. **Sum** the GHG intensities written in the RSB_result_table_1.
4. **Otherwise**
 - i. **Multiply** the main input flow of step n-1 with the GHG intensity of the upstream process (e.g. cultivation), i.e. the value entered by the user in the basic data section.
 - ii. **Write** the resulting GHG intensity to the RSB_results_table_1 and tag it as “up-stream process”.
 - iii. **Select** all LCI flows included in the LCI flow table
 - iv. **Multiply** the value of each flow with the corresponding impact value, i.e. for the RSB with column Recipe, GWP100a where Flow_id.LCI_flow_table = Flow_id.RSB_impact_table.
 - v. **Write** results, i.e. all flow attributes to the RSB_result_table_1.
 - vi. **Sum** all GHG intensities written in the RSB_result_table_1.

Remark: **Don't multiply** the LCI flows tagged as ‘Main input flows’ or as ‘Main product’ in the id-sqcb_crop_flowcategory, idsqcb_process_flowcategory, etc.). The main input and output of a process are not computed, i.e. not multiplied with the respective impact factor, and not written to the results table. The reason is that the RSB_IMPACT_TABLE include the impact of all process flows available in ecoinvent 2.2. The stored GWP100 value to, for example, the process ‘rape oil, at oil mill’ includes all impacts caused by the life cycle of rape oil, i.e. the impacts of rape cultivation are already included in this value. Thus, when both the main input and output flows would be included, we would double count the impacts.

4.6 Results representation

Depending on the calculation method the user has chosen, the result page shows different tabs with the results of the corresponding methodology. E.g.: if the user chooses all methodologies additionally to the RSB, the result page shows five tabs (see Figure 44).

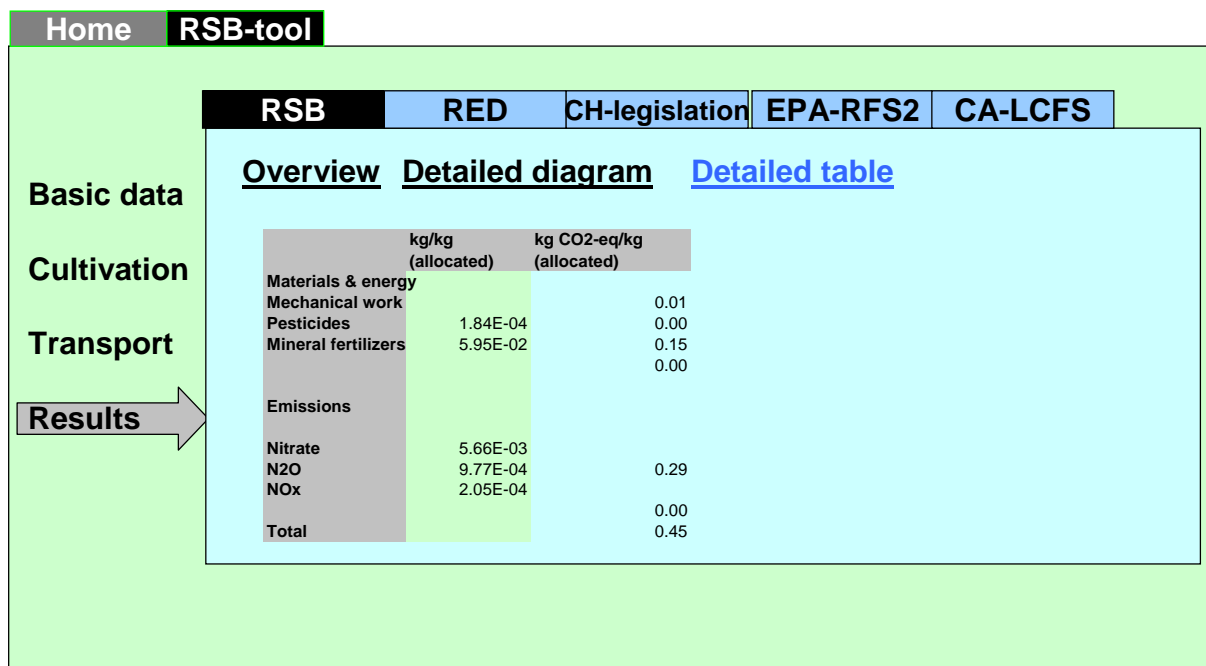


Figure 44. Overall presentation of result.

The user can navigate through the results associated with the respective methodologies by ticking the respective tab. For the three methodologies RSB, RED and CH-legislation, the user can view (i) an overview bar chart (overall results), (ii) its detailed composition (detailed diagram) and (iii) a detailed table. The detailed table can contain flows (datasets or emissions) which do not have any direct GHG impacts but still are relevant for the overall results, as it is the case with nitrate which is a parameter in the N2O model but does not have a GHG factor. On the contrary, these flows do not appear in the detailed diagram.

