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## **Life cycle assessment and its use in BASF: integrating economic, environmental and social concerns**

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Resources and Environment**

## ***Master Thesis***

### **Life cycle assessment and its use in BASF: integrating economic, environmental and social concerns**

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*To my wonderful parents,  
my biggest supporters  
and responsible  
for everything I am*

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It was not an easy decision to leave my life in my home country (Brazil) for two years and come to a “strange” country (Germany) to get an MBA diploma. To compensate the huge effort, I have the feeling that not only my career got an upgrade, but also my life was enriched. For the first time I experienced the world alone, and I can say I had a wonderful time. Having such a personal and professional enrichment surely changed my life, making me having contact with new cultures, different perspectives, new friends... The term “citizen of the world” makes more sense to me now.

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*"I truly believe that individuals  
can make a difference in society.  
Since periods of change such as the present one  
come so rarely in human history,  
it is up to each of us to make  
the best use of our time to help  
create a happier world."  
Dalai Lama, 1935*

## Table of contents

Acknowledgments.....	i
List of figures.....	vi
List of abbreviations .....	vi
1. Introduction.....	1
2. Life cycle assessment: overview .....	3
2.1. Definition and standards.....	3
2.2. Development of LCA .....	4
2.3. Main characteristics and applications .....	5
3. Why and when to use LCA? .....	6
3.1. Reasons to use LCA.....	6
3.2. Users of LCA .....	7
3.3. LCA and other tools.....	9
4. How to do an LCA? .....	10
4.1. Goal definition and scope .....	10
4.2. Inventory analysis.....	13
4.3. Impact assessment.....	14
4.3.1. Classification .....	14
4.3.2. Characterization .....	15
4.3.3. Normalization .....	16
4.3.4. Weighting .....	16
4.4. Interpretation of results.....	17
5. The eco-efficiency analysis by BASF: environment and economic dimensions.....	18
5.1. Definition of customer benefit, definition of alternatives.....	20
5.2. Determination of environmental impacts (inventory, classification and characterization).....	20
5.3. Cost calculation .....	23
5.4. Normalization.....	23
5.5. Weighting .....	24
5.6. Eco-efficiency Portfolio .....	26
6. The inclusion of social dimension in the eco-efficiency analysis: SEEBalance® .....	27
6.1. Stakeholders and indicators .....	28

6.2.	Social fingerprint.....	30
6.3.	SEEcube®.....	31
7.	Adaptation of the SEEbalance® to Brazil. ....	32
7.1.	Working accidents .....	34
7.2.	Fatal working accidents .....	34
7.3.	Occupational diseases .....	35
7.4.	Toxicity potential (employees) + transport .....	35
7.5.	Wages and salaries .....	35
7.6.	Professional training .....	36
7.7.	Strikes and lockouts .....	36
7.8.	Child labor .....	37
7.9.	Foreign direct investment .....	37
7.10.	Imports from developing countries.....	38
7.11.	Number of trainees .....	39
7.12.	Research and development (company expenditures) .....	39
7.13.	Capital investments .....	39
7.14.	Social security .....	40
7.15.	Toxicity potential (consumers).....	40
7.16.	Other risks and functional product characteristics .....	40
7.17.	Number of employees .....	41
7.18.	Number of qualified employees .....	41
7.19.	Gender equality .....	42
7.20.	Integration of handicapped people .....	43
7.21.	Part time work.....	43
7.22.	Family support.....	43
7.23.	Summary list of adaptation of indicators.....	44
8.	Summary .....	45
9.	References .....	48

## List of figures and table

Figure 1: Phases of an LCA.....	10
Figure 2: Example of Ecological Fingerprint. ....	24
Figure 3: Example of weighting factors. Self-prepared. ....	26
Figure 4: Example of eco-efficiency portfolio. ....	27
Figure 5: Inclusion of the social pillar in the eco-efficiency analysis.....	28
Figure 6: Indicators per stakeholder of a SEEBalance® analysis. ....	29
Figure 7: Example of Social fingerprint. ....	31
Figure 8: Example of SEECube®. ....	32
Table 1: Summary of adaptation measures of SEEBalance® indicators.....	44

## List of abbreviations

AP	Acidification Potential
CAT	Communication of Working Accident (in Portuguese)
CEMPRE	National Register of Enterprises (in Portuguese)
CNAE	National Classification of Economic Activities (in Portuguese)
COD	Chemical Oxygen Demand
CPA	Classification of Products by Activity
DIEESE	Labor Unions Department for Statistics and Socioeconomic Studies (in Portuguese)
EEA	Eco-efficiency Analysis
EIA	Environmental Impact Assessment
EPA	Environmental Protect Agency in Unites States of America
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GTZ	German Agency for Technical Cooperation (in German)
GWP	Global Warming Potential

IBGE	Brazilian Institute of Geography and Statistics (in Portuguese)
ILO	International Labor Organization
INSS	National Institute of Social Security (in Portuguese)
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
MRI	Midwest Research Institute
NACE	Classification of Economic activities in the European Community (in French)
NCM	Mercosul Common Nomenclature (in Portuguese)
NGO	Non Governmental Organization
ODP	Ozone Depletion Potential
PAC	Annual Trade Survey (in Portuguese)
PAER	Regional Economic Activity Survey (in Portuguese)
PAIC	Annual Construction Industry Survey (in Portuguese)
PAS	Annual Services Survey (in Portuguese)
PIA	Annual Industry Survey (in Portuguese)
PINTEC	Industrial Survey of Technological Innovation (in Portuguese)
PNAD	National Household Sample Survey (in Portuguese)
POCP	Photochemical Ozone Creation Potential
R&D	Research and development
RA	Risk Assessment
REPA	Resource and Environmental Profile Analysis
SETAC	Society of Environmental Toxicology and Chemistry
SETEC	Secretariat for Professional and Technological Education (in Portuguese)
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Program

## 1. Introduction

During the United Nations Conference on Environment and Development, in 1992 in Rio de Janeiro, Brazil, one key issue on the sustainable development agenda was raised: sustainable production and consumption. The main idea of the agenda was to involve the whole society (government, business, communities and households) “in implementing measures to promote efficiencies in production and sustainable patterns of consumption”.<sup>1</sup> Examples of measures to be taken include: to use natural resources in an efficient way, to minimize the production of waste and to optimize products and services in a way to reduce energy consumption.

The business sector plays a very important role regarding sustainable development. Companies are the intermediate step between human beings’ consumption and nature and, as such, they are responsible for changing resources into goods. Therefore, they are the main changing agents of the environment, acting on behalf of millions of customers and carrying the responsibility of transforming the world into a better one. According to Falkman (1996), business influence on sustainable development derives from its decisions regarding design, manufacture and delivery of goods, consumption of goods, services, natural resources, energy and also advertising and marketing.

One question may arise then: how can business contribute to improve sustainable production and consumption? One possible answer, and maybe the solution most companies are seeking for, is eco-efficiency. Eco-efficiency, as a corporate strategy, “emphasizes economics, in addition to environmental improvement [...] increasing value while simultaneously reducing the ecological impact of one’s activities and the use of resources.”<sup>1</sup> Life Cycle Assessment (LCA) is one helpful tool being used in the chase for eco-efficiency.

This master thesis is the result of the author’s research on LCA. This advanced analytical method is being used more and more by companies to evaluate the environmental burdens associated with their activities, and to

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<sup>1</sup> Extracted from reference [10], page 11

design more environmental friendly products. The first part (chapters one, two and three) contains the description of the LCA methodology.

The second part focuses on the research done by the author in the worldwide leading chemical company, BASF. The research was done on how the company applies LCA in evaluating in a comparative way the economic, environmental and social aspects of products. For that, the eco-efficiency analysis (EEA) and the SEEBalance® methods were created. Whereas EEA is already used in the author's home country, Brazil, the SEEBalance® is still not applied there. A first assessment of what needs to be done to apply SEEBalance® in Brazil was also done.

The current chapter, chapter one, introduces the topic and shows the motivation of the research.

Chapter two gives an overview on the LCA methodology, explaining what it is and tracing its history. Main characteristics and main applications of LCA will be presented.

Chapter three brings some reasons to use LCA and also some uses of the tool. It contains also the relation between LCA and other tools.

Chapter four describes more completely the tool, showing how an LCA is made, the results one can expect and how to analyze them.

Chapter five is dedicated to explain how BASF started to use LCA as a tool to measure the eco-efficiency of products and how and where this method is used today.

Chapter six deals with how BASF updated the eco-efficiency analysis to comprehend social issues, transforming the tool in a sustainability measure method, the SEEBalance®.

Chapter seven is the main result of the author's research in BASF, which was done on how to adapt the SEEBalance® method to Brazil. A detailed discussion on the adaptation measures is presented.

