



**Submission for
NSF Protocol P352
Validation and Verification of Eco-Efficiency Analyses,
Part A.**

**BASF's AgBalance™ Methodology
September 2016**



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1. Purpose and Intent of this Submission

1.1. Purpose of Submission:

The purpose of this submission is to establish BASF's methodology for performing AgBalance™ Assessments for the intent of having it validated under the requirements of NSF Protocol P352, Part A: Validation of the Eco-Efficiency Assessment Methodology. The EEA methodology includes two strictly defined versions of Eco-Efficiency Assessments, the "EEA6" and "EEA10", with 6 and 10 fixed environmental impact criteria. However with AgBalance™, at a minimum "EEA10" will be utilized so that Land Use is assessed in all AgBalance™ studies. LCAflex may be utilized in an AgBalance™ study if additional environmental categories are required above the "EEA10".

1.2. Intent of Submission:

It is the intent of BASF to use the same validated Eco-Efficiency methodology and model to conduct AgBalance™ studies and have these studies submitted to NSF for verification under NSF Protocol P352, Part B: Validation and Verification of Eco-Efficiency Analyses.

2. Content of this Submission

2.1. Content of Submission:

BASF's Eco-Efficiency Analysis (EEA) is used to assess the sustainability of downstream processes in the agricultural value chain, such as the processing, packaging, storage, transport and consumption of food. However, BASF identified that a comprehensive assessment of the farming sector – effectively, information on how agricultural production happens on the farm – needed further agricultural-specific indicators. Discussions with stakeholders, experts and consumers confirmed the view that further development was required to adequately assess end-to-end sustainability in the agriculture sector. AgBalance™ methodology considers agricultural-specific factors and integrates them within an overall life cycle approach. Based on its many years of experience in sustainability assessment, BASF believes that AgBalance™ will contribute to a more objective, fact-based assessment of agricultural sustainability. BASF expects that AgBalance™ will be used to assess and manage sustainable development in agriculture at several levels, see Table 1.

Table 1: Impact of AgBalance on sustainable development at different levels

Farmer	Assessing current practices and processes; identifying options for improvement.
Agricultural value chain	Assessing the contribution that farming and downstream processes make over the complete product life cycle as well as identifying opportunities for improvement.

Policy makers	Assessing the impact of regulations on products and farming practices.
Public	Demonstrating the impact of farming practices at different levels; including their relationship to issues like biodiversity or resource consumption.

2.2. Additions to AgBalance™ from EEA methodology

BASF developed AgBalance™ based on the BASF EEA methodology. The AgBalance™ incorporates all the indicator categories in the EEA methodology, however there are additional indicator categories in AgBalance™ related to Agricultural applications. Each of these additions are explained in more details within this document. The additional indicator categories are:

Environmental indicator categories:

- Soil
- Biodiversity
- Eco-Toxicity

Economic indicator categories:

- Separate fixed and variable costs
- Macro economy “costs”

Social indicator categories:

- Employees
- Consumer
- Local and National Community
- International Community
- Future Generations

2.3. Enhanced Fingerprints:

The AgBalance™ methodology also enhances the environmental fingerprint diagram to include soil, biodiversity, and eco-toxicity indicator categories. The eco-toxicity indicator category replaces toxicity in the environmental indicator category and toxicity is evaluated in the social indicator category under employees. The AgBalance™ methodology adds an economic fingerprint diagram and a social fingerprint diagram. The EEA portfolio diagram part of the AgBalance™, is individual environmental, economic and social diagrams, as well as an overall total socio-eco-efficiency score diagram.

3. BASF's AgBalance™ Methodology

3.1. Overview:

BASF developed AgBalance™ methodology in 2009-2010. During the development process BASF consulted with international stakeholders, experts and decision-makers on the specific indicators required to comprehensively

assess sustainability in agricultural production. From the range of options proposed, BASF selected the most appropriate indicators, based on the following criteria: relevance, inclusiveness, practicality of quantification and availability of data sources. AgBalance™ methodology includes many features from the previously published BASF EEA and SEEBALANCE® methods for sustainability impact assessment, (EEA: Ref. 1,2,3; SEEBALANCE®: Refs. 4,5). The procedure and assessment of some of the environmental categories is based on both mandatory and optional parts of the ISO 14040 and 14044 standards for lifecycle assessment.⁶ However, AgBalance™ also incorporates the evaluation of specific indicators that are not covered by a conventional LCA. It also includes methods for sensitivity analyses and data aggregation, designed to facilitate review and decision-making. Important aspects are in line with the ISO 14045 standard on eco-efficiency analyses, which is currently under development.

3.2. Workflow:

AgBalance™ studies follow specific and defined calculation methods (cf. Figure 1):

- 1) calculation of the total cost for the product system, and its impacts in terms of economic sustainability,
- 2) a specific life cycle analysis for all investigated products or processes, according to ISO 14040 and 14044 standards,
- 3.) assessment of specific indicators relating to agricultural impact,
- 4) determination of social impacts for the product system,
- 5) calculation of relevance and calculation factors for specific weighting,
- 6) weighting of life cycle analysis factors with societal factors,
- 7) determination of the relative importance of environmental versus economic impacts as well as social versus economic impacts
- 8) creation of fingerprint and single-score diagrams,
- 9) analyses of appropriateness, data quality, sensitivities, and scenario analysis, and
- 10.) investigation of additional sustainability impacts, which are not covered by the AgBalance™ set of quantitative indicators, through a Hot-Spot Analysis.

A diagram showing the general workflow and elements of an AgBalance™ study is presented in Figure 1.

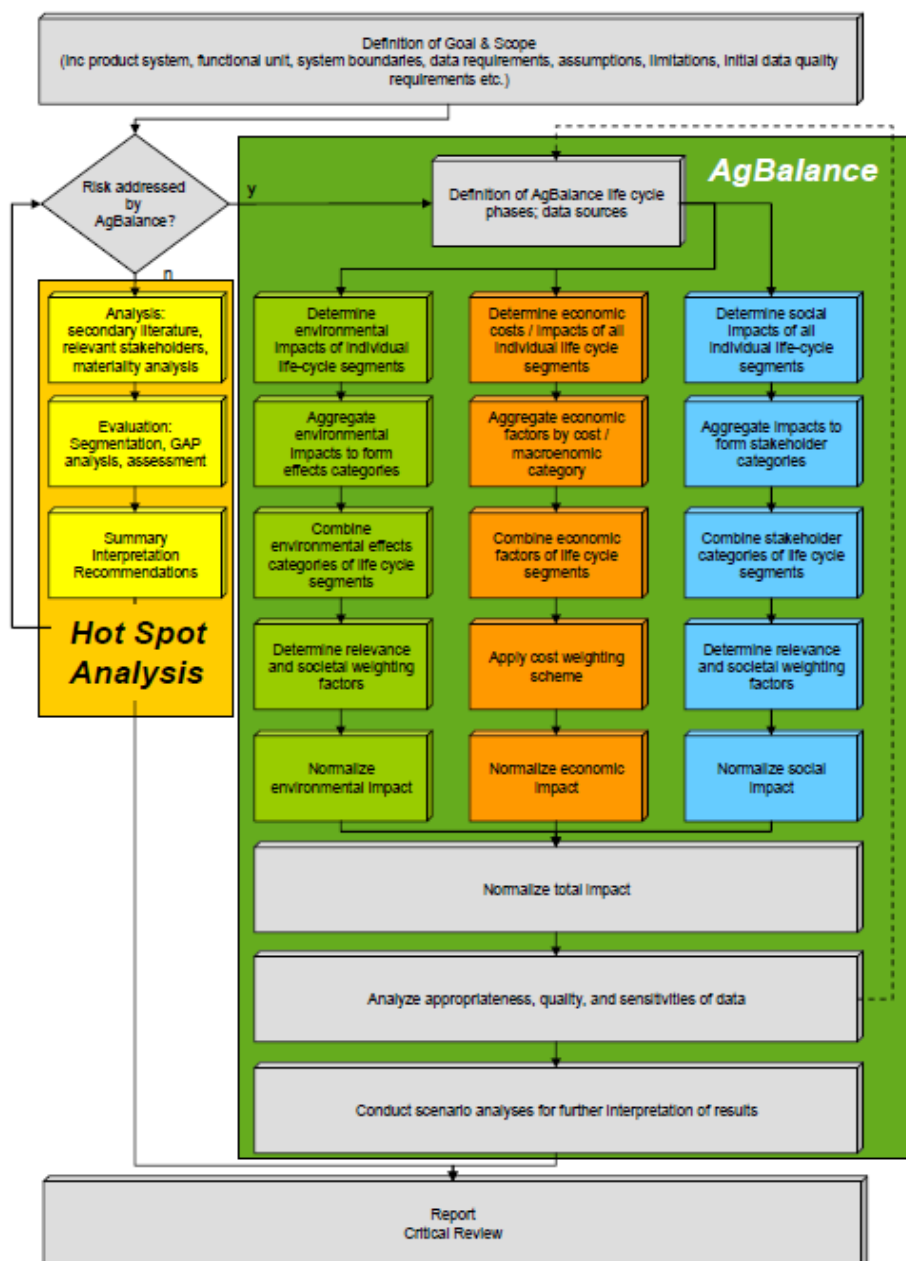


Figure 1: Overall workflow for the AgBalance™ methodology.

3.3. Relationship of AgBalance™ to other reporting or assessment standards

Developed by BASF, AgBalance™ is a methodology used to evaluate sustainability, based on the principles of the Life Cycle Assessment framework, as defined in the ISO14040 and 14044 standards. However, it also defines a specific set of indicators and indicator categories that relate exclusively to primary agricultural production.

In addition to these standards, AgBalance™ derives guidance from the following certification and reporting standards or initiatives (see below). However, it is important to clarify that AgBalance™ is not a certification or reporting standard for sustainable agriculture. It is a methodology, which is designed to quantify and compare the performance of agricultural solutions and products from a sustainability perspective.

UNEP-SETAC Guidelines for Social Life Cycle Assessment of Products: This is a general methodology framework for integrating social aspects within the LCA concept. AgBalance™ references the SEEBALANCE® method for the social LCA, which covers the most important aspects of the UNEP-SETAC guidelines, e.g., the concept of stakeholder categories.

ISO26000SR, and SA8000: These globally accepted standards for reporting and certifying social sustainability within enterprises were considered during the development of AgBalance™ agro-specific social indicators. AgBalance™ indicators are aligned with these standards, e.g., categories 'farmers/workers' and 'local/national community'.

ProSustain™: Is a standard developed by DNV for product sustainability. BASF had already developed the Sustainability, Eco-Efficiency, Traceability (S.E.T) program to help companies and products meet the requirements of the ProSustain™ standard. The concept of combining an LCA with the assessment of additional sustainability criteria as well as the optional inclusion of a Hot Spot analysis have been adopted within AgBalance™.

ISCC (International Sustainability and Carbon Certification): BASF is a member of the ISCC. ISCC is a certification system for renewable raw materials and defines a set of environmental and social sustainability criteria, e.g., it implements good agricultural practice and prohibits production in carbon-rich soils and high-value nature regions. In contrast, AgBalance™ is designed to compare different product alternatives through comprehensive analysis, where a holistic set of environmental, social and economic indicators are quantified. Basic sustainability requirements, as set out by ISCC, can be used as principle pre-conditions that alternatives have to fulfill or comply with (assuming a comparative analysis with AgBalance™ has been initiated).

GRI (Global Reporting Initiative): BASF is an organizational stakeholder and reports, according to GRI principles. For example, BASF's 2011 report has been labeled A+ by GRI. While GRI principles are focused on the reporting of corporate sustainability criteria, they are not specific to agriculture. However, GRI Biodiversity indicators EN11-EN15 have influenced the development of some indicators in the Biodiversity category of AgBalance™; e.g., endangered species and protected areas.

WBCSD (World Business Council for Sustainable Development): BASF is member of WBCSD. The 'Guide to Corporate Eco-system Valuation' provides guidance on how corporations can evaluate their relationship with the eco-system and how they use eco-system services such as clean water and air, renewable raw-

materials. BASF sees AgBalance™ as supporting the implementation of WBCSD-inspired principles.

European Water Partnership: BASF is a strategic partner in this alliance, which has the overall goal of developing a global standard for water stewardship. AgBalance™ indicators 'Water emissions', 'Water consumptive use' and parts of the 'Biodiversity' indicator relate to the principles, set out in this standard.

3.4. Documentation:

As required under NSF P352 Part A, BASF is submitting a written document describing the elements of the BASF AgBalance™ methodology. BASF is currently using GaBi software from Thinkstep to evaluate EEA studies and will be utilizing this software for AgBalance™. Other equivalent calculation model may be programmed in other software for use in AgBalance™ studies.

3.5. EEA Comparison:

EEA6, EEA10 and LCaflex: In order to address varying needs according to industry and geographic region three separate but similar Eco-efficiency Assessment tools have been developed. The EEA6 and EEA10 have defined environmental impact categories as well as set impact assessment methods. The EEA6 includes six environmental impact categories expected to adequately cover environmental impact for most chemical products and processes. The EEA10 includes impact categories which cover additional environmental aspects that become significant, for example assessments including bio based materials or agricultural studies. Therefore in all AgBalance™ studies, at a minimum an EEA10 will be assessed. The LCaflex is, in principle, completely flexible both in terms of environmental impact categories as well as impact assessment methods (see Table 2). However, the Relevance Check ensures that for each EEA6 and LCaflex sufficient environmental impact is covered and the most relevant impact categories are included. If this is not the case, then an EEA10 assessment is required.