For the EPA-RFS2 and CA-LCFS methodologies, only default values are available. They show in table form (CA-LCFS) or graphic form (RFS2).

4.6.1 Result RSB

The results for the RSB methodology are presented in 3 items:

- 1) overview (overall results of the pathway)
- 2) detailed diagram of the module's results

3) detailed table of module's results

4.6.1.1 Diagram of overall pathway

4.6.1.1.1 Blending module

The diagram (Figure 45) is built on the basis of:

1. GHG intensity of main input (in kg CO₂-eq / MJ combusted output, with allocation)
2. GHG intensity of the module (in kg CO₂-eq / MJ combusted output, with allocation, without the GHG intensity of the main input)
3. RSB benchmark for the global pathway

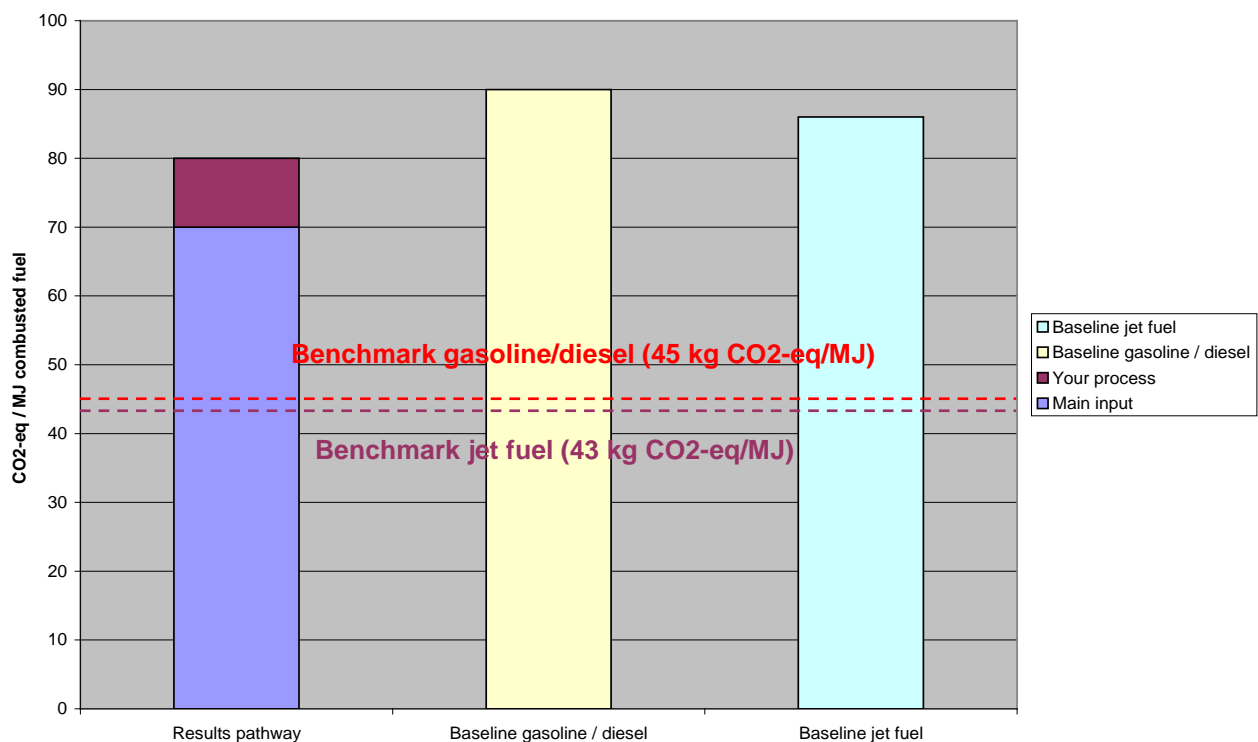


Figure 45. Presentation of the overall results, blending module (source: own depiction).

4.6.1.1.2 All other modules

The diagram (Figure 46) is built on the basis of:

1. GHG intensity of main input (in kg CO₂-eq / kg output, with allocation)

2. GHG intensity of the module (in kg CO₂-eq / kg output, with allocation, without the GHG intensity of the main input)

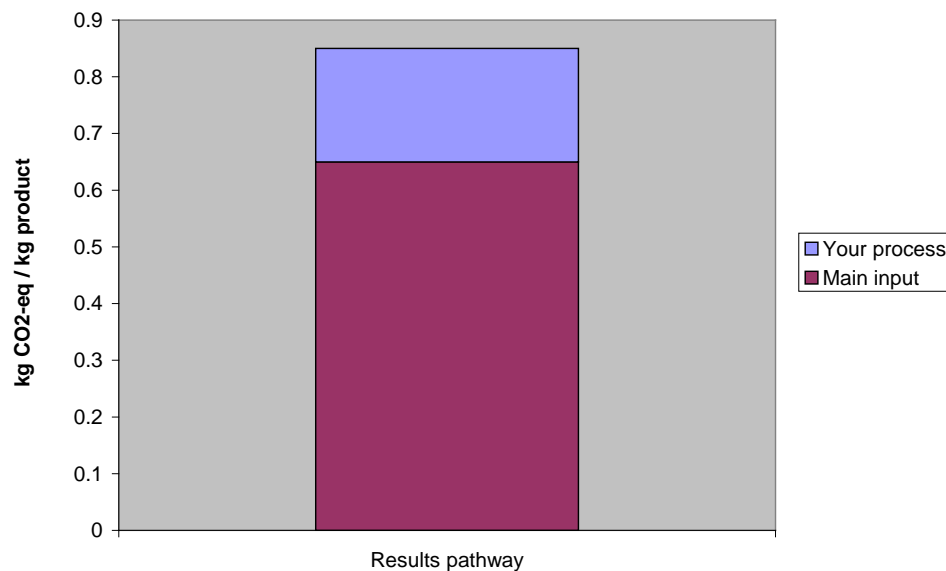


Figure 46. Presentation of the overall results (all modules except blending).

With the “complete default pathway” functionality, it will be possible in the future to calculate the whole pathway using default inventories for the missing items. However, this function will not be available in the April version.

4.6.1.2 Zoom in of „your process“

The detailed diagram shows the GHG intensities separated in the following categories:

- GHG intensities of ecoinvent datasets, separated in the RSB-tool flow-categories (e.g. mechanical work, mineral fertilizer, etc.)
- GHG intensities of the calculated emissions (e.g. dinitrogen oxide).

The GHG impacts of the feedstock (main input) are not shown.

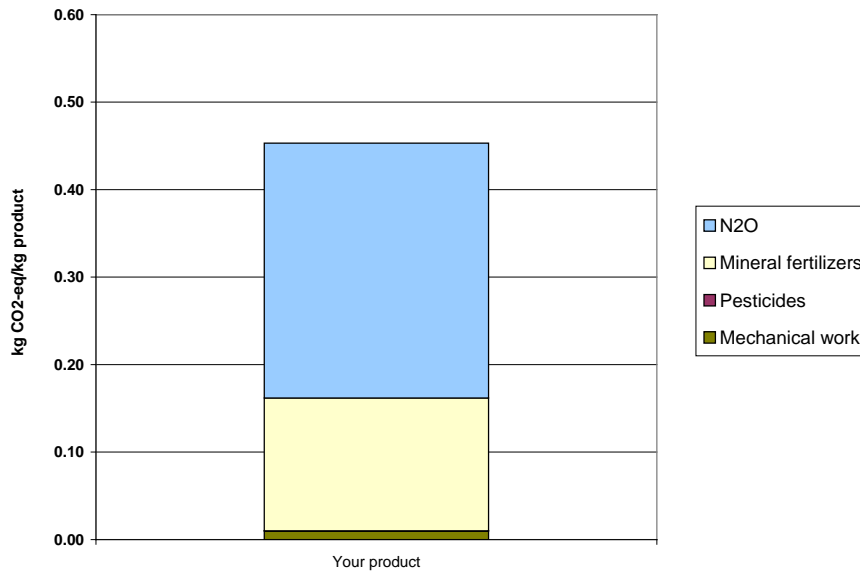


Figure 47. Presentation of the detailed results for the calculated module.

4.6.1.3 Detailed table

4.6.1.3.1 Presentation

Table 20 shows the presentation of the detailed table.

Table 20. Presentation of detailed tables

	kg/kg (allocated)	kg CO ₂ -eq/kg (allocated)
Materials & energy		
Mechanical work		0.01
Pesticides	1.84E-04	0.00
Mineral fertilizers	5.95E-02	0.15
		0.00
Emissions		
Nitrate	5.66E-03	
N ₂ O	9.77E-04	0.29
NO _x	2.05E-04	
		0.00
Total		0.45

4.6.1.4 Content of the table

The table contains three columns. The first one contains the name of the input flows and emissions, the two others contain the calculated input data and the GHG intensity (Table 21).

Table 21. Units of the LCI data and GHG results

	LCI data (allocated)	GHG intensity (allocated)
Units for cultivation modules	kg / kg output (allocated results)	kg CO ₂ -eq / kg output (allocated results)
	h / kg output (allocated results) (mechanical work)	kg CO ₂ -eq / kg output (allocated results)
Units for other modules	kg / kg (allocated results)	kg CO ₂ -eq / kg output (allocated results)

The table is separated in three parts (Table 22).