A summary of the whole master thesis and the references are presented in the end as chapters eight and nine.

## 2. Life cycle assessment: overview

### 2.1. Definition and standards

Life cycle assessment is one of several tools that provide an evaluation of the environmental impacts of a service or product. The purpose of LCA is to evaluate the environmental burden of a product, process or service<sup>2</sup> during its entire life cycle. That means to assess the environmental impacts of a product during its whole lifespan, from the extraction of the raw materials to its final disposal, passing through the production, supply chain, use, reuse and recycle.

The International Organization for Standardization provides standards to LCA in the 14000 series, dealing with environmental management systems. Specifically, some up-to-date standards that explicitly address LCA are:<sup>3</sup>

- ISO 14040:2006 - Life cycle assessment - Principles and framework;
- ISO 14044:2006 - Life cycle assessment - Requirements and guidelines;
- ISO/TR 14047:2003 - Life cycle impact assessment - Examples of application of ISO 14042;<sup>4</sup>
- ISO/TS 14048:2002 - Life cycle assessment - Data documentation format;
- ISO/TR 14049:2000 - Life cycle assessment - Examples of application of ISO 14041 to goal and scope definition and inventory analysis.

The ISO 14040 defines LCA as a “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.”

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<sup>2</sup> For means of simplification, only the term “products” is going to be mentioned from now on. However, everything related to products in the LCA methodology can also be related to processes or services.

<sup>3</sup> Adapted from reference [28]. TR stands for Technical Report and TS for Technical Specification

<sup>4</sup> ISO 14042 is a previous standard dealing with impact assessment which was extinguished after the review of ISO 14040 and ISO 14044. Its content was distributed in both reviewed versions.

## 2.2. Development of LCA

The origins of LCA can be traced back to the oil crisis of the 1970's, when systemic and broad approaches started to evaluate energy consumption along the total life cycle of a product. The main objective of the analysis, at the time, was to assess and reduce energy consumption, due to the high prices of oil and consequently energy. The life cycle approach of this analysis influenced the development of LCA methodology, in which not only energy resources are evaluated, but also other environmental impacts.

The concern for raw materials was in the spotlight during the 1960's. In 1965, Coca-Cola paid the Midwest Research Institute (MRI) to make a comparison of different types of packaging for its beverages. The process of quantifying raw material consumption and emissions indices became known as REPA (resource and environmental profile analysis). MRI improved REPA In 1974, during a study for the environmental protection agency of the USA (EPA). This improved version of REPA is usually taken as a milestone for the appearance of LCA.<sup>5</sup> From that time until the late 1980's, the first reports published dealt only with declarations of environmental superiority, e.g. paper cups versus plastic cups. Due to the lack of a methodology, these reports brought more polemics than orientation and results varied from project to project.

An obvious need for standardization was clear and several international workshops occurred, resulting in a Code of Practice for LCA. The developer of this code in the middle 1990's was the Society of Environmental Toxicology and Chemistry (SETAC). Based on the publications of SETAC, ISO started to work on the elaboration of standards and in 1997 the first standard related to LCA was launched, the ISO 14040 – Life Cycle Assessment – Principles and Framework.<sup>6</sup>

Together with SETAC, the United Nations Environment Program (UNEP) launched the Life Cycle Initiative in 2002 “to enable users around the world to put life cycle thinking into effective practice.”<sup>7</sup>

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<sup>5</sup> Adapted from [6], page 2

<sup>6</sup> Adapted from reference [6], pages 8-9

<sup>7</sup> Extracted from reference [31]

### 2.3. Main characteristics and applications

According to Heijungs et al. (1996), LCA “is a decision support tool” that provides “information on the environmental effects of all the stages of a product’s life cycle.”<sup>8</sup> The authors explain that it can be used by governments, companies, NGOs and individuals to make decisions on production processes, policies and consumption behaviors.

LCA is particularly different from other environmental tools like environmental impact assessment or risk assessment. While the first tool deals with new facilities and the second with assessing the impacts of pollutants from a specific installation, LCA studies the environmental load that a product carries. Being more specific, LCA evaluates the impacts associated with the function this product is designed to perform.

One main characteristic of LCA, which differs from other tools, is that it is an evaluation of the environmental load from cradle to the grave of the product. This means that the assessment is made from its birth to its death. Other terms, however, are often used to specify the different parts of the assessment, such as: cradle to entrance’s gate (extraction and transport of raw materials), gate to gate (internal activities of a company) and gate to cradle (use phase of the product). Therefore, it is possible to evaluate all the different effects derived from different aspects of the product under investigation. An LCA is equally concerned with global or local impacts, as well as with consumption of natural resources and energy or to the release of hazardous substances.

LCA is especially important because it can provide objective answers. When comparing the impacts to the environment, for example, the method can determine if a plastic cup is better than a paper cup, or if recycling a plastic bottle is worse than washing and reusing a glass one.

Because of its characteristics and the way it is done, an LCA brings along deep knowledge about the influence a product has on the environment. With this knowledge, several applications and benefits can be extracted from the study. The main ones of these include: communication to society,

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<sup>8</sup> Extracted from reference [15], page 3

improvement in products and processes, development of business strategies, eco-labeling and purchasing decisions.

### **3. Why and when to use LCA?**

#### **3.1. Reasons to use LCA**

According to Heijungs et al. (1996), “LCA can help shift environmental arguments from mere personal opinions to more objective facts”. The authors defend that there are three main reasons why to use LCA, which together summarize the benefits of the tool. They are:

- **Product orientation:** as already mentioned above, differently from risk assessment or environmental impact assessment, LCA transposes the physical barriers of a production site and addresses the environmental impacts to the product itself. LCA can help in the decision making process by analyzing the influence of products in a broader view. As all economic activities depend on the consumption and use of products (a car factory exists only because people need to move from one point to the other), such a complete assessment is essential in policy making and therefore can contribute to sustainable production and consumption;
- **Integration:** LCA can focus its analysis either on a product (plastic bottle) or a function (one liter of beverage packed). The integrative approach of the LCA, over the entire life cycle of the product, avoids the transfer of environmental impacts from one place to another, or even a substitution of these impacts by others. For instance, a returnable glass bottle may seem better than a plastic one, as the first doesn't generate solid waste. However, the glass bottle has to be transported back and washed by a company, which implies consumption of energy and water and generation of detergent waste. LCA helps to analyze which of both options has a lower burden, in a complete and holistic view;

- Scientific and quantitative method: the outcome of an LCA is supposed to be as most objective as possible, diminishing uncertainties due to intuition, for instance. Going back to the example of the beverage bottles, LCA allows an impartial assessment, without previous prejudice that might exist against the plastics industry, for instance. Finally, relying on scientific data to analyze different kinds of impacts, LCA makes a fair comparison of products disturbing the environment in different ways.

### **3.2. Users of LCA**

At least four main users of LCA can be easily identified: industry, government and regulative bodies, NGOs and consumers.<sup>9</sup> They have different motivations and objectives to use the tool:

- Industrial applications: companies mainly use LCA as a tool for strategic decision-making. The role a product plays in the environment is to be deeply investigated, i.e. all the environmental impacts related to its production and use are to be quantified. The assessment helps the company in improving its products or designing them in a more environmental friendly way, or even providing customers and government with more information on environmental impacts. The results of the assessment can also be used to formulate one company's environmental policy, a marketing strategy, or to negotiate material specifications with suppliers and to find better ways of distributing the products (logistics). Decisions on the production process of a product, location of the plant, suppliers and environmental performance during the phase use are influenced by LCA;
- Government and regulative bodies: sustainable forms of development pass through regulations and policies. Government, therefore, has a responsibility in developing this tool and can use it to create subsidies or taxations, eco-labeling and public policies on

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<sup>9</sup> Adapted from reference [15], page 27

environmental issues. LCA, for example, can be used to assess what is more dangerous to a particular environment: CO<sub>2</sub> in the air or Phosphates into water, giving government a technical background to decide better on a tax policy. Another example is to decide which fuel is better for the public transportation of a country. Finally, eco-labeling is the concession of a label to more environmental friendly products and can be used to better orientate customers;

- NGOs: differently from companies, government and consumers, NGOs can not influence directly the way of consumption and production. However, they can play an important role towards sustainable development by being able to mobilize large parts of citizens from the previous groups. Usually NGOs apply LCA to supply better information to consumers and to influence enterprises and government. One example of NGO using LCA is the International Iron and Steel Institute, which, since 1999, performs studies to increase the environmental performance of steel, like to increase its rate of recycling.<sup>10</sup> SETAC is also involved with LCA, providing “an international infrastructure to support [...] groups in advancing the science, practice, and application of LCA and related approaches worldwide”.<sup>11</sup> As mentioned before, UNEP is also deeply engaged in LCA, thorough the “Life Cycle Initiative”, which mission is “to develop and disseminate practical tools for evaluating the opportunities, risks, and trade-offs associated with products and services over their entire life cycle to achieve sustainable development”.<sup>12</sup>;

- Consumers: in fact, consumers are much more often the recipients than authors of LCAs. Because of their major influence in consumption, they can demand for more trustworthy information on products and therefore play an important role on the execution of LCAs.