Table 2: Impact categories for EEA6 and EEA10 (required) and LCaflex (optional)

EEA6	EEA10	LCaflex
Abiotic depletion potential	Abiotic depletion potential	Abiotic depletion potential
Global warming potential	Global warming potential	Global warming potential
Photochemical ozone creation potential	Photochemical ozone creation potential	Photochemical ozone creation potential
Acidification potential	Acidification potential	Acidification potential
Human toxicity potential	Human toxicity potential	Ozone depletion potential
Eutrophication (marine and freshwater) or ecotoxicity	Eutrophication (marine and freshwater) or ecotoxicity	Consumptive water use
	Ozone depletion potential	Land use
	Consumptive water use	Eutrophication (terrestrial)
	Land use	Eutrophication (overall)
		Eutrophication (marine)
		Eutrophication (freshwater)
		Respiratory inorganics
		Ionizing radiation
		Human Toxicity potential
		Human Toxicity potential (cancer)
		Human Toxicity potential (non-Cancer)
		Particulate matter
		Ecotoxicity potential (freshwater)
		Ecotoxicity potential (terrestrial)
		Ecotoxicity potential (marine)

3.6. Preconditions:

The basic preconditions in BASF AgBalance™ are as follows: 1) products or processes studied have to meet the same defined customer benefit (also known as functional unit), 2) the entire life cycle is considered, 3) data gathering and constructing the system boundaries are consistent with the customer benefit and 4) both an environmental and an economic assessment are carried out.

3.7. Relevance Check:

The Relevance Check ensures that each Eco-Efficiency Assessment (a) covers sufficient environmental impact and (b) includes the relevant environmental impact categories. For the Relevance Check the environmental impact of the EEA10 is defined as 100%. Since AgBalance™ is an agricultural tool, EEA10 will be the method used in AgBalance™, however a Relevance Check should be done to make sure additional environmental impact categories are not ignored if important to the study.

4. Study Goals and Context

4.1. Study Goals:

The starting point for any AgBalance™ study is to determine the specific goals. This provides the broader context and helps to define the target audience, the alternatives for the study and the system boundaries. This definition of the study goals and context also helps to identify the various points along the value-chain (in the life cycle), where sustainability issues are the most prominent and hence have to be mirrored by the choice of system boundaries). To this end, initial research should be conducted to record any economic, environmental, and social aspects, associated with the process or product under consideration. This can range from desk research to additional consultation with specific institutions or data providers as well as potentially extending to wider involvement and discussion with stakeholders, like NGOs, research institutes and authorities. Also, the criteria for decision making is defined based upon consideration of economies, markets, and innovations. It will be reported and assessed according to ISO 14040:2006, ISO 14044:2006 and ISO 14045:2012.

4.2. Study Context:

Development of the study goals and context for decision making should include consideration of the following criteria:

4.2.1. Study Drivers, e.g. R&D decisions, capital investment, market differentiation, process optimization, quantify benefits of the sustainable changes made to products, regulatory issues, response to green-washing claims, etc.

4.2.2. Geography, e.g. global, national/regional, or local

- 4.2.3.** *Scenario and Horizon*, e.g. 3 years, 10 years, 40 years, or other timeframe
- 4.2.4.** *Engagement*, e.g. customers, regulators, consumers, academics, non-governmental organizations (NGOs), internal use, etc.
- 4.2.5.** *Life Cycle*, e.g. full life cycle, supply chain, production etc.
- 4.2.6.** *Product and Market*, e.g. one product/one market, few products/one market, one product/few markets, all products/all markets etc.
- 4.2.7.** *Economy*, e.g. developed, emerging, or under development
- 4.2.8.** *Innovation*, e.g. incremental, gap closure, step change

The definition of the study goals and the scope also helps to identify the various points along the value chain (in the life cycle), where sustainability issues are the most prominent. Where this occurs, they should be included in the choice of system boundaries. To this end, initial research should be conducted to capture the economic and environmental aspects of the processes or products under consideration. This can range from desk research to additional consultation with specific institutions or data providers, or even extended to a wider involvement and discussion with various stakeholders. The range selected depends on both the complexity of the study and the requirements of the customer. The results of the analysis will also be used to make decisions on the specific data sources to be used within the study.

5. Functional Unit, Alternatives and System Boundaries

5.1. Functional Unit:

The term functional unit (customer benefit) is defined in the International Standard ISO 14040 as the “quantified performance of a product system for use as a reference unit in a life cycle assessment.” For BASF AgBalance™ the term functional unit (FU) or customer benefit (CB) is used as the defined level of output and basis of comparison in an Eco-efficiency assessment. The CB will be defined specific to each BASF AgBalance™ study and will take into consideration the elements described in Section 4 and incorporate a life cycle perspective in accordance with ISO 14040 and 14044. For example, as discussed in Section 4, engagement, geography, market, scenario and horizon, economy, life cycle, and level of innovation should all be considered when selecting the CB. Justification will be provided as to the reasons for selecting a particular CB.

5.2. Alternatives:

These represent the products or processes that will be compared in the AgBalance™; a minimum of two alternatives will be included. The alternatives

will be defined specific to each AgBalance™ and will take into account the CB, system boundaries and consideration of the elements described in Section 4. Each alternative must be analyzed against the same functional unit and justification will be provided as to the reasons for selecting particular alternatives.

5.3. System Boundaries:

The scope of any BASF AgBalance™ is defined by its system boundaries, which define the specific elements of raw material extraction, acquisition, transportation, production, use, and disposal that are considered as part of the analysis. The studies consider the entire life cycle but then may concentrate on the specific stages in a life cycle where the alternatives under consideration differ. Following the ISO guidance, the practitioners ensure that an overall view about alternatives are given and the concentration on specific life cycle stages do not change the overall order of alternatives compared in the system. It is important to note that the same life cycle stages must be included when analyzing each alternative.

Process steps for the life cycles that are deemed to be the same, or sufficiently similar, for all alternatives under consideration do not have to be included in the analysis. For example, if the study is comparing three different manufacturing processes for the identical chemical X, then the use and the disposal phases do not have to be taken into account. Expert opinion is used when deciding if process steps can be excluded from the analysis. The written Final Report and/or Final Presentation shall clearly state those process steps that were not included in the analysis and consideration should be given in the data quality assessment as to the impact of exclusion.

The system boundaries will be defined specific to each study and will take into account the CB, the alternatives analyzed and consideration of the elements described in Section 4 above as well as ISO 14040, 14044 and 14045. Justification will be provided as to the reasons for selecting particular system boundaries. An example of three system boundaries is shown conceptually in Figure 2.

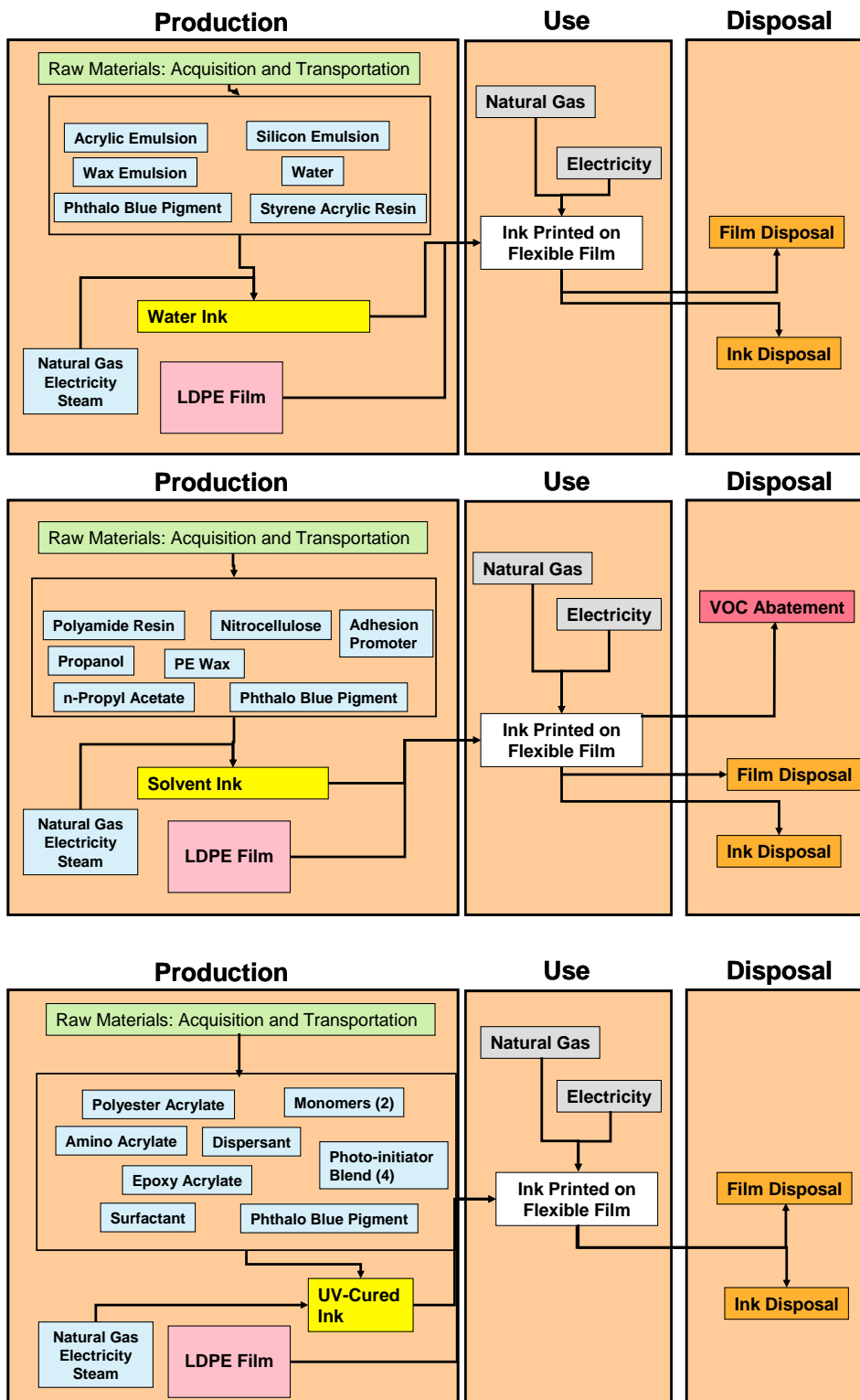


Figure 2: Conceptual diagrams of system boundaries for three technologies (Top: Water-based, Middle: Solvent-based, Bottom: UV-Cured)

6. Environmental Impact Metrics

6.1. Overview:

For BASF AgBalance™ studies, environmental impact is characterized using ten impact categories following the EEA10 approach. The overview of required (for EEA6 and EEA10) or optional (for LCAflex) impact categories is given in Table 1. The assessment methods used for the different impact categories are fixed in EEA10 but are flexible in LCAflex to take into account specific customer needs. LCAflex will be evaluated in AgBalance™ to make sure other environmental impacts are not overlooked as important.

6.2. EEA10 Impact Assessments:

The following assessment methods are used in the EEA10 to determine the included impact categories.

Environmental impact categories	method [source]
ADP / abiotic depletion potential	EU PEF [van Oers] ⁷
GWP / global warming potential	EU PEF [IPCC] ⁸
POCP / photochemical ozone creation potential	EU PEF [Van Zelm] ⁹
AP / acidification potential	EU PEF [Seppälä] ¹⁰
ODP / ozone depletion potential	EU PEF [WMO] ¹¹
Eutrophication potential (freshwater, marine)	EU PEF [Struijs] ¹²
Ecotoxicity potential	EU PEF Rosenbaum] ¹³
Human toxicity potential	BASF [Landsiedel, Saling] ¹⁴
Consumptive water use	FWC [Pfister] ¹⁵
Land use	EU PEF [Milà i Canals] ¹⁶

The specific scientific models used in EU PEF are shown in Table 3. The BASF method for determining the Human Toxicity Potential is described in [Landsiedel & Saling 2002]¹⁴. More details regarding the BASF Human Toxicity Potential are given in section 6.4. The Pfister methodology for consumptive water use is described in Pfister 2009¹⁵. The Land use methodology from EU PEF standards is based on the Soil Organic Matter (SOM) modeling.¹⁶

Table 3: EU PEF impact categories and impact assessment models¹⁶

EF Impact Category	EF Impact Assessment Model	EF Impact Category indicators	Source
Climate Change	Bern model - Global Warming Potentials (GWP) over a 100 year time horizon.	kg CO ₂ equivalent	Intergovernmental Panel on Climate Change, 2007
Ozone Depletion	EDIP model based on the ODPs of the World Meteorological Organization (WMO) over an infinite time horizon.	kg CFC-11 equivalent	WMO, 1999
Ecotoxicity for aquatic fresh water	USEtox model	CTUe (Comparative Toxic Unit for ecosystems)	Rosenbaum et al., 2008
Human Toxicity - cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Human Toxicity - non-cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Particulate Matter/Respiratory Inorganics	RiskPoll model	kg PM _{2.5} equivalent	Humbert, 2009
Ionising Radiation - human health effects	Human Health effect model	kg U ²³⁵ equivalent (to air)	Dreicer et al., 1995
Photochemical Ozone Formation	LOTOS-EUROS model	kg NMVOC equivalent	Van Zelm et al., 2008 as applied in ReCiPe
Acidification	Accumulated Exceedance model	mol H ⁺ eq	Seppälä et al., 2006; Posch et al., 2008
Eutrophication - terrestrial	Accumulated Exceedance model	mol N eq	Seppälä et al., 2006; Posch et al., 2008
Eutrophication - aquatic	EUTREND model	fresh water: kg P equivalent marine: kg N equivalent	Struijs et al., 2009 as implemented in ReCiPe
Resource Depletion - water	Swiss Ecotoxicity model	m ³ water use related to local scarcity of water	Frischknecht et al., 2008
Resource Depletion - mineral, fossil	CML2002 model	kg antimony (Sb) equivalent	van Oers et al., 2002
Land Transformation	Soil Organic Matter (SOM) model	kg (deficit)	Milà i Canals et al., 2007
¹ CFC-11 = Trichlorofluoromethane, also called freon-11 or R-11, is a chlorofluorocarbon. ¹¹ PM _{2.5} = Particulate Matter with a diameter of 2.5 µm or less. ¹¹¹ NMVOC = Non-Methane Volatile Organic Compounds ¹¹¹¹ Sb = Antimony			

6.3. Additional AgBalance assessments:

6.3.1. Biodiversity State (state indicator)

In AgBalance™, the vulnerability status of biodiversity in a particular region is assessed by the number of endangered species published in the IUCN Red List for that region.¹⁷ For Germany, the number of Red List species are assigned a biodiversity state of 0.7. This definition is based on the published German national biodiversity index. Other regions are assigned values through interpolation with zero endangered Red List species, corresponding to a biodiversity state indicator of 1, and 4000 Red List species to an indicator value of 0.1.