Table 22. *Structure of the detailed table*

Part	Module	Flows
Materials & energy	Cultivation	Detailed listing of: Main input (feedstock) Mechanical processing Mineral fert. production Pesticide production Transports
	All other modules	Detailed listing of: Main input (feedstock) Energy use Material use Chemical use Fertilizer use Water use Transports
Emissions	Cultivation	In RSB methodology calculated emissions Ammonia into air Dinitrogen monoxide Nitrous oxides LUC emissions
	All other modules (except transportation)	List of GWP relevant emissions according to the drop down (=substances with GWP factors in ReCiPe method)
	Transportation	No calculated emissions
	Total	Sum of GHG intensities

4.6.1.5 Value for benchmark

RSB defines three fossil fuel baselines (in review, 11.03.2011):

- Gasoline : 90 gCO₂e/MJ;
- Diesel: 90 gCO₂e/MJ;
- Kerosene-based Jet: 86 gCO₂e/MJ.

According to Criterion 3c of the Principles and Criteria, biofuel blends shall have on average 50% lower lifecycle greenhouse gas emissions relative to the fossil fuel baseline.

4.6.2 Results RED

The results for the RED are presented in the same way as for RSB method, except for the overall results of the blender module.

4.6.2.1 Diagram of overall pathway

4.6.2.1.1 Blending module

For pathways with a default value, the overall results of the blender module are presented as follow:

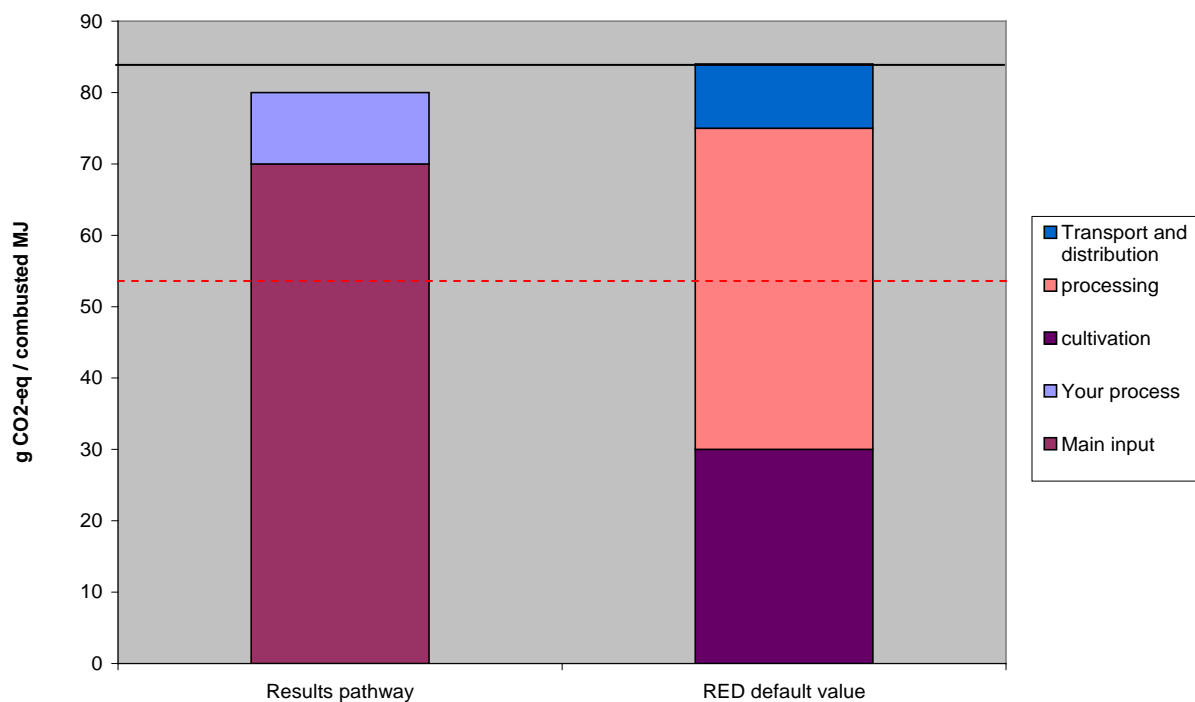


Figure 48. Presentation of blender module. The black line represents the fossil baseline for biofuel according to RED (83.8 g CO₂-eq / MJ fuel), the red line the benchmark of 35% reduction (54.5 g CO₂-eq / MJ).

4.6.2.2 Value for benchmark

The fossil baseline for biofuel according to RED is 83.8 g CO₂-eq / MJ fuel; the red line the benchmark of 35% reduction is therefore 54.5 g CO₂-eq / MJ fuel.

4.6.3 Results CH-legislation

4.6.3.1 Diagram of overall pathway

4.6.3.1.1 Blending module

The diagram (Figure 49) is built on the basis of:

- GHG intensity of the overall pathway (blending module + main input) in % of the fossil baseline
- UBP results of the overall pathway (blending module + main input) in % of the fossil baseline
- Green quadrant corresponding corresponding to a 40% GHG reduction and 125% UBP.