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<sup>10</sup> Adapted from reference [26]

<sup>11</sup> See the SETAC webpage: [http://www.setac.org/htdocs/who\\_intgrp\\_lca.html](http://www.setac.org/htdocs/who_intgrp_lca.html)

<sup>12</sup> See the UNEP Life Cycle Initiative webpage: <http://lcinitiative.unep.fr/>

### 3.3. LCA and other tools

Certainly, there are other environmental tools that can be used in the context of policy decisions. They are in essence different from LCA. Their main characteristics and differences from LCA are discussed below.

- Environmental impact assessment (EIA): this tool is used to identify and quantify the environmental effects of an activity. Usually it is done at a certain point in time at a specific position, like before a chemical plant is installed. In this case, the EIA would be used to give information about the environmental impact both to the public and government. However, the impacts of the production of raw materials wouldn't be taken into account, as in a LCA. Theoretically, LCA can be seen as the aggregation of different EIAs, one for each process of the production system, but they (LCA and EIAs) are not substitutes;
- Risk assessment (RA): like the EIA, this tool has geographical (specific for a location) and temporal (specific for a point in time) limitations. It intends to analyze the probability of a severe accident to occur, like the melt down of a nuclear reactor. Because of the low probability of occurrence, RAs are not easily included in LCAs, which quantify regular emissions;
- Non-environmental tools: one point of criticism of LCA is the lack of non-environmental and social-economic effects like costs, income, employment and consumer safety. For instance, the high prices and costs, usually linked to more environmentally friendly products are frequently not subject of the analysis. In the same direction, shifts on technologies resulting from environmental factors may have an influence on revenues (more sales due to better public awareness) and costs (more qualified employment), which can be left aside when using LCA alone. Aware of this limitation of the method, companies are trying to combine LCA with other tools, like a cost-benefit analysis. An example of the combination of LCA and cost-benefit analysis is the eco-efficiency method from the chemical conglomerate BASF, which

intends to determine total costs and ecological impact of a product during its entire life cycle.<sup>13</sup>

#### 4. How to do an LCA?

ISO 14040 establishes that an LCA shall include four different phases: goal definition and scope, inventory analysis, impact assessment and interpretation of results.<sup>14</sup>

All four phases are correlated to each other, but as LCA is an iterative tool, which means that phases already conducted, can and should be reviewed after posterior phases have been carried out. For example, after the inventory analysis, the definition of goal and scope can be reviewed to exclude processes that do not have data available, or that are not relevant for the environmental impact of the whole life cycle of the product. A description of each phase is presented in figure 1 below.

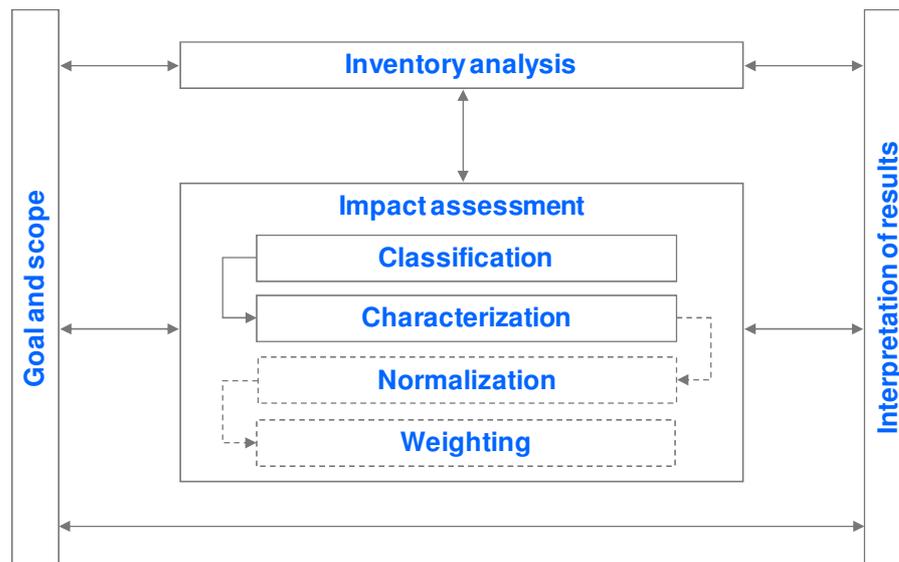


Figure 1: Phases of an LCA. Self-prepared.

##### 4.1. Goal definition and scope

This phase is the initial step of LCA and has to be carried out very carefully, for the future success of the study. All the steps of an LCA depend

<sup>13</sup> Adapted from reference [2]

<sup>14</sup> Based mainly in reference [6], pages 21 until the end

on the decisions made in this step, which will give the framework for the entire project.

According to Chehebe (1997), in this phase, one must define “the main reason to conduct the study, its coverage and limits, the functional unit, the methodology and the procedures” to be used.

The reason to conduct the study must be clearly defined, whether it would be done for internal purposes (comparison of processes, opportunities of improvements, decision about suppliers, etc.) or for external ones (environmental declaration, eco-labeling, marketing, etc.). The level of detail of the study that must be achieved depends on this decision, i.e. which processes to include, which kind of data to use, how to address processes where no data is available, etc. When conducting studies to external parties, a more complete and detailed investigation must be done, in comparison to internal screenings. For internal screenings, i.e. internal studies within a company, when the inputs or outputs of a process are not measured, estimations can be done to give a rough idea of the results of an LCA. However, for external LCAs, for publication for example, these estimations need to be carefully justified, and only if not statistical or scientific data is available.

Coverage and limits (scope) refer to how extent the study is supposed to be. In principle, LCA covers all stages of a product’s life cycle. However, due to time and money constraints, the product system<sup>15</sup> to be studied is often limited. Theoretically, an LCA for paper, as an example, must contain the impacts of wood production, fertilizers, diesel to fuel the trucks that transport the materials to the forest, the steel to produce these trucks and so on. It is clear that such an analysis could be very time and money consuming and also arrive at a level of complexity that could not be transposed, including all activities of the planet. Therefore, rules have to be stipulated to determine the time horizon and which raw materials are relevant to be included in the LCA.

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<sup>15</sup> According to ISO 14040, a product system is the “collection of materially and energetically connected unit processes which performs one or more defined functions”. The same standard defines unit process as the “smallest portion of a product system for which data are collected when performing a life cycle assessment”.

One of the most important decisions that have to be made in this phase is the determination of the functional unit, i.e. to determine the function of the product to be analyzed. In the example of the bottles, it could be very unfair to simply compare one plastic bottle with one glass bottle, since the second one can be reused several times. A proper functional unit in this case would be 10 liter of packed liquid. It is important to note that a simple reduction of a material in a product might not diminish its environmental burden. If a paper towel, for instance, is reduced to half of its size, but now people need two towels to dry their hands, the final result would be the same, i.e. the consumption of one old paper towel (bigger) is equivalent to two new towels with half of the size of the bigger one. An example of functional unit to be studied in this case would be “100 dry hands”, to make a fair comparison between the two sizes of towels. “The functional unit must be well defined, measurable and consistent with the scope and objectives of the study”. [Chehebe (1997)]

Finally, the methodology and procedures must be defined in order to give directions to the next phase of the LCA, the inventory analysis.

In a simple way, the minimum requirement of ISO 14040 for the scope determination is the establishment of the three dimensions of an LCA: duration of time (extension), which subsystems<sup>16</sup> to include (width) and level of details required (depth).

The next step is to draw the flowchart of the systems and all subsystems included. From that, one must divide the whole system in several processes units, which can represent a single operation, or a combination of many. It is important to define the unit processes according to the level of complexity of the study. Each unit process is subject to mass and energy conservation, which may be used to verify the validity of data gathered in the inventory analysis phase.

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<sup>16</sup> Subsystems are the aggregation of two or more unit process, that for means of simplification, are treated as only one.

## 4.2. Inventory analysis

After the completion of definition of objective and scope, which guides the way the study is going to be conducted, the next phase is the inventory analysis. The inventory refers to the gathering of data concerning all systems and subsystems included in the scope. It can be comparable to an accounting balance sheet, but in this case, with fluxes of mass and energy. Everything that comes in the system must be equal to what leaves it.

In practice, the inventory analysis is very difficult and time demanding, due to the extensive list of data to be collected, the lack of sources and the quality of data available.