6.3.2. Agri-Environmental Schemes (increase factor)

Farmers may receive funding from Agri-Environment Schemes for services that promote elements of biodiversity. Examples are flower strips (to support pollinators), pre-agreed time of mowing (to improve the breeding success of meadow-inhabiting birds) or the support of traditional farming practices. Programs include the Conservation Reserve Program (US Department for Agriculture Farm Service Agency) and subsidies paid under Pillar 2, Axis 2, of the EU Common Agricultural Policy agreement. Determining the evaluation of the performance value (1.0 – 1.5) is specific for each study, according to the following protocol. The lowest performance value of one (1.0) is assigned to zero funding. The optimal performance value of 1.5 is given to the maximum attainable funding in the countries or regions that are included in the specific study. Intermediate values are then calculated from linear interpolation.

6.3.3. Protected Areas (increase factor)

The availability of protected (frequently but not always uncropped) zones is a very important type of protection measure that promotes biodiversity in general. This indicator measures any increases in protected area coverage.¹⁸ The indicator, "Protected Area Coverage", as defined and published by the Biodiversity Indicators Partnership (BIP), is used.¹⁹ The protected area coverage (PAC) indicator is calculated, using the designated national protected areas as recorded in the World Database of Protected Areas (WDPA).²⁰ The WDPA provides the most comprehensive, global and spatial dataset on marine and terrestrial protected areas available. The data in the WDPA is obtained from national and regional authorities as well as from non-governmental organizations. The WDPA uses the IUCN definition of a Protected Area²⁰. The evaluation of the performance value (1.0 – 1.5) is calculated using the following protocol: the lowest value (1.0) is defined for 10 percent Protected Area Coverage (PAC) and the highest value (1.5) for 30 percent PAC. Intermediate values are then calculated from linear interpolation.

6.3.4. Eco-toxicity (decrease factor)

Plant protection products – including plant-incorporated protectants, such as GMO crop varieties containing Bt-toxins for insect resistance – have the potential to influence biodiversity. This potential is dependent on the product-specific ecotoxicity profile of each compound, which are tested in laboratory, semi-field and field conditions for registration purposes. Data for short-term (acute) and long-term (chronic) eco-toxicity of plant protection products on earthworms, honey bees, rodents, birds, water fleas and fish are therefore available from pesticide toxicity databases.²¹ Using the Initial Dose concentration of the crop protection products, the LD50 values are determined by dilution. The eco-toxicity potential of plant protection products is calculated by designing the LD50 values of these products along a logarithmic scale with no dilution being assigned the least worst value (1.0) and a dilution of 0,0001 assigned the worst score (0.6). This process is followed for all crop protection products as well as for short and long-term toxicity. The resulting ecotoxicity score is then multiplied by the amount of

crop protection product for each active ingredient, applied in g / ha / a. The final ecotoxicity potential is calculated by adding the individual values for all crop protection products. Finally, the indicator value is returned to the category scale within the biodiversity indicator (0.6 – 1.0). This is achieved through a step-wise function, where the best score (1.0) is assigned to alternatives having a low ecotoxicity potential and the worst score (0.6) is assigned to the high ecotoxicity score.

6.3.5. Farming intensity (decrease factor)

Farming intensity, i.e. the intensity in the number and types of activities that occur in the field as result of farming practices, such as plowing, mechanical treatment, fertilization, crop protection etc., influence important elements in primary diversity, associated with ecosystems. The trans-European study of Geiger et al.²², shows that there is a significant correlation between biodiversity and yield. In AgBalance™, farming intensity is therefore assessed indirectly as a function, located between the maximum attainable yield and the actual yield of the alternative under study. Evaluating the performance of this indicator is done by plotting the percentage of maximum attainable yield on a scale from the worst score (0.6), relating to 100 percent of maximum attainable yield, to the best score (1.0) for 20 percent of maximum attainable yield. A possible difference between the maximum attainable yield and the actual yield has to be clearly linked to measures that are promoting biodiversity, e.g., extensification.

6.3.6. Nitrogen Surplus (decrease factor)

Low rates of natural or synthetic fertilizer promote biodiversity since species-rich plant societies are found in soils that are nitrogen-poor. Therefore, a nitrogen surplus is rated as detrimental for biodiversity while AgBalance™ gives no credits for production systems that are nitrogen depriving. The performance of this indicator is evaluated by plotting the N-balance on a linear scale with the best score, (1.0) reached at minus 50 kg N/ha and the worst score (0.6) at a surplus of 150 kg N/ha.

6.3.7. Potential for intermixing (decrease factor)

The goal of this indicator is to assess the potential of specific crops to intermix with the natural vegetation. Although the potential for outcrossing – coupled with the bewildering range of modern crop varieties and their genes – is mostly discussed in relation to genetically modified plants, all crop species have the potential to intermix with natural vegetation. The intermixing potential is crop-specific and highly dependent on the geographic region where the crop is grown (climatic conditions for growth and survival; presence of pollinators and wild relatives). This indicator considers factors like the potential for pollen dispersal through wind and insects, the availability of wild relatives, the size of seed banks and seed persistence in soils as well as its adventitious presence in machinery. A score is determined for each of these factors, ranging from worst (0.6) to neutral (1.0) performance, based on a defined set of decision criteria. The final score is the average of the individual scores.

6.3.8. Crop Rotation (bidirectional factor)

High crop rotation rates provide a diversity of plant-based resources that promote biodiversity, such as root diversity (promoting soil organisms), flowers (promoting pollinators), and foliage diversity (promoting plant feeding animals). From a biodiversity perspective, the contribution of crop rotation can be summarized as follows: high rates contribute to biodiversity increase and low rates to biodiversity decline. The evaluation for this indicator is conducted on a linear scale for field crops. One element in crop rotation commands the lowest score (0.6), three crops in a two-year rotation are deemed as neutral (1.0) and seven elements in crop rotation within two years are assigned the highest score (1.5). Crop rotation regimes may consist of several elements, including intercropping of coverage or use of fertilization crops that promote soil fertility.

6.3.9. Soil

General Remarks - The AgBalance™ methodology for the Soil impact category uses different indicators, which are designed to capture the main impacts to long-term soil quality as a result of human agricultural activity on arable land. These indicators consist of: Soil Organic Matter balance, Nutrients (N, P, K) balance, Soil Compaction Potential, and Erosion.

6.3.9.1. Soil Organic Matter Balance (assessed kg carbon /ha)

Organic soil matter is an important in determining soil quality as it influences the chemical, physical and biological functioning of soils, especially in relation to the soil's capacity to store nutrients and water, its buffering and filtering capacity, its biodiversity and structure. While it is obvious that a reduction in organic matter content will eventually impair soil quality, the reverse is also true – high organic content is not a positive development as this leads to high mineralization of nitrogenous compounds and effluxes in the hydro- and atmosphere. The method used in AgBalance™ assesses anticipates changes in the soil carbon balance due to cropping and allows the opportunity for the soil to react to these influences, as published by Hülsbergen et al.²³ The organic matter balance is a function of the influx of organic matter through organic fertilizers (plant residues, manure, compost) and the crop specific change in organic matter (due to type and intensity of soil preparations as well as the characteristic of its root system). To identify the balance of organic matter, the degradation of organic compounds is measured against the influx of degradable material. Soil organic matter is quantified as organic carbon (C).

In AgBalance™, the carbon balance is calculated, using a computer model from the Bavarian State Office for Agriculture (Bayerische Landesanstalt für Landwirtschaft). The carbon balance result is subsequently evaluated, using a model designed by Hülsbergen et al.²⁴ Effectively, a carbon balance between minus 100 kg C/ha and

plus 200 kg C/ha is rated optimal (1.0) with scores decreasing in a linear fashion for lower or higher carbon balances.

6.3.9.2. Nutrients Balance (assessed kg nutrient / ha)

Assuming the ecological impacts of over-fertilization, the input of fertilization should be optimized, according to both the crop's requirements and the nutrient status of the soil. This approach ensures an appropriate supply of nutrients for crops. The nutrient balance is therefore a function of the amount of fertilizer applied and the amount of nutrients retrieved through the harvesting of the crop. This balance is further adjusted to factor in the ability of the soil to mineralize and provide nutrients, as indicated by soil nutrient supply classes. The nitrogen balance considers different sources e.g., nitrogen fixation by leguminous crops. The result of the nutrient balances is subsequently evaluated, using nutrient-specific models with optimal scores (1.0), approximately equating to an equal nutrient balance of zero and with decreasing scores for either nutrient deprivation or over-fertilization.

6.3.9.3. Potential for Soil Compaction (performance score)

Soil compaction refers to the deterioration of soil structure (the loss of soil features) due to mechanical pressure, predominantly from agricultural practices. The method for assessing soil compaction in AgBalance™ has been devised by Dr. Paul Newell-Price et al. at ADAS UK Ltd.²⁴ The aim of the method is to produce a simple empirical relationship that allows the soil compaction risk to be assessed, either at field, farm or regional level, taking into account any parameters/factors that have an influence on soil compaction. These factors can be related to the nature of the soil being assessed, using the Harmonized World Soil Database²⁵, climate as well as considering the way the soil is being managed. The individual evaluation factors are given a numerical score of 1 (low risk for compaction) to 3 (high risk). The overall risk for soil compaction is evaluated by a multiplication of all factors. The resulting indicator value for each alternative is normalized to the worst alternative. This normalized result is subsequently used as a parameter in the calculation of the soil index.

6.3.9.4. Soil Erosion (t/ha/a)

In AgBalance™, soil erosion caused by runoff is calculated, using the Universal Soil Loss Equation (USLE). This equation predicts the long term average annual rate of erosion in a field, based on slope, rainfall pattern, soil type, topography, crop system, and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a slope and does not take into account additional soil losses that might occur from gully, wind or tillage erosion. Where these effects have a significant impact, they are factored in by appropriate modeling, e.g., wind erosion through

estimates by the Revised Wind Erosion Equation. In addition, alternative management and crop systems can be evaluated to determine the adequacy of conservation measures in farm planning.²⁶ In AgBalance™, the absolute calculated soil loss – resulting from the USLE calculation for each alternative – is used to relatively compare alternatives with the normalized result. This normalized result is subsequently used as a parameter in the calculation of the soil index.

6.4. LCAflex Impact Assessments:

For LCAflex the selection of impact categories is flexible and may include, in addition to the EEA10 categories, the categories shown below. At a minimum, the impact categories indicated by the Relevance Check are required. The assessment methods may be chosen from standard market tools such as EU PEF, Traci 2.1, ReCiPe and CML 2002. In addition, published and accepted methodologies for specific impacts may also be applied as described in section 6.2 (for example consumptive water use according to Pfister 2009 and BASF Human Toxicity Potential [Landsiedel and Saling 2002]).

Additional Environmental impact categories (LCAflex)

- Eutrophication (terrestrial)
- Eutrophication (overall)
- Respiratory inorganics
- Ionizing radiation
- Human toxicity potential (cancer)
- Human toxicity potential (non-cancer)
- Ecotoxicity potential (freshwater)
- Ecotoxicity potential (terrestrial)
- Ecotoxicity potential (marine)

This is an open list and can be extended (with published impact categories/methodologies) depending on the needs of the customers in various industries and in different regions.

All these impact categories may be aggregated to a total environmental impact if: (a) at least all the impacts indicated by the Relevance Check are included (b) if weighting factors obtained by a poll run by professional third parties exist for all impact categories (c) there is no double counting of an impact category (for example, if Eutrophication (overall) and Eutrophication (terrestrial) may not both be included in the aggregation to a total environmental impact since the terrestrial component would be counted twice).

It is possible to report additional categories in the LCAflex without including these in the aggregated total environmental impact.