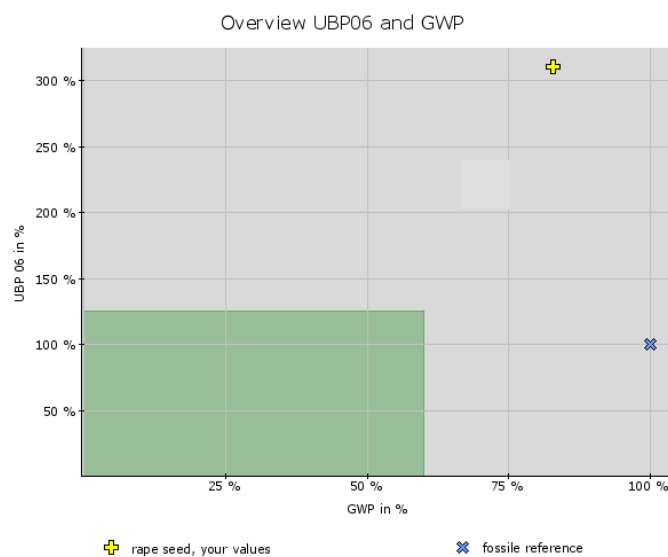


Figure 49. Presentation of the overall results, blending module.

4.6.3.1.2 All other modules

Two diagrams show the results for the actual module:

- GHG intensity of the actual module and main input (Figure 50)
- UBP results of the actual module and main input

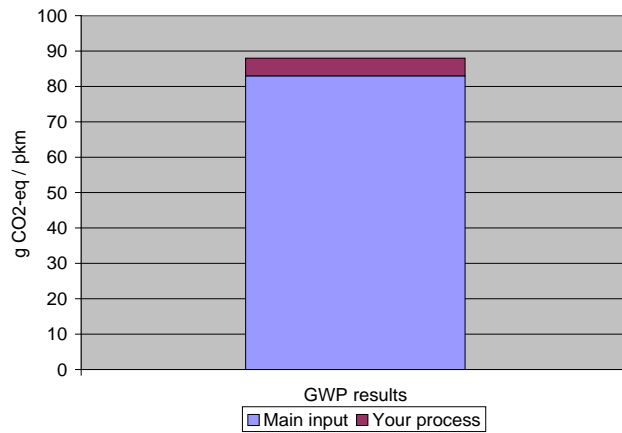


Figure 50. Presentation of the GWP results, all other module.

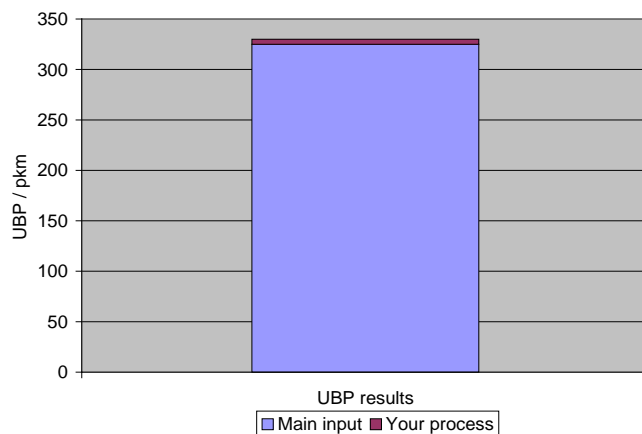


Figure 51. Presentation of the UBP results, all other module.

4.6.3.2 Zoom in of „your process“

The zoom-in “your process” shows the same categories as in the RSB methodology. However there are two diagrams, one with GWP, one with UBP.

4.6.3.3 Detailed table

The detailed table shows the same categories as in the RSB methodology. However, it contains an additional column with UBP results



4.6.4 Results CA LCFS

The results presented show a table with the relevant values for the pathway chosen.

For all pathways with specific results (see paragraphs 4.6.4.1 to 4.6.4.5), the according tables are shown additionally to the default data tables (4.6.4.6 and 4.6.4.7). Table 28. is shown for biodiesel pathways, Table 29. for ethanol pathways.

4.6.4.1 Feedstock = soybean, country = US

Table 23. US soybean biodiesel pathways results in the CA LCFS scheme.

Fuel	Pathway Description	Total CI	Fuel Pathway Code
Biodiesel	Pathways for conversion of Midwest soybeans to biodiesel (fatty acid methyl esters -FAME)	83.25	BIOD001
Renewable Diesel	Pathways for conversion of Midwest soybeans to renewable diesel	82.16	RNWD001

4.6.4.2 Feedstock = waste oil, country = US

Table 24. US waste oils (Used Cooking Oil) biodiesel pathways results in the CA LCFS scheme.