For each of the unit processes defined in the scope phase, a data sheet has to be prepared. Data can be divided and grouped into three main topics:

- Energy, raw materials, auxiliary materials and other physical inflows;
- Products and intermediate flows;
- Emissions to air, water, land and other emissions.

It is not unusual that obtaining good quality data will only be possible by making local measurements, which will cost money and take lots of time. It is necessary then to look for other sources of data, which include environmental statistics, class associations and international databases. When using these external sources of data, special care needs to be taken regarding the quality of data, i.e. details like the period and geographical area covered and the measurement units. The inconsistency of time horizon and units can result in additional efforts to treat data and make it consistent to the study and, therefore, to accomplish the goals of the project.

While making the inventory, one must pay attention on allocation rules. It is not rare that the outcome of a production system is more than one product. In this case, the environmental burden has to be allocated to all products, either using a mass or an economic basis. For example, during the production of sugar from sugar cane, ethanol is also produced. An allocation rule has to be defined to divide the amount of environmental impact that is

going to each product, sugar and ethanol. In this case, as the outflows of both products are similar in terms of mass and they all have a similar economic value, an allocation rule based on mass could be used.

In a gold mine, where gold in a small amount and other minerals in much larger amounts are produced, a mass rule wouldn't function so well. The reason of existence of a gold mine is the extraction of gold and by allocating the environmental burden by mass, the gold would carry only a small amount of impacts. An economic rule, based on the value of each product would be better in this case.

The objective of the inventory phase, to summarize, is to collect all information about in and outflows of all the processes units defined in the previous step. An analysis of the data available has to be done, in order to have consistent units and proportions of inflows and outflows. It is necessary, during this phase, to do mass and energy balances to verify the consistency of the data and whether they represent the reality or not. It is important to regularly check objectives, scope and procedures defined previously, either to correct the conduction of the study or to make corrections in the definitions.

### **4.3. Impact assessment**

After the inventory analysis, it is necessary to assess the environmental impact associated with the results of the previous phase. The assessment is a qualitative and quantitative process to understand the magnitude and significance of the impacts. This phase is composed mainly of four elements: classification, characterization, normalization and weighting of the environmental impacts.

#### **4.3.1. Classification**

Each single aspect of the inventory, i.e. material inflows, energy inflows, emissions to air, water and land, etc., is classified into one or more environmental problems it may cause. Usually, these aspects are classified

into major environmental problems: global warming, acidification, depletion of natural resources, eutrophication, toxicity etc.

Depending on the scope and objective of the study, all categories may be included, but this is not a rule. One may choose only the categories relevant to a particular region. However, the right association between each aspect with its category is crucial for the interpretation and validity of the study. Some substances may have influences on more than one category. Copper, for instance, contributes to abiotic depletion, human toxicity, aquatic and terrestrial ecotoxicity.

### **4.3.2. Characterization**

The characterization is the modeling of the inventory data within impact categories, i.e. to quantitatively relate each aspect to the environmental problem it is causing. Each category is measured by a numerical indicator and a reference measurement unit. These reference indicators, that show how the environmental problem is measured, are scientifically determined and universally taken for granted.

For instance, global warming potential is measured as the total amount of carbon dioxide (CO<sub>2</sub>) emitted to the atmosphere. The global warming potential (GWP) of a substance is measured in relation to the effect of 1 kg of CO<sub>2</sub>. The GWP for methane, as an example, is 23, which means that each kg of methane emitted to the air is equivalent to 23 kg of carbon dioxide<sup>17</sup>, as calculated by the International Panel on Climate Change.

In this phase, all data is assigned to impact categories and modeled in such a way that a quantitative measurement of the environmental impact resulting by the inventory can be calculated.

With this method, all aspects of the inventory can be grouped in only a few numerical indicators (one for each category), which simplify the analysis and comparison. The outcome of this phase is the environmental profile, i.e. the environmental impact a product causes, related to each different impact category analyzed. It is possible to evaluate which unit process contributes

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<sup>17</sup> Adapted from reference [27], chapter 4, page 244

more to each category of environmental impact. The total environmental impact can also be assessed.

#### **4.3.3. Normalization**

Characterization results in an environmental profile, which, despite of being an aggregation of many inventory aspects into few impact categories, may be difficult to compare or analyze. It is possible, nevertheless, to do a normalization of each category indicator, referring it to reference values, which can be: the impact caused by another product, the limit of pollution stipulated by law or the total pollution in a certain geographic area.

The last case provides a good example. Imagine a certain process emits 1 ton of CO<sub>2</sub> and the total emission from all sources in the world is one million tons per year. To normalize the CO<sub>2</sub> emissions indicator in this case, it is necessary to divide the contribution of the analyzed process by the total amount of emissions. The contribution of the process then is (1ton)/(1.000.000tons/year), which means 31,54 seconds of emissions, i.e. the contribution of the process is equal to the global amount of CO<sub>2</sub> emitted during 31,54 seconds.

The normalization step is not mandatory, but it results in a better way to understand and visualize the contribution of a certain process to the environment.

#### **4.3.4. Weighting**

After the phases of classification, characterization and normalization, the environmental profile of a product is presented. However, in some cases, due to the complexity of the studies and the large amount of data to be assessed, one may want a single indicator to be assessed.

One solution in this case is to make a weighting among all categories, multiply the single indicators of each category by weighting factors and sum them up in a single number.

The weighting process may vary from country to country, or even from region to region, within a country. The choice of the factors is influenced by

political issues, economics, social problems and the community which the company is part of. How to decide, for instance, which is more relevant: global warming or acidification? Depletion of ozone layer or human toxicity? So far, there is no consensus on which is the best way to determine weighting factors.

Problems may arise from aggregating all the categories into one single number. Because the determination of weighting factors is very subjective, different results for the same study may appear. Another problem is that, by simplifying the inventory data too much, i.e. to have only a single indicator describing the whole inventory environmental impact, one may face the risk of losing the origins of information and not knowing where the single indicator comes from. Therefore it is always important to go to the previous phase and assess the characterization process, which can be scientifically sustained, differently from the weighting step.

Having the inventory and a list of reference values, the impact assessment can be done with a simple pocket calculator. However, one should notice that this would be very effort demanding and it is not practical at all. There are many kinds of software today that help in conducting an LCA, bringing databases and making the calculation automatically after one enters the inputs and outputs of each unit process. Most of these software presents different methodologies to assess the impact. LCA software types widely used are: SimaPro (Netherlands), umberto (Germany), GaBi (Germany), Ecobilan (France) and Idemat (Netherlands).

#### **4.4. Interpretation of results**

It was explained already that LCA is an iterative process, where the work during each phase has to be continuously checked with the initial scope and objectives. However, in the end of the study, a final interpretation of the results has to be made in order to analyze the whole process and translate its results into conclusions and recommendations to the decision makers.

Usually the interpretation of the results of an LCA includes three steps:

- Identification of most relevant environmental issues, according to the results of LCA;

- Evaluation of the whole process, to check the integrity of data and assess the sensibility of the assumptions made, i.e. scope, functional unit, allocation rules, assignment of environmental categories, etc;
- Conclusions, recommendations and writing of reports about the relevant environment issues.

It is only after this last phase that an LCA method can be considered done and submitted to peer review and/or to publication. In the end, a very detailed knowledge of the impacts that a product cause in the environment is available. Companies may then make their decisions under a very consistent assessment other than only an economic view.

## **5. The eco-efficiency analysis by BASF: environmental and economic dimensions**

In 2006, the total World GDP was estimated on around US\$ 48 trillion<sup>18</sup>. In the same year, world chemical sales were estimated on nearly € 1.64 trillion<sup>19</sup>, or US\$ 2.06 trillion<sup>20</sup>. The chemical industry employed in 2001 about 10 million people<sup>21</sup>. BASF is the world's leading company in the sector, employing more than 95.000 people worldwide and with almost € 53 billion in sales in 2006.<sup>22</sup>

Many companies of the chemical industry are involved with Responsible Care, which is the “global voluntary initiative under which companies [...] work together to continuously improve their health, safety and environmental performance”.<sup>23</sup> This initiative was launched in 1985 by the Canadian Chemical Producers Association, one year after the Bhopal disaster in India, “in which an estimated 5800 to more than 20000 people were killed due to a toxic chemical spill of methyl isocyanate at a Union Carbide plant”.<sup>24</sup> At the World Summit on Sustainable Development in

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<sup>18</sup> See reference [39]

<sup>19</sup> See reference [5]

<sup>20</sup> Average exchange rate 1 € = 1,2556 USD, calculated after the European Central Bank ([http://sdw.ecb.europa.eu/quickview.do?SERIES\\_KEY=120.EXR.D.USD.EUR.SP00.A&periodSortOrder=ASC](http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=120.EXR.D.USD.EUR.SP00.A&periodSortOrder=ASC))

<sup>21</sup> After reference [25]

<sup>22</sup> After references [11] and [1] Key data BASF group

<sup>23</sup> Based on reference [32] Responsible care website

<sup>24</sup> Based on reference [14]

Johannesburg in 2002, Responsible Care was recognized by the United Nations Environmental Program (UNEP) as “being a significant contribution by the chemical industry to sustainable development”.<sup>23</sup> Nowadays, chemical companies in 52 countries have Responsible Care implemented. BASF joined the initiative in 1992.