6.5. The BASF Human Toxicity Potential Method:

For BASF EEA the human toxicity potential is assessed not only for the final products, but for the entire pre-chain of chemicals used to manufacture the products as well. The quantities of each substance to be included in the analysis must be inventoried in order to calculate toxicity potential. The result is an assessment of life cycle toxicity potential that includes the final products as well as the reactants needed for their manufacture. In addition, the toxicity potential is also quantified for the use and disposal stages of the life cycle. The general framework for performing the analysis of toxicity potential is described by [Landsiedel and Saling]¹² and, in the first version, was based upon the Hazardous Materials Regulations (R-phrases) as outlined in Directive 67/546/EEC. The R-phrase system was widely used in Europe for the classification of a substance's various toxic effects but has been replaced by the H-phrase system of the Global Harmonized System (GHS). BASF Human Toxicity Methodology has been adapted to the new GHS classification scheme by mapping the R-phrases to the H-phrases of the new system.

6.6. De Minimis Levels:

Materials or processes can be excluded from consideration in the key environmental impact metrics if they are viewed as being at de minimis levels (i.e. below minimum levels). Thus, eco-profiles or toxicity potential scores are not required for de minimis materials. The cutoff criteria for raw materials and energy consumption is < 1.0% while the cutoff criteria for toxicity potential is consistent with the OSHA Hazard Communication Standard requirements for development of Material Safety Data Sheets (MSDSs). In this case, the de minimis level is 1.0% unless the listed toxic/hazardous chemical is an OSHA-defined carcinogen. The de minimis level for OSHA-defined carcinogens is 0.1 %.

Consideration is also given to the cumulative percentage of de minimis components not being considered for specific materials or unit operations. If the cumulative de minimis quantity not included in an impact assessment of a material or process is greater than 3%, then the project team will evaluate the significance and what potential impact this may have on the study results. As this will be done on a case by case basis, the decision of the project team and justification on what, if any, course of action was taken shall be clearly communicated in the final report.

7. Economic Metrics

7.1. Statement of Intent:

It is the intent of the BASF AgBalance™ methodology to assess the economics of products or processes over their life cycle and to determine an overall total cost of ownership for the identified customer benefit (\$/CB). The approaches for calculating costs vary from study to study. When chemical products of manufacture are being compared, the sale price paid by the customer is used followed by any subsequent costs incurred by its use and disposal. When different production methods are compared, the relevant costs included are

normally further itemized along the various life cycle stages and include for example, operating costs, maintenance costs, the purchase and installation of capital equipment, depreciation, and waste disposal costs. The costs incurred are summed and combined in appropriate units (e.g. dollar or EURO) without additional weighting of individual financial amounts. Regardless of the method used, the BASF AgBalance™ methodology will incorporate

- the real costs that occur in the process of creating and delivering the product to the consumer;
- the subsequent costs which may occur in the future (due to tax policy changes, for example); and
- costs having an ecological aspect, such as the costs involved to treat wastewater generated during a manufacturing process.

7.2. Economic Cost Metrics:

The exact metrics chosen for a study depend upon the scope of the study, the identified functional unit, the alternatives considered, system boundaries and consideration of the elements described in Section 4. Economic metrics included in BASF AgBalance™, each of which must be consistently applied to each alternative, cover all relevant costs and, at times, revenue and, at a minimum, include consideration of the following:

- Raw material;
- Labor;
- Energy (electric, steam, natural gas, and other fuels);
- Capital investment;
- Maintenance;
- EH&S programs and regulatory costs;
- Illness & injury costs (medical, legal, lost time);
- Property protection & warehousing costs;
- Waste costs (hazardous, non-hazardous);
- Transportation;
- Training costs; and,
- Others, as applicable (e.g. taxes, levies).

For the life cycle module of the Farming Step, several specific costs, associated with agricultural production, have to be considered. The AgBalance™ methodology will incorporate (but is not restricted to) the following economic metrics, specific for agricultural activities:

Variable costs

- (1) Costs for soil preparation
- (2) Costs for seed and sowing
- (3) Costs for crop protection
- (4) Costs for harvest
- (5) Costs for drying
- (6) Costs for machinery

Fixed costs

- (7) Depreciation
- (8) Maintenance costs
- (9) Insurance
- (10) General repair cost
- (11) Investment
- (12) Employees

7.3. Macro-economic indicators:

For each alternative, the macro-economic indicators are quantified, according to the principles outlined below. The resulting values, expressed in monetary value per hectare, are then summed, according to the formula:

Macro-economic Indicator Result (a) [USD/ha]

= Farm Profits (a) [USD/ha] – Subsidies (a) [USD/ha] + Productivity (a) [USD/ha].

Here (a) denotes the specific result for a given alternative. The macro-economic indicator value is then aggregated with the costs in order to calculate the economic score for each alternative.

(1) Subsidies (monetary value per unit of area)

Negative - lower are seen to be better

As subsidies make up a large percentage of farm income in many countries, this aspect is taken into account. The definition of subsidies in this instance includes all direct payments to the farmers by national or supranational authorities, excluding those paid for agri-environmental schemes. However, subsidies per se, have a distorting effect on the national and international economy and create uncertainty for the farmer in the mid- to long-term. Economists also argue that subsidies for agricultural production over the long-term result in increases in the cost of leasing land.

(2) Productivity (monetary per unit of area)

Positive - higher numbers are seen to be better.

The indicator is defined as the (i) the absolute contribution that production makes for each alternative to the national agricultural gross domestic product (GDP) per unit of area (ii) weighted by what agricultural GDP contributes to the total national GDP, expressed as a percentage. By combining these two features, each alternative's economic contribution to the societal role of agriculture is duly quantified. In cases where agriculture makes up a larger percentage of total GDP, the second factor can be viewed as a characterization factor that gives agricultural GDP per area a higher impact

(3) Farm Profits (monetary value per unit of area)

Positive - higher numbers are seen to be better)

This metric is an important economic indicator of profitability. Profitability is closely related to sustainability as sustained economic activity ultimately drives environmental and social responsibility. Profits are quantified per unit of area

(e.g., hectare) since economic figures related to profitability, like profits or subsidies, cannot be meaningfully related to a certain crop production volume. For example, increasing the yield per hectare might result in a higher profit per hectare and higher farm business profits but not necessarily in a higher profit per ton of product. Also, crop yield is not the only driver of profits. For example, extensive organic farming may have substantially lower yields than conventional farming but can nonetheless deliver high profits through higher sales prices.

7.4. Time and Regional Value of Money:

Cost analysis in BASF AgBalance™ can be calculated as either a point in time or over a period of time that takes into account the time value of money. If the analysis is performed to account for the time value of money, then a Net Present Value, or similar metric, shall be calculated; with the time frame of the cash flow and assumed discount rate specified. The regional currency of the costs calculation shall be specified (e.g. US dollars (\$), Euros (€)) and exchange rates shall be applied when necessary.

7.5. Cost Dimension Importance:

In a BASF AgBalance™, the cost dimension and environmental dimension are weighted equally.

8. Social Factors

Social parameters are not addressed specifically in the ISO LCA standards. There are no other consensus standards that can be referenced to define the criteria for a social LCA. AgBalance™ represents BASF's best attempts to create a social LCA framework through the identification and use of relevant factors associated with life cycle principles. Even though there are no industry standards available, important developments from different groups like the UNEP/SETAC working group or existing standards in the Agro-sector like RISE were considered.

The social assessment in AgBalance™ is built on the SEEBALANCE® scheme for social LCA, which was developed in 2005 by the Universities of Karlsruhe and Jena, the Öko-Institut (Institute for Applied Ecology) Freiburg e.V., and BASF respectively.^{4/5} During this development process, concrete targets for social sustainability for products and processes were derived. This was done through analysis of more than 60 published studies on the topic of social goals by various institutions. As a result, more than 700 goals and more than 3,200 indicators were systematically recorded, categorized and summarized.

For AgBalance™, this set of social parameters has been extended and in parts modified, to address specific agricultural sustainability topics, e.g., access to land, level of organization or international trade with agricultural products. These topics were initially identified through a stakeholder process in 2009 and 2010, organized by BASF, and were subsequently discussed with leading experts. Feedback from this process was then integrated into the development of these indicators.

Social factors as part of AgBalance™ means integrating social parameters into the assessment model, taking all three pillars of sustainability into account, as originally proposed in the definition of sustainability by the UN Brundtland commission. The strength of a life cycle approach is that social aspects along the life cycle, e.g., the considered value chain of a product are tracked and any problems associated with shifting from one life cycle stage to another is avoided. The assessment of social indicators shows the sustainability risks or weaknesses, as well as strengths of any given alternative. It is worth noting that any alternatives that reflect conditions conflicting with legal rights or basic human rights will not be assessed in an AgBalance™ study.

In the specific case of child labor, an assessment of an alternative, i.e., comparing an agricultural process with child labor versus a process without child labor will not be subjected to comparative analysis within AgBalance™. However, child labor might occur in upstream processes, e.g., mining of raw materials that are part of the pre-chain of many manufactured goods. In such a case AgBalance™ can address and quantify this sensitive aspect in order to be transparent and comprehensive on the life cycle of a product system,

8.1. Social Factors for Up- and Downstream Processes

The assessment of social impacts in the upstream and downstream processes within AgBalance™ is based on the SEEBALANCE® method⁴. This approach to social assessment is based on a sectoral approach where key social figures from different industry segments are related to their corresponding production volumes. The resulting social profiles for processes or products then assume a format, equivalent to the eco-profiles in the environmental section.

For all social indicators, the production volumes are related quantitatively to a given industry sector (e.g., 'occupational diseases per kg product'). With this approach, it is possible to relate the inputs and outputs from the environmental life cycle assessment to the individual social indicators. To this end, different statistical databases are combined to connect social indicators to production volumes. The link between products and corresponding social impacts is made by a sector assessment. This is based on either the 'Nomenclature générale des activités économiques dans les Communautés Européennes' (NACE, general nomenclature of economic activities in the European Community) – an initiative that classifies all industries into different sectors – or the ISIC, the International Standard Industrial Classification. All products can be linked to these NACE/ISIC codes, using the product classification list (CPA = Classification of Products by Activity). The numbers for official statistics in Europe are frequently stored in this format.

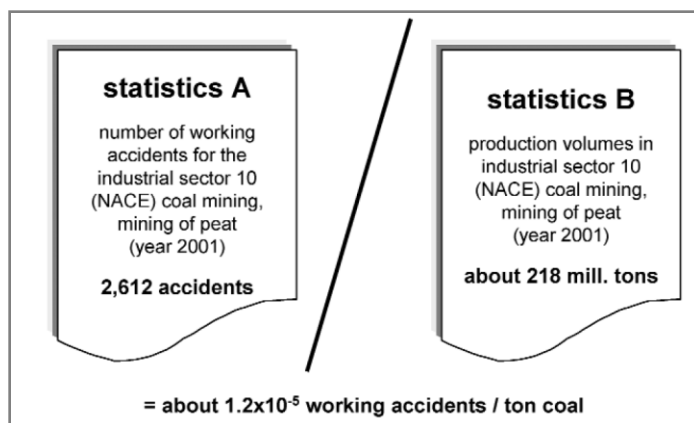


Figure 3: The relation between social indicator and product (example).

Using statistical data for both production volumes and working accidents, a database for each industry sector is created (see Figure 3). This procedure is repeated for every indicator in the SEEBALANCE[®] scheme.

When comparisons between national currencies are made, all monetary quantities are adjusted, using purchasing power parity, Analogous to the process of producing an (environmental) eco-profile, an inventory is taken of the social impacts for a certain product or process. These are then stored in a social profile. In an AgBalance[™] study, the social impacts are quantified, according to the customer benefit, and aggregated for all up- and downstream life cycle segments.

8.1.1. Stakeholder Category Employees

8.1.1.1. Working accidents and fatal working accidents (number per CB)

Negative – lower numbers are seen to be better.

The definition of this indicator evaluates the potential of working accidents: Events are considered as working accidents if the affected staff members are unable to work for more than three days. The number of working accidents is recorded in association with an activity (production). The numbers are expressed as the numbers of accidents or fatal accidents.

8.1.1.2. Occupational diseases (number per CB)

Negative – lower numbers are seen to be better.

Occupational diseases are illnesses that can be definitively attributed to occupational activity. The number of occupational disease is recorded in association with an activity (production). The numbers are expressed as the number of occupational disease cases.

8.1.1.3. Human toxicity (toxicity score per CB)

Negative – lower numbers are seen to be better.

The assessment of human toxicity potential is not based on statistical figures but rather on a calculation scheme for chemical substance, described below. The toxicity potential is assessed not only for the final products but also for the entire pre-chain of chemicals, used to manufacture the products. An inventory of the quantities of each substance, included in the analysis, must be maintained in order to calculate overall toxicity potential. The result is an assessment of life cycle toxicity potential that includes not only the final products but also the reactants required in its manufacture. In addition, the toxicity potential is also quantified for the use and disposal stages of the life cycle. The general framework for performing the analysis of toxicity potential is described by Landsiedel and Saling²⁷ and is based upon the Hazardous Materials Regulations (R-phrases), as outlined in Directive 67/546/EEC. This method was chosen because in order to score the toxicity of a substance, the consideration of all possible effects is needed. The R-phrases system is widely used in Europe for the classification of a substance's various toxic effects. With the introduction of the Globally Harmonized System (GHS) for the classification of hazards, the existing scheme adapts to the new classification by mapping the R-phrases to the new system categories.