Fuel	Pathway Description	Total CI	Fuel Pathway Code
	Conversion of waste oils (Used Cooking Oil) to biodiesel (fatty acid methyl esters -FAME) where “cooking” is required	15.84	BIOD002
	Conversion of waste oils (Used Cooking Oil) to biodiesel (fatty acid methyl esters -FAME) where “cooking” is not required	11.76	BIOD003

4.6.4.3 Feedstock = tallow, country = US

Table 25. US tallow (Used Cooking Oil) biodiesel pathways results in the CA LCFS scheme.

Fuel	Pathway Description	Total CI	Fuel Pathway Code
Renewable Diesel	Conversion of tallow to renewable diesel using higher energy use for rendering	39.33	RNWD002
	Conversion of tallow to renewable diesel using lower energy use for rendering	19.65	RNWD003

4.6.4.4 Feedstock = Corn, country = US

Table 26. Corn ethanol results in the CA LCFS scheme.

Fuel	Pathway Description	Total CI	Fuel Pathway Code
Corn Ethanol	Midwest average; 80% Dry Mill; 20% Wet Mill; Dry DGS; NG	99.4	ETHC001
	California average; 80% Midwest Average; 20% California; Dry Mill; Wet DGS; NG	95.66	ETHC002
	California; Dry Mill; Wet DGS; NG	80.7	ETHC003
	Midwest; Dry Mill; Dry DGS, NG	98.4	ETHC004
	Midwest; Wet Mill, 60% NG, 40% coal	105.1	ETHC005
	Midwest; Wet Mill, 100% NG	94.52	ETHC006
	Midwest; Wet Mill, 100% coal	120.99	ETHC007
	Midwest; Dry Mill; Wet DGS; NG	90.1	ETHC008
	California; Dry Mill; Dry DGS, NG	88.9	ETHC009
	Midwest; Dry Mill; Dry DGS; 80% NG; 20% Biomass	93.6	ETHC010
	Midwest; Dry Mill; Wet DGS; 80% NG; 20% Biomass	86.8	ETHC011
	California; Dry Mill; Dry DGS; 80% NG; 20% Biomass	84.2	ETHC012
	California; Dry Mill; Wet DGS; 80% NG; 20% Biomass	77.44	ETHC013

4.6.4.5 Feedstock = Sugarcane, country = Brazil

Table 27. Sugarcane ethanol results in the CA LCFS scheme.

Fuel	Pathway Description	Total CI	Fuel Pathway Code
Sugarcane Ethanol	Brazilian sugarcane using average production processes	73.4	ETHS001
	Brazilian sugarcane with average production process, mechanized harvesting and electricity co-product credit	58.4	ETHS002
	Brazilian sugarcane with average production process and electricity co-product credit	66.4	ETHS003

4.6.4.6 Pathway = Biodiesel, country = all

Table 28. Default Values for Biomass-Based Diesel 3/1/11 in the CA LCFS scheme.

Fuel	Pathway Description	Total CI	Fuel Pathway Code
Biodiesel	2011 Interim Default Value	94.71	INTV9471
Renewable Diesel	2011 Interim Default Value	94.71	INTV9471

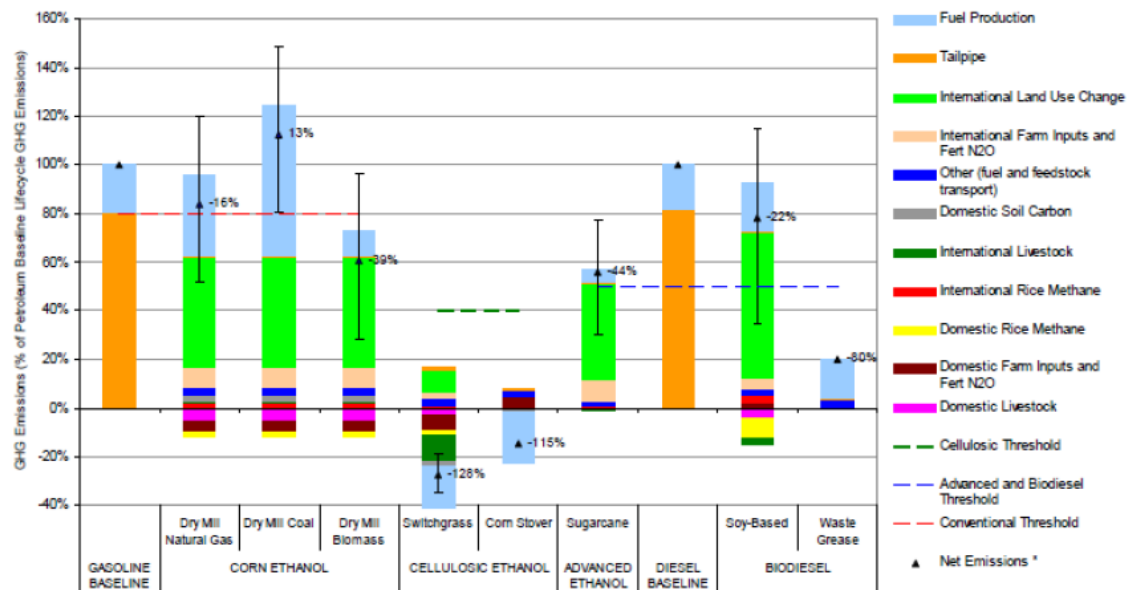
4.6.4.7 Pathway = Ethanol, country = all

Table 29. Default Values for Ethanol 3/1/11 in the CA LCFS scheme.