Contributing to the Responsible Care concept implemented in the company, and based on the fact that environmental aspects are more and more ranked alongside financial issues, BASF developed a tool of eco-efficiency analysis (EEA). According to Saling et. al (2002), the company wanted to “address not only strategic issues, but also issues posed by the market places, politics and research”. The EEA by BASF is a tool for decision-making process and was already used to analyze more than 300 products or processes, not only within the company, but also in external partners.<sup>25</sup> The methodology is certified by an external body, the TÜV Rheinland/Berlin-Brandenburg in Germany.

It is important to consider that an EEA by BASF is a comparative tool and therefore does not present an absolute value as a result. As observed by Saling et. al (2002), “a product that comes out as the best alternative in one EEA can be the least eco-efficient variant in another application”.

When designing the method, BASF decided to consider the economic and environmental influence of products and processes during all their life cycle. The environmental assessment is based on the ISO 14040 standard, whereas the costs are assessed from the point of view of the final customer. The main outcome of an analysis is an eco-efficiency portfolio, where the relative costs of the alternatives and their total environmental impact are plotted in the same graphic. The steps to draw this portfolio and its relation to LCA are briefly presented below. BASF conducts all the mandatory and optional phases of an LCA, which are presented on chapter 3.

The objective of this chapter is not to deeply investigate the EEA, but to briefly describe the LCA steps involved. It will also serve as a basis for the understanding of the SEEbalance® method.

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<sup>25</sup> Based on reference [2] BASF website

## **5.1. Definition of customer benefit, definition of alternatives**

According to the LCA methodology, the first step of an analysis is the definition of goal and scope. During this step of an EEA, the customer benefit (functional unit) of the product, process or service in study has to be defined. Since the BASF method is a comparative analysis between products performing the same function, possible alternative products to the product under investigation have also to be determined in this phase. Saling et. al (2002) suggests that “as many as possible alternatives represented in the marketplace should be included”.

The scope of the analysis is also set in this phase. As a rule, the overall process of the alternatives is to be studied, so the complete determination of environmental impact is assessed. Nevertheless, it is not unusual that the alternatives have similar production processes, and therefore have some identical modules.<sup>26</sup> The eco-efficiency method by BASF restricts the analysis to the truly differentiating modules.<sup>27</sup>

## **5.2. Determination of environmental impacts (inventory, classification and characterization)**

During this phase of an EEA, data is collected, according to the requirements of ISO 14040. The environmental impact is assessed considering six main categories:<sup>28</sup>

- energy consumption;
- emissions;
- material consumption;
- toxicity potential;
- risk potential (also hazard potential);
- land use.

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<sup>26</sup> Module in this case can also be understood as “unit process”, term mentioned in the description of LCA, chapter 4. The term module is used by BASF in the EEA.

<sup>27</sup> After reference [33], page 205

<sup>28</sup> Based on references [30], [33] and [34]

The category energy consumption is related to the consumption of primary energy. The sources used for the calculation are: coal, oil, gas, lignite, nuclear energy, waterpower, biomasses and others.

The overall emissions are primarily calculated according to the different receptor media: emissions to air, emissions to water and solid wastes.

In emissions to air, the inventory is classified into 4 subcategories: global warming potential (GWP), ozone depletion potential (ODP), photochemical ozone creation potential (POCP) and acidification potential (AP). An aggregate indicator for 'emissions to air' is calculated using a normalization and weighting scheme for each subcategory, which will be explained later.

The category 'emissions to water' is calculated according to the method of critical volumes or critical limits for discharges into surface waters. Saling et. al (2002) observes that this method considers the amount of water necessary to dilute the emission of a certain pollutant, up to its statutory limit. A numerical factor is stipulated for each substance or impact to water bodies, and is represented by the reciprocal of the statutory limit. For example, if the legal limit of emission of COD (chemical oxygen demand) is 75 mg/l, the factor used is  $1/75$ , which equals to 0,013. If the limit of Cl<sup>-</sup> (chlorine) is 1000 mg/l, its factor would be  $1/1000$ , which equals to 0,001. By doing this, one can multiply all the different emissions to water (COD, biochemical oxygen demand, Cl<sup>-</sup>, total nitrogen, etc...) by their factors, and sum them up to a single number, the critical volume of water, representing the total amount of water necessary to dilute the pollution of the effluent, in order to consider it appropriate for emission. The more polluter the effluent is, the more amount of water is necessary to dilute it.

The category 'solid wastes' is assessed considering three waste categories: "special wastes, wastes resembling domestic refuse and building rubble/gangue material".<sup>29</sup> The sum of the impact of these three categories is done with a factor based on the costs of disposal of each kind of waste. The more hazardous is the waste, the more expensive is to dispose it, and the

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<sup>29</sup> After reference [22], page 208

higher the factor would be. The indicator for solid wastes is the sum of the amount of each kind of waste multiplied by its factor.

The three indicators of the category 'emissions' (emissions to air, emissions to water and solid waste) are aggregated in a single indicator 'emissions' using a weighting scheme, which will be explained below.

Regarding material consumption, the total mass of raw material needed in the production of each alternative is calculated. To aggregate the consumption of different materials, the amount of each material is multiplied by a factor based on their availability<sup>30</sup>. The bigger the reserves of the material are, the smaller is the multiplier factor. The indicator for the category is a weighted consumption, based on amount of raw material used and its availability.

The next two categories, toxicity potential and risk potential, are usually not assessed in an LCA, but BASF decided to include them in the eco-efficiency tool. Toxicity potential is based on the toxic effect of a substance and the exposure to this substance. The hazard is evaluated according to the R-phrases<sup>31</sup> of the substance. The exposition depends on the amount used, on the use pattern (from closed system, to widely dispersive use) and also on the exposure route (oral uptake, inhalation and dermal uptake). Similarly to toxicity potential, the risk potential is evaluated considering the probability and the severity of "dangers of accidents in the manufacture, use and recycling of the product".<sup>32</sup> The assessment is done with statistical data. The indicator reflects a comparison between the alternatives, and therefore there is no absolute value that represents the risk.

The land use is evaluated considering the different types of land that are necessary during the whole life cycle of the product: natural areas, agricultural areas, roads, sealed soil, and so on. The more the land used diverges from natural areas, the higher its influence on the numerical indicator, which is done by multiplying the area by a factor based on the type of land.

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<sup>30</sup> The availability of the materials considers their reserves in years, based on statistical calculations of the USGS (United States Geological Survey) and other sources. See reference [22], page 209.

<sup>31</sup> The R-phrases of a substance reflect the different toxic effects that it may cause. See reference [23], page 262.

<sup>32</sup> After reference [23], page 211

The result of the inventory, already classified and categorized, will be assessed with following normalization, weighting and aggregation scheme, explained later.

### **5.3. Cost calculation**

In a similar way that the environmental impact is assessed during the whole life cycle of a product, the costs calculation involves the real costs of the product and the costs that might occur in the future, like the use and disposal stages. If the product is a durable good, a car for example, depreciation and the resale price can enter in the calculation. The eco-efficiency tool by BASF offers the possibility to include different costing models, according the country or the product involved in the study.