For AgBalance™, the toxicity potential assessment focuses on human toxicity potential. The scoring system (Table 4) is based on six groups of toxic properties, described as H-phrases. Each group is given a score, ranging from 100 to 1,000, based on the severity of the toxic effects. A substance is assigned to one of these groups on the basis of its toxic properties, also described as H-phrases. If there is only one H-phrases for the substance, it will be assigned to the appropriate group. However, if there are additional H-phrases, the substance will be upgraded. However, weak effects or local effects (group 1 and group 2 respectively) or alternatively, the same effect, caused by an additional exposure route (e.g., oral and dermal), will not lead to an upgrade. In general, there is only one upgrade for a substance, irrespective of how many additional H-phrases are present. Scoring for toxicity, based on H-phrases, is conducted, according to the following scheme. Refer to Table 2.

Table 4: Scoring system for toxic properties, as described by H-phrases. A detailed account of the toxicity scheme is provided in the publication by Landsiedel and Saling.²⁷

Hazard Group	ProScale H-Phrase Grouping	Score
6	Combination of two high scores	1000
5	H340, H350, H360, H362	750
4	H300, H310, H330, H334*, H341, H351, H361, H372	550
3	H301, H311, H314, H317, H318, H331, H335, H370, H373	400
2	H302, H312, H332, H371	300
1	H303, H304, H305, H313, H315, H316, H319, H320, H333, H336 and all H-numbers not otherwise listed	100

*H334 grouped in D due to possible consumer uses; discussion should specify if consumer and professional uses should be distinguished

8.1.1.4. Wages and salaries (monetary value per CB)

Positive – higher numbers are seen to be better.

This indicator evaluates the wages for people in (industrial) upstream and downstream processes, expressed in financial terms. To be sustainable, incomes need to reach a level that supports acceptable living standards. Higher wages also contribute to creating societal opportunities for further development through tax contributions to public investments and welfare.

8.1.1.5. Professional Training (monetary value per CB)

Positive – higher numbers are seen to be better.

This indicator evaluates professional training, i.e., informal education through occupational education in the respective industry sectors for upstream and downstream. For example, professional training of employees enhances his/her qualification profile, and contributes to job security, higher wages and employee satisfaction.

8.1.1.6. Strikes and lockouts (lost working hours per CB)

Negative – lower numbers are seen to be better.

Freedom to assemble and a guarantee of human rights are assumed to be preconditions that must be fulfilled. Otherwise, this topic would be critically assessed as a hot spot and might mean that a comparative AgBalance™ study would not be appropriate (kill criterion). Taking this as a basic criterion, the indicator highlights working conditions and the recognition of employee interests.

8.1.2. Stakeholder Category Consumer**8.1.2.1. Human toxicity (toxicity score per CB)**

Negative – lower numbers are seen to be better.

This indicator evaluates potential human health impacts on customers. The assessment takes into account the toxicity potential of materials that are part of the studied system as well as a simple estimate of the exposure risk (toxicity points during use, exposure, and vapor pressure), using the methodology described above in Section 6.1.1.(3). These factors are combined into a performance rating, expressed in 'toxicity points'. This indicator is used to assess any toxicity risks that particularly affect the end-consumer.

8.1.2.2. Functional product characteristics (normalized performance per CB)

Positive – higher numbers are seen to be better.

Additional, relevant product characteristics – which are not considered in any of the other indicators – can be rated here. The indicator must be specifically defined, depending on the product and its requirements. It is evaluated on the basis of technical requirements being fulfilled with subsequent normalization or in some cases with ABC analyses. For example, fuels for combustion engines must fulfill the

requirements for purity and viscosity for use at cold temperatures. This might be a differentiating feature for biodiesel versus conventional fuels. These types of technical requirements and the extent to which they are realized must be considered if one is to arrive at meaningful and balanced results.

8.1.2.3. Other risks (normalized performance per CB)

Negative – lower numbers are seen to be better.

This indicator evaluates the potential risks to human health for any consumers that fall outside the toxicity assessment. The assessment takes into account product characteristics like explosiveness or corrosiveness etc. This indicator particularly assesses any risks that do not arise from farming activities but from upstream and downstream processes.

8.1.3. Stakeholder Category Local and national community

8.1.3.1. Employment (working years per CB)

Positive – higher numbers are seen to be better.

This indicator evaluates the number of working hours associated with the production system for the upstream and downstream processes. It specifically measures the contribution that the product system makes to employment and job creation.

8.1.3.2. Qualified employees (working years per CB)

Positive – higher numbers are seen to be better.

This indicator calculates the working time that qualified employees with a formal degree dedicate to a specific product system versus unskilled worker. A higher level of qualification is associated with improved social status for the employee. Typical benefits include better job security, salary and work satisfaction.

8.1.3.3. Gender Equality (working years per CB)

Positive – higher numbers are seen to be better.

In the assessment of upstream and downstream industrial production steps, this indicator is calculated by referencing the number of female managers (higher level) in the respective industry sectors. In general, gender discrimination limits the potential of families, communities and societies. There is a clear, positive link between gender equality and economic and social development.

8.1.3.4. Integration of disabled employees (working years per CB)

Positive – higher numbers are seen to be better.

This indicator assesses the employment rate for people with severe disabilities in upstream and downstream processes that are part of the product system. Results are expressed as the number of disabled people employed. Integrating people with disabilities into employment is commonly perceived as an indicator of societal development. As major employers in the world economy, it is important that

agricultural and food chain businesses offers employment opportunities for all members of society.

8.1.3.5. Part time workers (working years per CB)

Positive – higher numbers are seen to be better.

This indicator calculates the proportion of part-time workers with reduced working hours in comparison to full-time employees in the upstream and downstream processes, associated with the product system. In this instance, part-time work is viewed positively as it offers workers flexibility in managing their working and personal lives. This is associated with higher levels of satisfaction and well-being.

8.1.3.6. Family support (monetary value per CB)

Positive – higher numbers are seen to be better.

This indicator evaluates – in financial terms – the impact of parental leave and other bonuses offered to employees, who are married and/or have children, including health insurance and support for births, deaths etc. The indicator is included to reflect the support that employees receive for family issues. It measures how institutions and employers value the important role that families play in society.

8.1.4. Stakeholder Category International community

8.1.4.1. Child labor (working hours per CB)

Negative – lower numbers are seen to be better.

As discussed above, child labor is not included in the assessment of agricultural production activities. In short, the customer benefit definition and the definition of alternatives are not designed to assess child labor. However, child labor may still occur in upstream processes, e.g., mining of raw materials that form part of the pre-chain of many manufactured goods. AgBalance™ can address and quantify this sensitive aspect, ensuring visibility and tracking within the life cycle of a product system. Different regions are not excluded from studies as they may be important when considering complete markets and market shares for produced goods. This is important as a basic condition for AgBalance™. It also helps to identify improvement potential for alternatives that are linked with child labor.

8.1.4.2. Foreign direct investment (monetary value per CB)

Positive – higher numbers are seen to be better.

The definition of this indicator is foreign direct investment in developing countries from the perspective of the country under study. Investment in developing countries contributes to that country's economic development through the creation of job opportunities either directly or indirectly through demand for manufactured goods.

8.1.4.3. Imports from developing countries (monetary value per CB)

Positive – higher numbers are seen to be better.

This indicator rates the monetary value associated with the import of raw-materials, industrial goods etc., that are part of the product system for upstream and downstream processes. This specifically relates to situations where goods from developing countries are imported into well-developed countries, resulting in a net amount of money moving from the higher-income to the lower-income region. As it

contributes to the income of local producers, it also supports the economy in the developing region.

8.1.5. Stakeholder Category Future generations

8.1.5.1. Number of trainees (number of persons per CB)

Positive – higher numbers are seen to be better.

This indicator assesses the number of people in formal education within the industrial sectors, associated with the relevant upstream and downstream processes. In order to meet future economic challenges, it is a key societal responsibility to educate future generations to a high standard.

8.1.5.2. R&D expenditures (monetary value per CB)

Positive – higher numbers are seen to be better.

This indicator quantifies the internal and external expenditure of companies in R&D activities. R&D Investment in is seen to positively influence the future development of manufacturing industries. As such, it helps to maintain good, current working conditions as well as sustaining future job opportunities.

8.1.5.3. Capital investment (monetary value per CB)

Positive – higher numbers are seen to be better.

This definition covers the value of replacement and net investment, including general repair, purchase of concessions, patents and licenses (capital investment in € per product masses). A higher rate of investment indicates that the companies associated with the product system enjoy a positive economic situation that allows them to invest. This is an important criterion for sustained economic activity, which supports an improvement in both existing and future working opportunities.

8.1.5.4. Social security (monetary value per CB)

Positive – higher numbers are seen to be better.

This assessment summarizes the payments employers make to health insurance schemes and unemployment insurance, pensions and similar programs for their employees. The evaluation is done by each individual industry sector and relates to upstream and downstream processes that are part of the product system.

8.2. Social Factors for the Farming Module

The goal of these social, indicators is to quantify the relevant social impacts, described above, for the agricultural steps in the life cycle. The required degree of detail does not allow the use of general statistical data for the agriculture sector. Instead, specific data has to be generated and assessed for each indicator, using specific data-sources and algorithms. These indicators are designed to closely match the social sustainability areas, addressed in the assessment of the upstream and downstream processes. Some indicators are specific for the Agro sector, i.e., access to land and the degree of organization by farmers.

8.2.1. Stakeholder Category Farmer

8.2.1.1. Wages (monetary value per CB)

Positive – higher numbers are seen to be better.

The wages of agricultural workers are taken as a criterion for working conditions. They contribute to (i) the material welfare/well-being of employees and (ii) the attractiveness of agriculture as a sector.

The indicator is calculated as a function of the wages and the number of working hours, needed to produce the customer benefit.

8.2.1.2. Professional Training (ratio, training hours per working hours),

Positive- higher ratio is seen to be better.

Professional training benefits the individual farmer/employee as well as the overall farm operation. After all, the individual needs qualifications to ensure continued success and satisfaction in his/her job. Generally, qualified workers are required to ensure the economic success of the farm and to guarantee that proper practices are implemented. Professional Training is defined as non-formal, occupational education, associated with agriculture. This indicator is calculated as the ratio between the working hours spent on professional training relative to the total working hours.

8.2.1.3. Association memberships (ratio, number of memberships and associations per farmer)

Positive – higher ratio is seen to be better.

Membership of agricultural associations, unions and other organizations is seen to be a positive development as it supports and enhances (i) the individual interests of farmers/ employees, (ii) raises public awareness and acceptance of agriculture (iii) increases consumer confidence in agricultural products.

This indicator is calculated by taking the average of the ratio between the membership subscriptions for any agricultural organization as it relates to the total number of workers in the region and sector, as well as the number of all associations, organizations, etc. that serve farmer interests in the region and sector under analysis. This is then divided by the total number of workers in the region and sector.

8.2.2. Stakeholder Category Consumer

8.2.2.1. Residues in feed and food (performance rating, percentage maximum residue level exceedance)

Negative – lower numbers are seen to be better)

The indicator assesses the percentage of food samples that exceed official maximum residue limits (MRLs). The indicator is based on a retrospective analysis of MRL exceedances in food products, based on food monitoring reports by authorities. It is aimed at ensuring consumer safety and confidence.

This indicator assesses the number of exceedances in a defined region over a specific time period (typically a year), using a linear function that takes a value of one, if the exceedances are zero, and a value of 100 if exceedances are measured as

nine percent of the samples (as defined by expert judgement to be a worst case scenario). However, there is no upper limit.

8.2.2.2. Presence of unauthorized/unlabeled GMO in feed and food (performance rating, number of occurrences)

Negative – lower numbers are seen to be better.

This indicator is based on a retrospective analysis of reported occurrences of unlabeled or unauthorized residues of genetically modified organisms (GMO) in food products (based on official food monitoring reports). The indicator is aimed at consumer confidence.

This indicator assesses the number of reported occurrences of unauthorized or unlabelled GMO material, found in food samples in a defined region over a 10-year time period. The number of occurrences is indexed, using regression in time, i.e., one occurrence in the year of assessment is scored as one, whereas one occurrence five years before is scored as 1/5. The final score is the summary over 10 years.

8.2.3. Stakeholder Category Local & National Community

8.2.3.1. Land owner/access (monetary value per CB)

Negative – lower numbers are seen to be better.

Continued and reliable access to land is important for a farmer to plan his operations over the mid-term. In the long-term, it is a prerequisite for investment. A dependency on leased land means risk in terms of land availability and associated costs. Land lease prices are rising globally due to several factors, including property speculation.

This indicator therefore calculates the percentage of leased land – within the agricultural area – that is used for the benefit of the customer, multiplied by the cost of the lease.

For countries covered by the International Fund for Agricultural Development of the United Nations (IFAD), a performance ranking for "Access to Land" (equitable access to productive natural resources and technology) is available²⁸. In AgBalance™, the use of the IFAD indicator system is an alternative approach in studies where (i) the indicator system is available for all countries considered and (ii) discussions with stakeholders and experts have led to the conclusion that the use of the alternative approach is more appropriate, e.g., a well-developed market for land does not exist.

8.2.3.2. Employment (working hours per CB)

Positive – higher numbers are seen to be better.

Higher employment rates and good employment opportunities are generally regarded as positive for the local, rural community and society as a whole.

This indicator therefore calculates the number of working hours – associated with the production system – per customer benefit.

8.2.3.3. Gender equality (deviation from target value)

Negative – lower numbers are seen to be better.