Fuel	Pathway Description	Total CI	Fuel Pathway Code
Ethanol from Sorghum, Corn	Advisory 10-04 Default Value	99.40	ETH000
Ethanol from Corn	Advisory 10-04 Default Value	99.40	ETH000
Ethanol from Sorghum, Wheat Slurry, Corn	Advisory 10-04 Default Value	99.40	ETH000
Ethanol from Sorghum	Advisory 10-04 Default Value	99.40	ETH000
Ethanol from Sugarcane	Advisory 10-04 Default Value	99.40	ETH000
Ethanol from Waste Beverages	Advisory 10-04 Default Value	99.40	ETH000

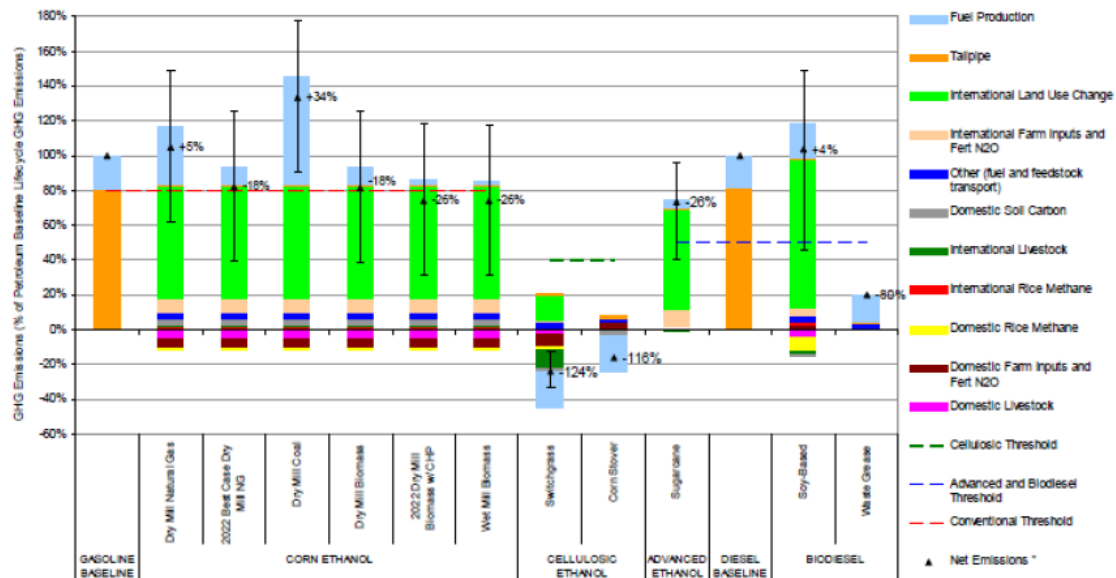
4.6.5 Results EPA-RFS 2

The results presented show a diagram with the relevant values for the pathway chosen.



*Range shows net emissions if we assume all land conversion from forest (upper bound) or all from grassland (lower bound).

Figure 12 – Lifecycle GHG results (including indirect emissions) using a 100-year net present value discounting method with a 2 % discount rate (source: EPA, 2009d)



* Range shows net emissions if we assume all land conversion from forest (upper bound) or all from grassland (lower bound).

Figure 13 – Lifecycle GHG results (including indirect emissions) using a 30-year annualisation method (source: EPA, 2009d)

5 Implementation

5.1 Modular Development with Drupal

The RSB Tool generally consists out of different custom modules written by developers from the HTW Berlin and for the web-content-management-system Drupal, and specifically, Drupal 6. The main code that runs in the background is a mix of php and drupal-proprietary syntax.

The modular development with Drupal contributed to a complexity reducing way of programming. Figure 12 gives another overview, this time over the complete hierarchy of the tool, while the bar in the bottom is an actual screenshot from the tab-bar of that specific page, in this case the first page of the cultivation module.

The coding was mainly split up into the design and implementation of the questionnaire, i.e. visual design / graphical user interface, which was substantial due to the requirement to show the fewest possible number of input fields to the user corresponding to his scope of operation and other relevant information and secondly the calculation procedures behind it.