### **5.4. Normalization**

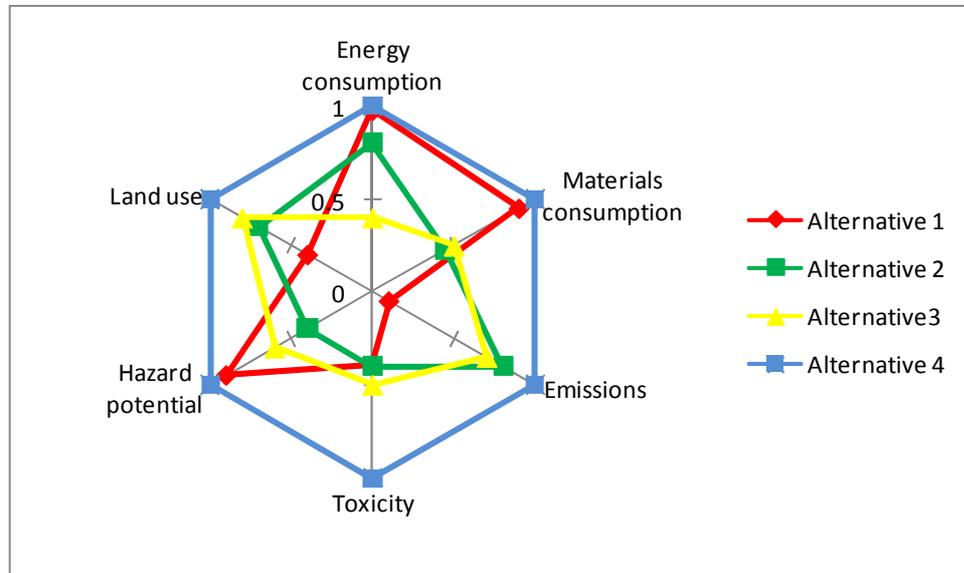
As previously discussed, according to ISO 14040, normalization is not an obligatory step in conducting an LCA. However, believing that the multiplicity of the results of a categorized inventory would not be easy to interpret, BASF developed the method in such a way that the final outcome of the environmental impact is a single indicator.

To compress the ecological data resulting from the inventory, categorization and classification, the first step is to normalize the results. Normalization occurs for all six categories mentioned above. The procedure is to attribute a value of 1 to the least favorable alternative in each category. The results of the other alternatives are all set in relation to the worst, which results in values from 0 to 1, where numbers closer to zero reflects the most favorable alternatives.

After normalization, it is possible to plot in a graph the results of all the alternatives, according to the categories mentioned previously. In the eco-efficiency method, BASF named the graph as “Ecological Fingerprint”. The graph makes it possible to visualize in a relative simple way the pros and cons of each alternative, in respect to the 6 categories. One alternative can

perform well on land use, and not so well on toxicity potential, if compared to other alternative.

An example of an Ecological Fingerprint can be seen in figure 2 below. Each of the colored line represents one alternative



**Figure 2: Example of Ecological Fingerprint.**  
Source: self-prepared based on BASF website, reference [2]

## 5.5. Weighting

The next phase of an EEA is the weighting. As explained in the LCA methodology, this phase is not obligatory. However, since BASF wanted to create a tool that could represent the environmental impact in a single number, one step of the analysis is the weighting phase.

The weighting scheme used by BASF is composed of two different types of weighting factors: relevance factors and societal factors. The overall weighting factor of a category is the weighted average of relevance and societal factors.

Relevance factors are determined for every EEA. They are calculated by dividing the impact of each category by the total impact in the country<sup>33</sup> or region of the study. The impact of the category is, as previously explained, the result of the inventory, classification and characterization phases. The total impact in a country or region can be found in statistical databases. The

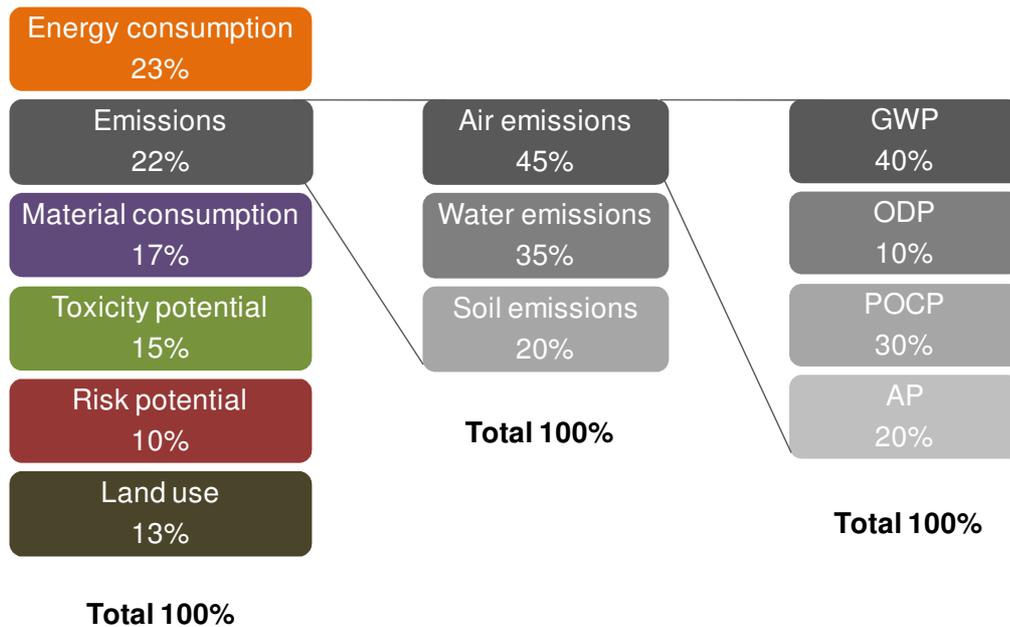
<sup>33</sup> For each category, the total impact in the country is the impact caused by all the sources of this impact. For example, the total impact of the category GWP is the total amount of CO<sub>2</sub> equivalent emitted during one year by all the sources in a specific country.

objective of this way of calculating the factors is to have a picture of the most relevant impacts on a certain study. If one is comparing electricity production by burning coal or by hydropower, the category emissions is expected to be more relevant than energy consumption, due to CO<sub>2</sub> emissions. The higher the contribution of a category to country values, the higher is its weighting factor. Therefore, one can argue that the focus of this weighting scheme is on the weaknesses of the alternatives, avoiding small impacts, which might be immaterial to the situation in a country, to be overvalued and larger and decisive impacts to be undervalued.

Relevance factors can be considered objective factors, due to the procedure of their determination, based on the inventory and on statistical data.

Differently from relevance factors, societal factors are not calculated for every analysis and they are considered subjective. They represent the importance of each environmental category for society and can be determined through surveys, public opinion polling or expert interviews. The factors depend on the region and the period of the study. Therefore, it is convenient to review them from time to time. For example, 20 years ago ozone depletion was considered much more important than climate change in the environmental debate.

As mentioned above, in the classification phase, there are six categories: energy consumption, emissions, material consumption, toxicity potential, risk potential and land use. Emissions are divided into: emissions to air, water and soil wastes. Emissions to air are subdivided into four subcategories: GWP, ODP, POCP and AP. In each level of aggregation, relevance and societal factors of all the categories have to sum to 100%. One example of weighting factors and the divisions of the category emissions can be seen in figure 3.



**Figure 3: Example of weighting factors. Self-prepared.**

The weighting factors of the subcategories shown in the second and third columns of the figure above are used in the aggregation of the single indicator emissions, explained in chapter 5.2.

After determining the relevance and the societal factors, the overall weighting factors are calculated. The results of the normalization step (the ecological fingerprint) are multiplied by these overall factors and summed up to a single indicator, which represents the environmental impact of the alternatives studied.

## 5.6. Eco-efficiency Portfolio

The calculation of costs and environmental impact are two separate steps of an EEA. Nevertheless, the main purpose of the analysis is to present both results together, facilitating their visualization and easing the decision making process. BASF developed the eco-efficiency portfolio, which is the plot of both results: costs and environmental impact.

All the alternatives studied are plotted together, each being represented by a ball on the portfolio. Since the EEA is a comparative assessment, if the data input changes in one alternative, all the balls are going to change their position. An example of eco-efficiency portfolio is shown in figure 4.

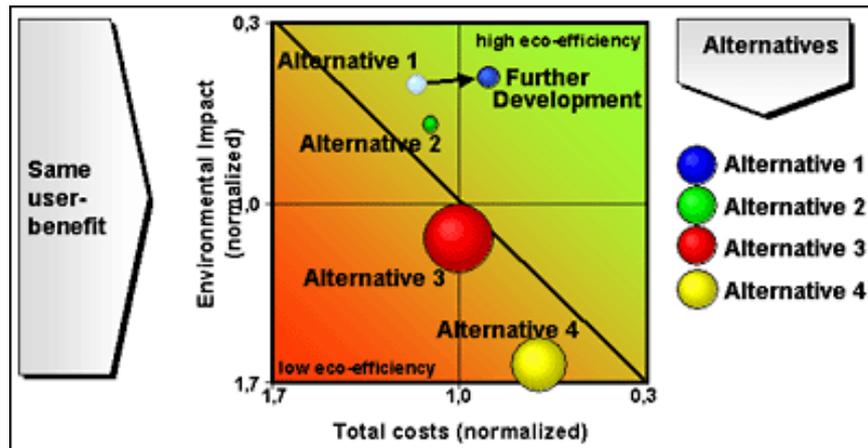
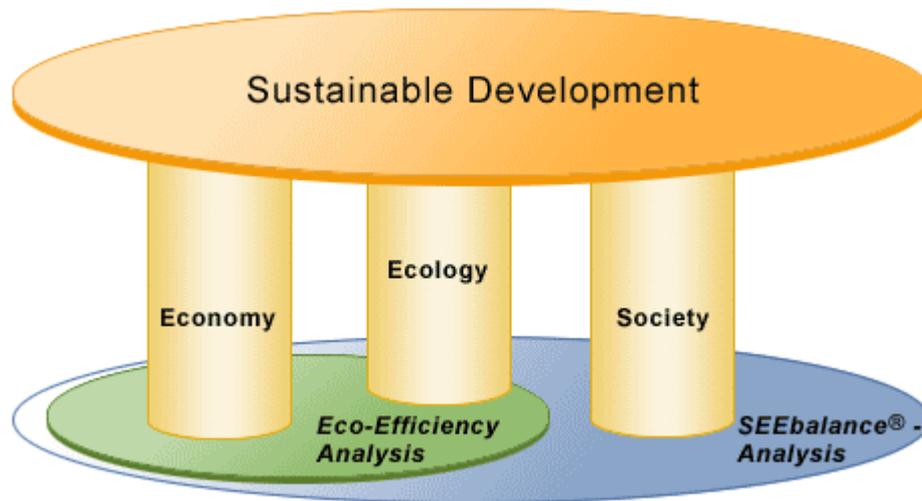