Discrimination by gender limits the potential of families, communities and societies in general. For example, the importance of gender to the agricultural sector was

recently highlighted in a comprehensive report, published by the FAO²⁹. There is a clear, positive link between gender equality and economic and social development. In this indicator, the percentage of women who are farm proprietors or farm managers is assessed in relation to the overall percentage of the female population in society. Deviations to both higher and lower values are rated negatively. However, the analyst generally evaluates which are the major barriers that women have to overcome in order to achieve gender equality. If necessary, the exact definition of the indicator can be adapted to suit study-specific needs, taking the overall context into account (regional, cultural, economic).

8.2.3.4. Integration of Disabled Employees (working hours per CB)

Positive – higher numbers are seen to be better.

Apart from discrimination by race, religion or gender, people with (severe) disabilities are frequently subject to discrimination in labor relations. This fact has been emphasized by ILO and in the ISO26000 Social Responsibility Report.³⁰ This indicator takes into consideration the employment of people with (severe) disabilities relative to the total working hours in the agricultural sector, per customer benefit.

8.2.4. Stakeholder Category International Community

8.2.4.1. Developing countries import / trade balance (monetary value per year)

Positive – higher numbers are seen to be better.

In developing countries, agriculture often contributes to a large percentage of GDP. One strategy is to raise the income of local farmers by exporting produce to other countries. However, the import of agricultural/food products from well-developed countries into developing countries often puts local producers under pressure as they have to compete with the (potentially low) prices of the imported goods.

This indicator rates the import and export value of the good(s) under analysis (e.g., potatoes) as it contributes to the trade between higher and lower income countries. In AgBalance™, the UN Human Development Index of per capita income is used to define how trading countries are ranked with the FAO TRADESTAT database seen as a major data source of import/export values for various agricultural products. A positive trade balance for the country with lower per capita income is favored.

8.2.4.2. Fair trade benefits (monetary value per CB)

Positive – higher numbers are seen to be better.

Producer prices are an important criterion for the social sustainability of agricultural production, especially for small farmers in developing countries. The goal is to compare the producer prices for different alternatives to producer prices on the free market, as provided by the UN Food and Agriculture Organisations database FAOSTAT.³¹ Benefits and premiums, obtained through the Fair Trade program and certified by the Fair Trade Labelling Organizations International (FLO, www.fairtrade.net) are taken into special consideration.

This indicator calculates the summary of benefits, such as guaranteed prices and premiums, paid to producers for each alternative that is associated with the same customer benefit.

8.2.5. Stakeholder Category Future Generations

8.2.5.1. Trainees (number per working hours)

Positive –higher numbers are seen to be better.

Given the challenges that agriculture faces, e.g., the need to increase productivity and consider environmental impacts, educating future farmers is of key importance. This indicator is assessed by calculating the ratio between the number of students, trainees and apprentices (effectively, participants in agricultural programs) and the total working hours of the agricultural labor force.

In this context, education refers to formal education (as defined by the UNESCO International Standard Classification of Education ISCED³²), i.e., courses offered through schools, colleges and universities that have dedicated agricultural content.

8.2.5.2. Social security (monetary value per CB)

Positive – higher numbers are seen to be better.

This indicator quantifies contributions to social security systems, including health insurance, contributions to public pension, old-age insurance and accidents insurance of farmers/agricultural workers. The payments made to the social security insurance system demonstrate just how well workers are protected in the event of sickness, accidents and old-age (retirement).

The indicator is calculated as the ratio between the total amounts paid into different insurance schemes and the total working hours in the sector as it relates to the customer benefit.

9. Aggregation and the Person Time Concept

9.1. Overview:

BASF's AgBalance™ methodology assesses environmental impacts and economic costs independently. The environmental impact categories are aggregated to an overall environmental impact using a conventional approach as recommended, for example, by the ILCD Handbook¹⁷. In a first step the impacts are normalized, followed by aggregating these with fixed weighting factors. Total life cycle costs are determined separately and combined with the total environmental impact in the Eco-Efficiency Portfolio.

9.2. Normalization:

The normalization step uses external (study-independent) values. The environmental normalization values used are annual regional statistical values provided with standard market tools. For TRACI impact categories reference US statistics (e.g. tons CO₂e/year emitted in the US) are used, while for all other impact categories reference EU statistics are used. For the normalization of the total costs the regional GDP (gross domestic product) is used. This value should be updated yearly and documented in the BASF mastersheet.xlsx or equivalent calculation model.

9.3. Weighting:

The normalized values are aggregated using weighting factors obtained by external polling consultants. These weighting factors may be for a region, country or world. The polls are based on the maximum difference scaling approach, in which respondents are asked to select, in a series of questions, the most important environmental impact category from three options. To be suitable for an AgBalance™, poll respondents should cover a balance of age, gender, income, household size and education. The BASF AgBalance™ weighting factors have been based on polls run by the external consultant TNS, a global research agency.

The aggregated environmental and economic values for each alternative are divided by the number of inhabitants in the region to obtain a single score total environmental impact expressed in person time (e.g. person years).

9.4. Eco-Efficiency:

The total environmental impact and the total costs, both expressed in terms of person time, are combined on the Eco-Efficiency Portfolio, described in more detail in 9.5

10. Study Outputs, Final Report and Presentation

10.1. Final Report and Final Presentation of Results:

BASF EEA methods, parameters, results and conclusions can be summarized in a written Final Report and/or Final Presentation. The single results are linked with the predefined functional unit or customer benefit (CB). At a minimum, the Final Report and/or Final Presentation shall include a discussion of the following:

- Executive summary
- Introduction and study goals;
- functional unit, alternatives and system boundaries;
- Input parameters and assumptions;
- Method of Economic impacts evaluation;
- Method of Environmental impact evaluation;
- Eco-Efficiency analysis results, interpretation and discussion;
- Data quality assessment;
- Sensitivity/uncertainty analysis, and
- Limitations of EEA study results
- References

10.2. Representations of Results:

Results of a BASF AgBalance™ are represented as bar charts for total costs and each of the environmental impact metrics (Table 1). An example for such a single bar chart graph is given in Figure 4. Additionally an Environmental (Ecological) Footprint plot (Figure 5) and an Eco-Efficiency Analysis Portfolio (Figure 6) will be reported. The BASF AgBalance™ methodology allows results to be graphically depicted and discussed, and may assist strategic decision making for implementing the most eco-efficient alternative. This contributes to more sustainable products and processes, and supports acceptance of applicable

investment and purchasing decisions. The basis for subsequent decisions may be backed with appropriate data, and the effectiveness of the particular measures may be reviewed and documented.

10.3. Bar Charts:

At a minimum, each BASF AgBalance™ shall include bar charts that show the results of the analysis for the economic and each of the environmental impact metrics. At a minimum, the bar charts should be generated based on characterized results, but not results that have been normalized or weighted. Figure 4 shows an indicative bar chart for representing an environmental impact. The bar diagrams give an indication in what life cycle steps process and product changes may be having the largest impact and thus offer the greatest potential improvement opportunities.

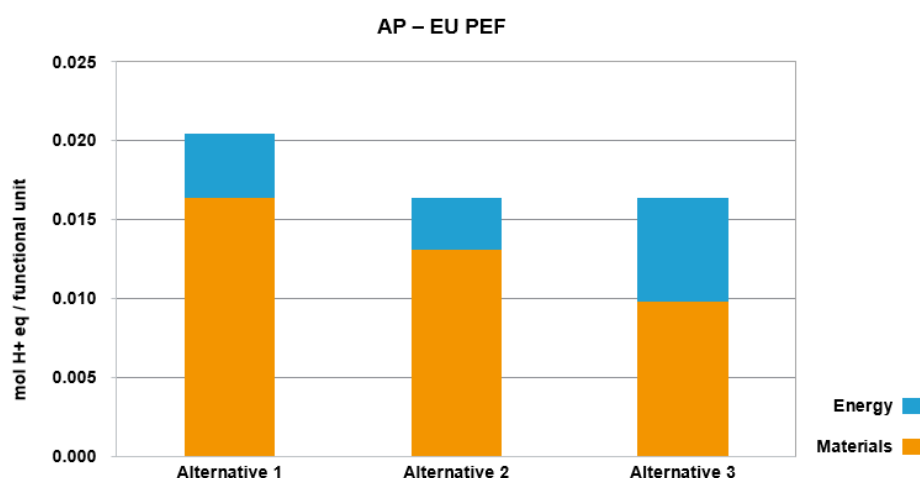


Figure 4: Single results of environmental impact, e.g. Acidification potential

10.4. Environmental (Ecological) Footprint:

The environmental Footprint shows the environmental impact of the alternatives relative to one another in all the assessed impact categories. The alternative that lies furthest out and has the value of 1.00 is the least favorable (highest impact) alternative in the category under consideration. The closer to the origin (0, 0 coordinate) an alternative lies, the more favorable (less environmental impact) it is. In principle, it is possible to change the direction of the results to the opposite if it is clearly described in the report. The axes coordinates are calculated independent of one another, so an alternative that, for example, does well in abiotic depletion (resource depletion – mineral, fossil) can perform worse with regards to consumptive water use (resource depletion water). A representative Footprint is depicted below in Figure 5.

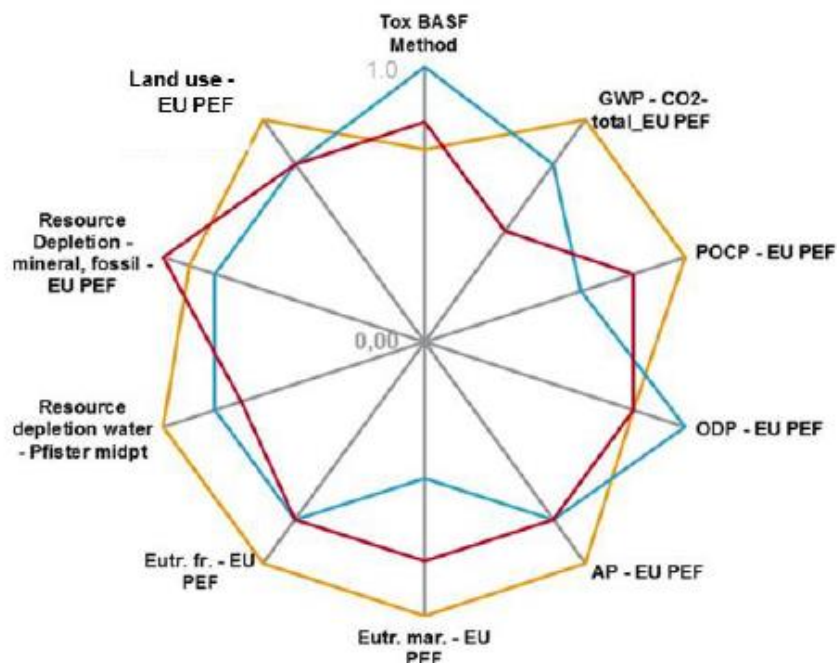


Figure 5: Comparison of alternatives in an Environmental Footprint (EEA10)

10.5. Eco-Efficiency Analysis Portfolio and Index:

The BASF Eco-Efficiency portfolio was developed to graphically depict both economic and environmental results on a single matrix. The total environmental impact is plotted against total costs; both values are expressed in terms of person time. The eco-efficiency is inversely proportional to the distance from an alternative to the origin (0, 0). A diagram of the Eco-Efficiency Index shows these distances for all alternatives. Alternatives whose Eco-Efficiency Index are within a specified sensitivity (normally 10%) are considered to be equally eco-efficient. Because the Eco-Efficiency Portfolio always includes the point (0, 0), it is normal for most alternatives to be located closer to the lower left corner; this is not an indication of low eco-efficiency (Figure 6).

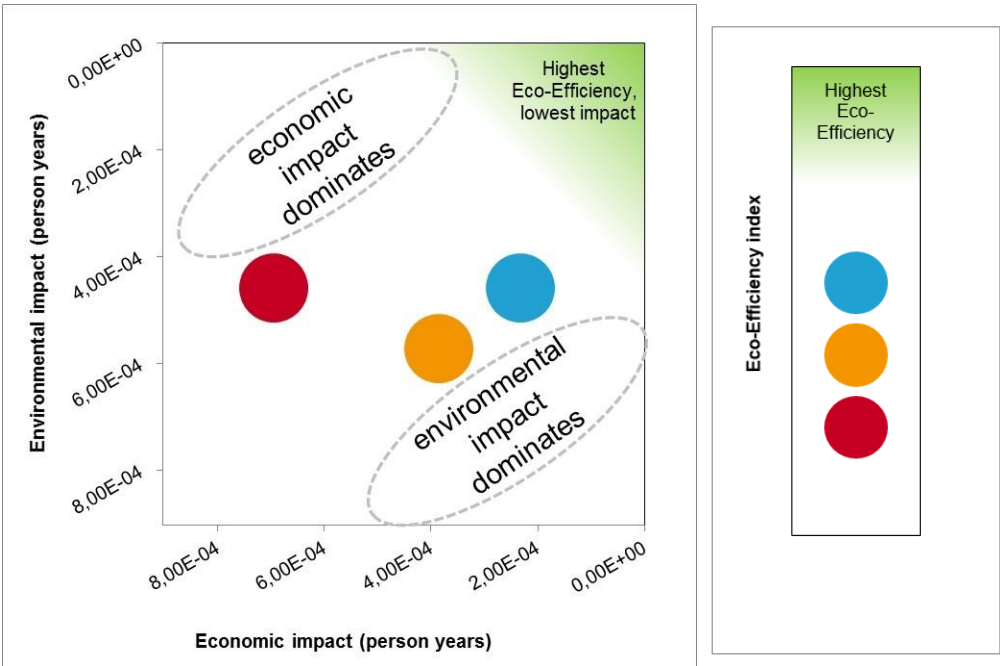


Figure 6: The Eco-Efficiency Portfolio and Index

10.6. Final Single Score Result:

Once aggregated, the results of the environmental, social and economic factors are shown as single score diagrams (example, see Figure 7). The final score is calculated as the average of the individual environmental, social and economic single score values for each alternative. No weighting factors are applied at this stage. The alternative with the best sustainability performance is at the top, the one with the worst performance at the bottom of the graph.