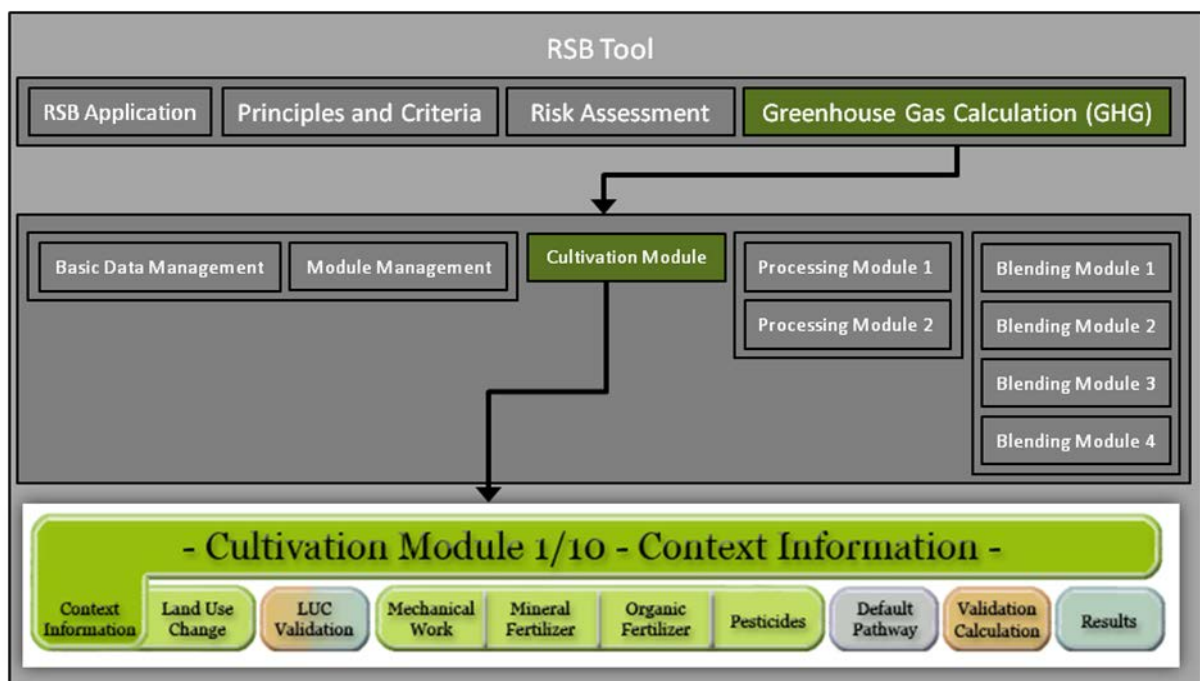


Figure 52. Complete overview over the RSB Tool functionality (source: own depiction).

The Database is MySQL. The majority of the necessary data tables can be qualified under a) tables necessary to store user information / user data input tables, b) tables related to the ecoinvent database, c) cross reference tables based on the methodology developed by the EMPA.

5.2 Accessing the tool

The detailed implementation can be accessed via <http://buiprojekte.f2.htw-berlin.de:1339/>

6 Conclusion

The RSB GHG tool streamlines the process of data collection, data storage and assessment and allows the interactive assessment of the GHG emissions of individual steps of biofuels pathways without the need of conducting a time and resource-intensive life cycle assessment study. It is based on state-of-the-art Life Cycle Inventory (LCI) modelling techniques and applies common accepted evaluation schemes for the GHG assessment of biofuels. Because the results are calculated immediately, the RSB tool can be used interactively. The user can observe the impact of each LCI flow and get insights on the hot spots within the scope of his production step. This enables the operator to understand the influence and interaction of different decisions and factors on the environmental performance under his scope of operation.

GHG emissions within the RSB GHG tool are calculated and assessed according to common certification schemes. Background data and modeling approaches are consistent per scheme. Therefore the tool allows the comparison of different production paths, which is not possible for LCA studies that are based on different goal and scope definitions. In the future the tool will allow operators to assess their compliance with the RSB Standard based on a benchmarking assessment of their existing sustainability certification schemes. This will shorten the time required for the assessment of compliance with the RSB Standard and enhance the understanding of differences between existing certification schemes.

The tool is quite flexible given its roots in the LCA framework and its generic and modular implementation. For example, the amount of biofuel pathways covered by the tool can be enlarged quickly. Moreover, additional impact assessment methods accounting for issues such like water, energy, ozone formation or ecotoxicity can be added easily.

The main difficulty of developing the RSB tool was the balancing act between wanting a tool that gives the user a “good feeling” through high usability, a variety of smart features, customization and adaptation depending on users choices and secondly the normative goal to have it as open as possible for browsers, (web-)platforms and computers that may not meet the western standards. Regarding the variety and the extend of the data one must question the possibility to double and triple check the users data input in the real world.

The RSB tool is publicly available and allows the operator next to the calculation of GHG emissions to assess their own sustainability against the RSB requirements. In doing so it increases the knowledge on critical issues with agro-biofuel production thus representing one important cornerstone for the implementation of more sustainable biofuel pathways.

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