Figure 4: Example of eco-efficiency portfolio. Source: BASF website, reference [2]

The most favorable alternatives are presented plotted on the top right side of the graph and the least favorable alternatives on the bottom left side. The size of the balls indicates the market share of each alternative. The distance between the alternative and the portfolio diagonal line is an indication of its eco-efficiency. The main feature of the portfolio is to present in a glance the results of a very detailed study. It is recommended, however, to evaluate the results of individual categories (categorization and normalization) for a more detailed assessment.

## 6. The inclusion of social dimension in the eco-efficiency analysis: SEEbalance®

For the completeness of the tool imagined by BASF, i.e. a tool that could be able to compare products regarding their sustainability, the social impact was included in the assessment. Based on the EEA, which already included the economic and environmental assessment, the SEEbalance® was created. The abbreviation SEE stands for Socio-Eco-Efficiency analysis. The SEEbalance® is therefore an improvement of the EEA that allows the quantification of all three pillars of sustainability, as shown in figure 5.



**Figure 5: Inclusion of the social pillar in the eco-efficiency analysis. Source: BASF website [3]**

The development of SEEBalance® is the result of a research project of BASF in cooperation with Karlsruhe University, Öko-Institut in Freiburg and Jena University, supported by the German Federal Ministry of Education and Research. The project started in 2002 and lasted three years.

The SEEBalance® methodology has the same structure of the eco-efficiency, based on life cycle assessment. A detailed description of the procedure and the presentation of the results are discussed now.

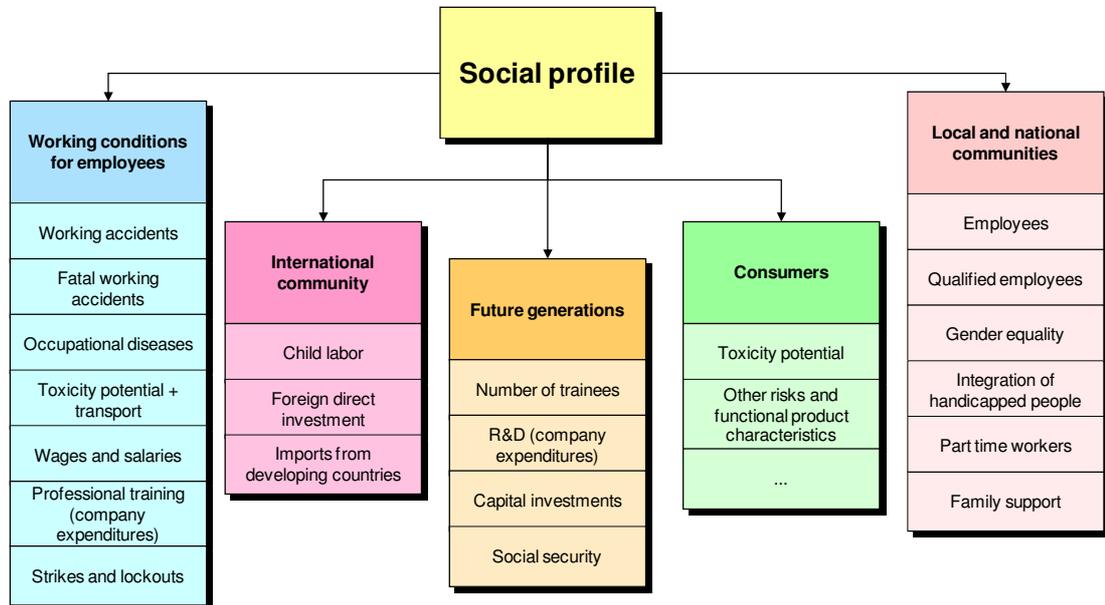
### **6.1. Stakeholders and indicators**

Whereas in the environmental assessment of SEEBalance® the impact is calculated according to environmental categories, for the social assessment the impact is evaluated according to different stakeholders. The stakeholders are the groups that might be affected during the life cycle of the product.

The SEEBalance® considers five different stakeholders:

- employees;
- international community;
- future generations;
- consumers;
- local and national communities;

For each of the stakeholders, several numerical indicators are calculated for the entire life cycle of the product and after that are aggregated following the same procedure of the environmental impact. The list of indicators for each stakeholder can be seen in figure in figure 6 below.



**Figure 6: Indicators per stakeholder of a SEEBalance® analysis.**  
**Source: Self-prepared based on BASF website [3]**

Some of the indicators have a positive influence, which means “the higher-the-better”. For instance, the higher the wages and salaries, the better to the employees. In other cases, the indicators influence negatively the social profile of a product, i. e. “the-lower-the-better”. For example, the lower the number of working accidents, the best for the employees.

The result of the social profile of the alternatives studied, i. e. the numerical indicators, is normalized and weighted in the same manner as the environmental categories in the environmental profile.

However, one important thing is not to be forgotten: the necessity of databases. As reminded by Schmidt et al. (2004), environmental databases with relevant inputs and outputs related to one product unit (usually 1 kg or 1 MJ) do exist, but the same is not valid for social aspects. In an LCA, databases are necessary to obtain data that can not be measured or calculated. Besides that, on the EEA and on the SEEBalance®, databases are also used to calculate the relevance factors, as the total impact of each aspect needs to be known.

Therefore, one step of SEEbalance® is the construction of such a database. The approach used to do so is based on an industrial sector assessment. As explained on Schmidt et al. (2004), statistical data for each aspect (e.g. working accidents) is related to the quantities of goods produced in various industries of the economy, e.g. agriculture, chemicals, pulp and paper, furniture. In Germany, this database is already being established, based on the EU classification of economical activities NACE rev.1.1.<sup>34</sup> The classification of products CPA<sup>35</sup> allows their assignment to the corresponding economic activity. The NACE classification groups the economical activities into:

- sections (identified by alphabetical letters A to U);
- sub-sections (identified by two-character alphabetical codes CA, CB, DA to DN)
- divisions (identified by two-digit numerical codes 01 to 99);
- groups (identified by three-digit numerical codes 01.1 to 99.0);
- classes (identified by four-digit numerical codes (01.11 to 99.00).

For example, paints are connected to the following classification of economic activity:

- section D: Manufacturing;
- sub section DG: Manufacture of chemicals, chemical products and man-made fibres;
- division 24: Manufacture of chemicals and chemical products;
- group 24.3: Manufacture of paints, varnishes and similar coatings, printing ink and mastics;
- class 24.30: Manufacture of paints, varnishes and similar coatings, printing ink and mastics.

## 6.2. Social fingerprint

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<sup>34</sup> NACE (French) = Nomenclature des Activités économiques dans les Communautés Européennes [Statistical classification of Economic Activities in the European Community], available in <http://ec.europa.eu/eurostat/ramon/>

<sup>35</sup> CPA = Statistical Classification of Products by Activity in the European Economic Community. Also available in <http://ec.europa.eu/eurostat/ramon/>

Similarly to the environmental assessment, where different indicators are aggregated to give the impact of each environmental category, the same happens with the social indicators. They are firstly weighted using the same scheme (relevance factors x social factors) and then aggregated to one indicator for each stakeholder. The six stakeholder indicators of each alternative are then normalized likewise the environmental indicators: the worst alternative receive the value of 1 and all the others receive proportional values.

The results of the aggregation and normalization are plotted in a graph, the so called social fingerprint. One example of social fingerprint can be seen in figure 7 below.