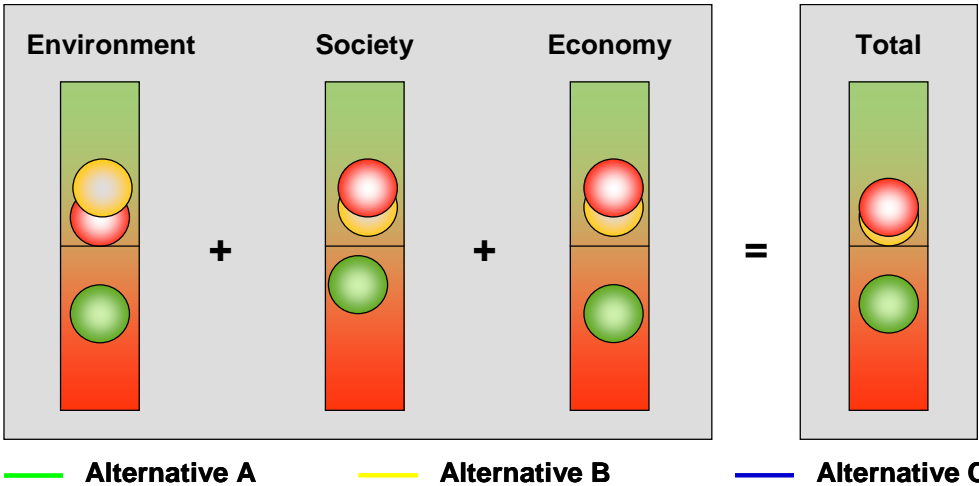


Figure 7: How the calculated scores are presented. This diagram shows the environmental, social and economic assessment as well as the total socio-economic efficiency score for sustainability within AgBalance™.

10.7. Alternative Graphical Representation:

A web-based visualization application has been developed specially for presenting AgBalance™ study results. It can be run in a web-browser as well as other electronic platforms including mobile devices. The representation of study results with this tool has particular features, which are highlighted below. In all representations, *relative* results of the alternatives considered are plotted on normalized scales. The worst alternative in each impact is normalized to one, and the other alternatives are expressed proportionally, with an *improvement* indicated by a *higher* number.

(1) Individual impact indicator results are shown as points on a normalized scale, represented as sliders, showing the relative difference between the alternatives considered. For an example see Figure 8. Points that are higher on the sliders indicate a better result.

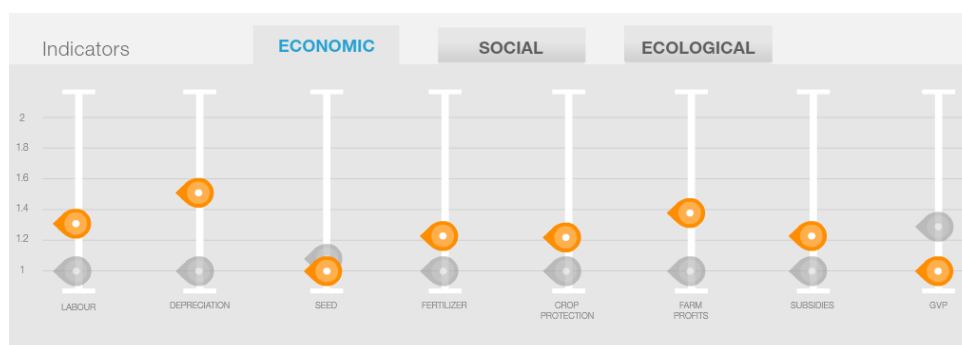


Figure 8: AgBalance™ Visualization Tool: Representation of individual indicator results

(2) Normalized results for all impact 16 categories (environmental, social and economic) are presented in a single graph. Each alternative is represented by petals of a certain color, the size of the petal being indicative of the relative sustainability performance in the respective impact category. Larger petals indicate a better result (cf. Figure 9).

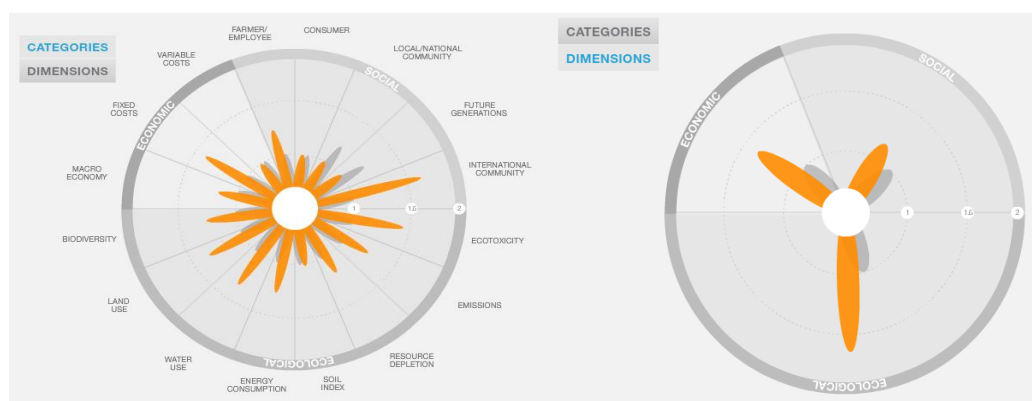


Figure 9: AgBalance™ Visualization Tool: Representation of impact category results (left) and single scores of environmental, social and economic dimensions (right).

(3) The three single score results derived for the total environmental, social and economic impacts, are likewise symbolized, with petals of a certain color representing each alternative and the size of the petal indicating the relative sustainability performance in the respective sustainability dimension. Larger petals indicate a better result (cf. Figure 9).

(4) The aggregated total sustainability score of each alternative is represented in a bar chart, with the worst alternative normalized to one, and the other alternatives expressed proportionally. Again, the relative *improvement* is indicated by a *larger* bar result (cf. Figure 10).

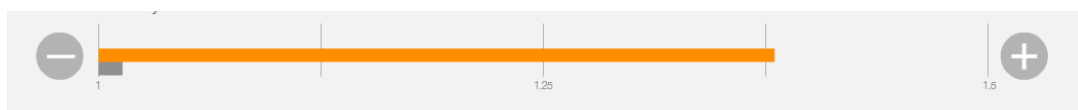


Figure 10: AgBalance™ Aggregated Total Sustainability Score

11. Life Cycle Inventory Data – Eco-Profiles

11.1. Overview:

BASF manages its life cycle inventory (LCI) data in a manner consistent with ISO 14040 and ISO 14044. LCI data is one of the types of information critical to performing a BASF EEA, the other being the model parameters. LCI is essentially an inventory of input/output data with respect to the product or process under consideration. Input/output data includes about 3000 flows or more required to calculate the impact categories shown in Table 1 and is stored in the BEST database or similar database (see 10.7 for a more detailed explanation). From the BEST database LCIA (life cycle impact assessment) are extracted for use in the BASF mastersheet.xlsx (or equivalent calculation model). The LCIA are obtained by multiplying all the flows of the LCI with corresponding characterization factors from the various assessment methods (e.g. TRACI). It is also possible to extract an LCI from a database, with the impact assessment performed subsequently. BEST and other databases use primary data sets as well as secondary data sets. Both types can be used and selected for studies if a consistent data quality management is applied.

The general process of selecting Eco-Profiles for use in BASF AgBalance™, shown schematically in Figure 11, involves using existing Eco-Profiles or creating a new one and using a specific Eco-Profile or an analogous one. General descriptions of *existing*, *new*, *specific* and *analogous* Eco-Profiles are provided in Section 10.4. All LCIA used in a BASF EEA should be provided in the “LCIA” worksheet, and can be seen, as an example, in the enclosed BASF Mastersheet.xlsx. See Section 11.8 for BASF AgBalance™ reporting requirements in regards to development and use of Eco-Profiles.

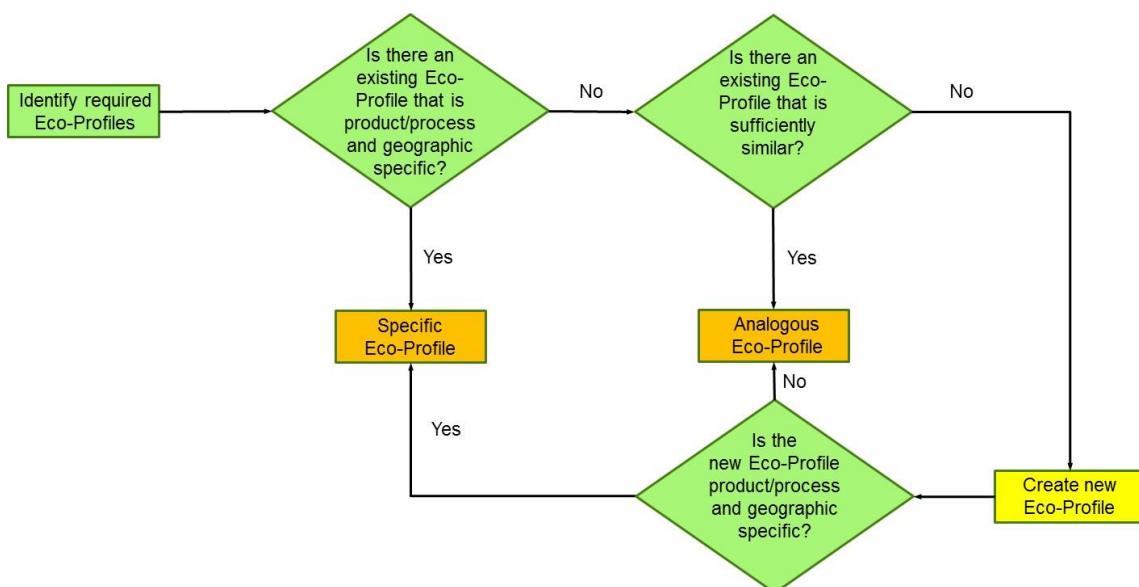


Figure 11: Process flow for selecting Eco-Profiles

11.2. Identifying Required Eco-Profiles:

The goals of the study, the defined functional unit, alternatives and system boundaries (as discussed in Section 4 above) are considered when identifying what specific Eco-Profiles are necessary for a given BASF AgBalance™. Because the process of completing a BASF AgBalance™ is often iterative, as data is collected and more is learned about the system, new data requirements or limitations may be identified that require a change in the necessary Eco-Profiles, and; therefore, there should be an ongoing evaluation of the appropriateness and quality of the Eco-Profiles throughout the BASF EEA study.

11.3. Elements of LCIA:

The basic BASF LCIA shall contain all of the elements that comprise the environmental impact metrics. As shown in Figure 12, different impact assessment methods are integrated in the LCIA format derived from the LCI to allow for flexible selection of impact assessment methods in the LCAflex. In some cases, one flow may impact more than one environmental metric. Methane (CH₄), for example, is a chemical that impacts both the GWP and POCP impacts.

Reference flow		Product A		
BEST-ID		16761		
Unit		kg		
Amount		1.0		
Region				
Year		1/1/11 12:00		
Completeness		3		
Reliability		5		
Environmental Impact Categories		Units		
Tox BASF Method	Tox-Points	4514,82064		
GWP				
GWP - 100a - CML 2001		3,03201767		
GWP - CO2 fossil incl. CO2 & CO & SF6_CML 2001	kg CO2 eq	3,03201767		
GWP - CO2 biogenic assimilation_CML 2001	kg CO2 eq	3,03201767		
GWP - CO2 biogenic emissions incl. LUC_CML 2001	kg CO2 eq	3,03201767		
GWP - CO2 biogenic net_CML 2001	kg CO2 eq	3,03201767		
GWP - CO2-total_CML 2001	kg CO2 eq	3,03201767		
GWP - EU PEF		3,03149699		
GWP - CO2 fossil incl. CO2 & CO & SF6_EU PEF	kg CO2 eq	3,03149699		
GWP - CO2 biogenic assimilation_EU PEF	kg CO2 eq	3,03149699		
GWP - CO2 biogenic emissions incl. LUC_EU PEF	kg CO2 eq	3,03149699		
GWP - CO2 biogenic net_EU PEF	kg CO2 eq	3,03149699		
GWP - CO2-total_EU PEF	kg CO2 eq	3,03149699		
GWP - ReCiPe H		2,72921257		
GWP - CO2 fossil incl. CO2 & CO & SF6_ReCiPe H	kg CO2 eq	2,72921257		
GWP - CO2 biogenic assimilation_ReCiPe H	kg CO2 eq	2,72921257		
GWP - CO2 biogenic emissions incl. LUC_ReCiPe H	kg CO2 eq	2,72921257		
GWP - CO2 biogenic net_ReCiPe H	kg CO2 eq	2,72921257		
GWP - CO2-total_ReCiPe H	kg CO2 eq	2,72921257		
GWP - TRACI 2.1		3,03174248		
GWP - CO2 fossil incl. CO2 & CO & SF6_TRACI 2.1	kg CO2 eq	3,03174248		
GWP - CO2 biogenic assimilation_TRACI 2.1	kg CO2 eq	3,03174248		
GWP - CO2 biogenic emissions incl. LUC_TRACI 2.1	kg CO2 eq	3,03174248		
GWP - CO2 biogenic net_TRACI 2.1	kg CO2 eq	3,03174248		
GWP - CO2-total_TRACI 2.1	kg CO2 eq	3,03174248		
POCP				
POCP - CML 2001	kg ethylene eq	0,02127552		
POCP - EU PEF	kg NMVOC eq	0,04520012		
POCP - ReCiPe H	kg NMVOC eq	0,044571		
POCP - TRACI 2.1	kg O3 eq	0,39777671		
ODP				
ODP - CML 2001	kg CFC-11 eq	5,11E-06		
ODP - EU PEF	kg CFC-11 eq	5,11E-06		
ODP - ReCiPe H	kg CFC-11 eq	1,4036E-10		
ODP - TRACI 2.1	kg CFC-11 eq	5,11E-06		
AP				
AP - CML 2001	kg SO2 eq	0,0134982		
AP - EU PEF	mol H+ eq	0,01639009		
AP - ReCiPe H	kg SO2 eq	0,01247072		
AP - TRACI 2.1	kg SO2 eq	0,01368527		
Eutrophication Ter				
Eutr. ter. - EU PEF	mol N eq	0,03623304		
Eutrophication Mar				
Eutr. mar. - EU PEF	kg N eq	0,00335289		
Eutr. mar. - ReCiPe H	kg N eq	0,00038146		
Eutrophication Fresh				
Eutr. fr. - EU PEF	kg P eq	6,0273E-06		
Eutr. fr. - ReCiPe H	kg P eq	6,0273E-06		
Eutrophication Aquatic				
Eutr. aquatic - TRACI 2.1	kg N eq	0,00048352		
Eutrophication Overall				
Eutr. generic - CML 2001	kg PO4 3- eq	0,00115185		
Human Tox (Cancer)				
Human Tox (Cancer) - EU PEF	CTUh	1,0237E-10		
Human Tox (Cancer) - TRACI 2.1	CTUh	1,1562E-10		
Human Tox (non-Cancer)				
Human Tox (non-Cancer) - EU PEF	CTUh	1,3526E-08		
Human Tox (non-Cancer) - TRACI 2.1	CTUh	1,3527E-08		
Human Tox overall				
Human Tox overall - CML 2001	kg 1,4-DB eq	0,05379902		
Human Tox overall - ReCiPe H	kg 1,4-DB eq	0,06722828		
Ionizing Radiation				
Ionizing Radiation - EU PEF	kg U235 eq			
Ionizing Radiation - ReCiPe H	kg U235 eq			
Respiratory Inorganics / Particulate matter				
Particulate matter - EU PEF	kg PM2,5 eq	0,00053304		
Particulate matter - ReCiPe H	kg PM10 eq	0,00341032		
Particulate matter - TRACI 2.1	kg PM2,5 eq	0,00053304		

Freshwater Ecotox (all emissions included)		
Freshwater Ecotox - CML 2001	kg 1,4-DB eq	0,0011221
Freshwater Ecotox - EU PEF	CTUe	0,01224063
Freshwater Ecotox - ReCiPe H	kg 1,4-DB eq	0,00087415
Freshwater Ecotox - TRACI 2.1	CTUe	0,01236623
Terrestrial Ecotox		
Terrestrial Ecotox - CML 2001	kg 1,4-DB eq	0,00044072
Terrestrial Ecotox - ReCiPe H	kg 1,4-DB eq	1,6243E-05
Marine Ecotox		
Marine Ecotox - CML 2001	kg 1,4-DB eq	14,1434923
Marine Ecotox - ReCiPe H	kg 1,4-DB eq	9,9609E-05
Resource Depletion (water)		
Resource depletion water - Pfister midpt	ass. m3	0,00162731
Resource depletion water - EU PEF	ass. m3	
Resource depletion water - ReCiPe H	m3	
Resource Depletion (total)		
Resource depletion minerals - CML 2001 ultimate	kg Sb eq	1,4474E-06
Resource depletion fossil fuels - CML 2001 ultimate	MJ	78,3126234
Resource depletion minerals - CML 2001 economic	kg Sb eq	4,3589E-06
Resource Depletion - mineral, fossil - EU PEF	kg Sb eq	7,8689E-05
Metal depletion - ReCiPe H	kg Fe eq	0,00195195
Fossil depletion - ReCiPe H	kg oil eq	2,14585363
Resource depletion - fossil fuels - TRACI 2.1	MJ	101,506383
Land Use (Total)		
Land use - Koellner, sum of occupation & transformati	Points	0,00105637
Land use - EU PEF	kg (deficit)	0,01954291
Natural land transformation - ReCiPe H	m2	
Agricultural land occupation - ReCiPe H	m2a	
Urban land occupation - ReCiPe H	m2a	0,00132047
EPD Wastes to treatment		
Waste 1		
Waste 2		
Waste 3		
Waste 4		
Waste 5		
Energy		
CED total	MJ	105,976562
CED fossil	MJ	105,670998
CED Biobased renewable	MJ	0,07265332
CED Non-biobased renewable	MJ	0,23291023

Figure 12: BASF LCIA elements (shown in three parts)

11.4. Selecting Eco-Profiles for Use in Study:

The process of selecting Eco-Profiles for use in BASF AgBalance™ is based on expert judgment. Once the required Eco-Profiles for a particular study are identified, then existing Eco-Profiles are used or new ones are created. Furthermore, the Eco-Profiles used in the study will be either specific or analogous. An *existing* Eco-Profile is one that was previously calculated by BASF or was obtained from a reputable external source (e.g. customer, supplier, US Life Cycle Inventory database, scientific literature etc.) A *new* Eco-Profile is created by BASF especially for a given AgBalance™. A *specific* Eco-Profile means the input/output data match very closely to the product or process under consideration. An *analogous* Eco-Profile means that the input/output data is sufficiently similar the product or process under consideration. The following decision criteria for evaluating the suitability of Eco-Profiles for use in a BASF AgBalance™ shall be considered:

- *Scope of study*: Selected Eco-Profiles should align with the goals of the study, the defined CB, alternatives and system boundaries (as discussed in Section 4 above).

- *Product/process specificity*: In general, eco-Profiles for a specific product/process are preferred, over analogous Eco-Profiles that may be based on industry averages. If product/process specific Eco-Profiles are not pre-existing, then an analogous Eco-Profile can be used.
- *Geographic specificity*: Eco-Profiles created within the geographic context of the study are preferred, in general, to Eco-Profiles for regions outside the study context. An exception to this rule is if an international Eco-Profile is deemed superior to the domestic Eco-Profile.

11.5. Time horizon:

In general, Eco-Profiles created within three years of the date of the EEA are preferred over older Eco-Profiles.

11.6. Creating New Eco-Profiles:

The BASF procedure for creating Eco-Profiles involves the compilation and quantification of material and energy inputs and outputs for each unit process within the system boundaries throughout its life cycle. For a BASF AgBalance™, these inputs include the use of energy, raw materials and land use/transformation, with outputs including releases to air, water and land (solid waste). In addition, BASF AgBalance™ considers toxicity “outputs”. The sources of data can include existing ecological studies, questionnaires completed by production plants, scientific publications, analogies and expert judgments. The procedures used for data collection vary depending on the scope, unit process or intended application of the study as defined in Section 4 above. As acknowledged in ISO 14040 and ISO 14044, data collection for development of an Eco-Profile can be a resource-intensive process and practical constraints on the scope of data collection are considered in the BASF AgBalance™ process.

11.7. Calculating Eco-Profiles:

BASF previously utilized the Boustead Model (ver. 5.0.11) for calculating Eco-Profiles. Boustead was a commercially available software that was both a database and a LCI modeling tool. This tool was replaced by a new software called “BEST”, an open LCA software type developed by BASF and GreenDelta, Berlin (<http://www.greendelta.com/>). The software was launched in 2013. All data content was shifted from Boustead to BEST and can be utilized on this platform. Furthermore, ecoinvent data (<http://www.ecoinvent.org/>) were implemented into the new software as well. Calculations done in BEST are based on a unit operation process that allows it to analyze highly complex linear and non-linear systems without resorting to approximations or simplifications which may otherwise introduce inaccuracies. A unit operation is a process which produces a single product. Each of these unit operations will take its inputs from other upstream unit operations and its output product will act as a feed for further downstream operations. In general, a unit operation will be independent of the upstream operations that are feeding it and the downstream operations that are taking its products and, therefore, any unit operation can be analyzed without reference to the other unit operations within the system. From BEST, LCIA can be extracted in different formats and can be integrated e.g. as an LCIA

data set into the Mastersheet for the preparation of EEA studies. The BEST software is compatible with other types of commercially available software like GABI, SimaPro or others. A data exchange via ILCD or EcoSpold format is also possible.

11.8. Eco-Profile Reporting Requirements:

The presentation and/or final report of BASF EEA results should include a description of the Eco-Profiles used in the study and assessment of the appropriateness of the Eco-Profiles as related to the goals of the study, the defined functional unit (CB), alternatives and system boundaries (as discussed in Section 4 above). Evidence of sufficiency and/or expert judgments used should be articulated in a transparent manner. In addition, the presentation or report shall contain a data quality assessment in regards to the Eco-Profiles which identifies critical uncertainties, or sensitivities, that have significant impacts on study results. It is not necessary to describe every Eco-Profile that was potentially available for use in the study, as this may be extremely resource-intensive and is, therefore, not consistent with ISO 14040 and ISO 14044.

12. Scope of studies

12.1. System boundaries:

The ISO 14040 and 14044 define in which way system boundaries of a study have to be defined. The BASF AgBalance™ methodology follows this requirements. In cases, where there is a high degree of similarity in the analysis between inputs into the model (e.g. energy consumption, mass, assumptions related to production, use and disposal of the alternatives etc.), performing the analysis utilizing differential inputs often provides a higher degree of resolution to the results. The system boundary determines which unit processes shall be included within the LCA. The selection of the system boundary shall be consistent with the goal of the study. The criteria used in establishing the system boundary shall be identified and explained. Decisions shall be made regarding which unit processes to include in the study and the level of detail to which these unit processes shall be studied.

The deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study. Any decisions to omit life cycle stages, processes, inputs or outputs shall be clearly stated, and the reasons and implications for their omission shall be explained. Decisions shall also be made regarding which inputs and outputs shall be included and the level of detail of the LCA shall be clearly stated.

It is an iterative process to identify the inputs and outputs that should be traced to the environment, i.e. to identify which unit processes producing the inputs (or which unit processes receiving the outputs) should be included in the product system under study. The initial identification is made using available data. Inputs and outputs should be more fully identified after additional data are collected during the course of the study, and then subjected to a sensitivity analysis.

12.2. Cut-off criteria

The cut-off criteria for initial inclusion of inputs and outputs and the assumptions on which the cut-off criteria are established shall be clearly described. The effect on the outcome of the study of the cut-off criteria selected shall also be assessed. Several cut-off criteria are used in LCA practice to decide which inputs are to be included in the assessment, such as mass, energy and environmental significance. Making the initial identification of inputs based on mass contribution alone may result in important inputs being omitted from the study. Accordingly, energy and environmental significance should also be used as cut-off criteria in this process. It should be decided which inputs and outputs data have to be traced to other product systems, including flows subject to allocation.

The presentation and/or final report of BASF EEA results shall include a description of cut-off rules and processes used within the model and the appropriateness of using them as it relates to the goals of the study, the defined CB, alternatives and system boundaries (as discussed in Section 4 above).

The system should be described in sufficient detail and clarity to allow another practitioner to duplicate the inventory analysis.

13. Data Quality Objectives

13.1. Data Quality Statement:

Because the process of developing a BASF EEA is often iterative, as data are collected and more is learned about the system, new data requirements or limitations may be identified that require a change in the inputs/outputs. The BASF EEA methodology calls for an ongoing consideration of the appropriateness, accuracy and preciseness of input data throughout the study. Geographic, technological and temporal appropriateness of the data is considered in the selection of input data. Sensitivity calculations are used to determine whether any specific inputs, assumption or life cycle inventory are critical for result stability.

13.2. Reporting Requirements:

Findings from the data quality assessment, which identifies critical uncertainties, or sensitivities, that have significant impacts on study results, shall be included in the written Final Report and/or Final Presentation.

14. Statements of Limitations and of Validation of EEA Study Results

14.1. Limitations:

At a minimum, each report or presentation of study results will carry the following statement regarding limitation of study results:

"These Eco-Efficiency analysis results and its conclusions are based on the specific comparison of the production, use, and disposal, for the described functional unit, alternatives and system boundaries. Transfer of these results and conclusions to other production methods or products is expressly prohibited. In particular, partial results may not be communicated so as to alter the meaning, nor may arbitrary generalizations be made regarding the results and conclusions."

14.2. Validation:

The report or presentation should include, at a minimum, the following statement if, and only if, the study was performed in complete accordance with BASF EEA methodology validated under the requirements of NSF P352:

"This Eco-Efficiency analysis was performed by BASF according to the methodology validated by NSF International under the requirements of Protocol P352. More information on BASF's methodology and the NSF validation can be obtained at <http://www.nsf.org/ecoefficiency>". Slight modifications to this statement are allowed, if required.

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