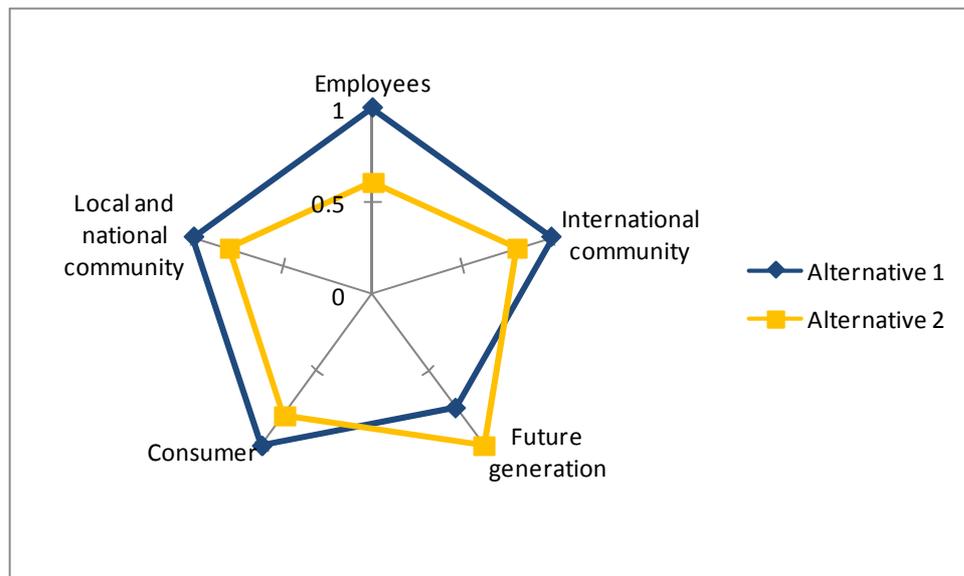


Figure 7: Example of Social fingerprint. Source: self-prepared based on reference [35]

### 6.3. SEEcube®

Using the same idea of the eco-efficiency portfolio, the results of the social fingerprint can be weighted once again and then aggregated to a single indicator. Therefore, each alternative of the study has now three indicators normalized and weighted indicators – costs, environmental and social – which can be plotted in a tridimensional graph, the socio-eco-efficiency portfolio, or SEEcube®, as BASF decided to call it. An example of SEEcube® is shown in figure 8.

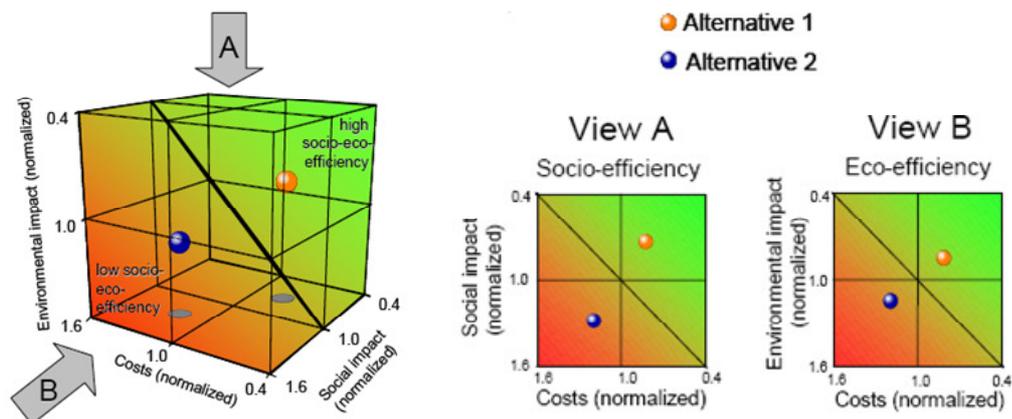


Figure 8: Example of SEEcube@. Source: adapted from reference [35]

By projecting the results on the faces of the cube (view A and view B), the socio-efficiency and eco-efficiency portfolios are obtained. Likewise the eco-efficiency portfolio, the main feature of presenting the aggregated results in only one graph is to be able to visualize in a glance the comparison of two alternatives regarding their economical, environmental and social aspects.

## 7. Adaptation of the SEEbalance® to Brazil.

The EEA is already used worldwide. In Brazil, the tool is implemented by *Fundação Espaço ECO*, which is a foundation resulting from the partnership between BASF and GTZ (which is the German agency for technical cooperation). Besides promoting the eco-efficiency tool in Latin America, *Espaço ECO* also carries out projects in the field of socio-environmental education, communitarian development and reforestation.<sup>36</sup> The foundation exists since 2005 and until 2009 more than € 1 billion will have been invested on it.

Having already established its expertise on the eco-efficiency tool, the next step to upgrade the portfolio of projects of *Espaço ECO* is to implement the SEEbalance® in Brazil. However, as the tool was conceived in Germany, it is necessary to take some measures to adapt it to the Brazilian reality. To be more specific, the adaptation has to cover the aspects that would be different in both countries, which might include:

- the definition of the indicators;

<sup>36</sup> Adapted from reference [13] *Fundação Espaço ECO* Webiste

- how the indicators are going to be measured;
- which sources are going to be used;
- the social factors in Brazil.

As already explained, the social factors are determined by public surveys or questionnaires sent to specialists. At this stage, the research described in this thesis didn't deal with organizing such questionnaires. As a result, the Brazilian social factors are not addressed in this work.

The following part presents the results of the research for each indicator, discussing their definition in Brazil, the sources of data available and how they are structured. In the end, a summary list is presented. However, before the discussion on the indicators, it is necessary to mention the construction of a social Brazilian database.

As explained above, the social database in Germany is based on the NACE code. In Brazil, the classification of the economic activities is the CNAE<sup>37</sup>, which is a bit different from NACE. By comparison, the classification of paints in CNAE would be:

- section D: Manufacturing;
- division 24: Manufacture of chemicals and chemical products;
- group 24.8: Manufacture of paints, varnishes and similar coatings, printing ink and mastics;
- class 24.81: Manufacture of paints, varnishes and similar coatings, printing ink and mastics.

Therefore, if BASF wants to have a worldwide social database, one first adaptation measure is to create a relation between the NACE and the CNAE codes. Some of the NACE classes are aggregation of CNAE classes and vice-versa. Some CNAE classes do not have matching classes in NACE. Hence, a correspondence at group or division level is necessary. What is important for the database is that at least on one level (section, division, group or class) a correspondence should be possible. It is also possible to have a database exclusive for Brazil, based only on CNAE, which would be

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<sup>37</sup> CNAE (Portuguese) = Classificação Nacional de Atividades Econômicas [National Classification of Economic Activities], available in <http://www.cnae.ibge.gov.br/estrutura.asp>

used on SEEbalance® projects carried out only on the country, i.e. not comparing products from different countries.

### **7.1. Working accidents**

Every company in Brazil is bound by law<sup>38</sup> to report within one working day (immediately in case of death) all working accidents, with or without loss of working time. The company must fill in the CAT (communication of working accident) to notify the National Institute of Social Security (INSS). The accident can be: "typical" (resulting from the activity itself) or "course" (accident on the way between the residence and the working place or vice-versa).

Statistical data is available for every CNAE code, including all the sections, which allows completing the social database for all the economic activities. The data source is the Statistical Yearbook of Working Accidents, which contains data for accidents per type (typical or course), consequence (death, permanent injury, occupational disease), month, State of the federation and gender.

Therefore, for this indicator, no major problem was identified for the construction of the database or in its application to Brazil.

### **7.2. Fatal working accidents**

The same discussion of the indicator "working accidents" applies to this one. Since the data source is the same, it is possible to distinguish fatal working accidents from other accidents. One difference to be mentioned is that there is no data available for each State of the federation like in the previous indicator. No adaptation of the indicator is needed and data is immediately available.

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<sup>38</sup> Law n° 8.213/91 article 22, available in Portuguese in <http://www81.dataprev.gov.br/sislex/paginas/42/1991/8213.htm>

### **7.3. Occupational diseases**

In Brazil, occupational diseases are considered as working accidents. Therefore, as in the case of the two previous indicators, there is plenty of data available for this indicator. The same discussion of “working accidents” applies to this indicator, where no major adaptation for Brazil is needed and the social database can be immediately constructed.

### **7.4. Toxicity potential (employees) + transport**

In this case, no social database is needed. The toxicity potential is analysed by BASF in the same way for an EEA, i.e. based on the R-phrases of a product.

No adaptation is needed for Brazil, where the same method can be applied.

### **7.5. Wages and salaries**

This indicator includes the fee for working hours, extra payments and salaries for free working days. These data can be easily retrieved in Brazil. The Brazilian Institute of Geography and Statistics (IBGE) conducts annual surveys on the following economic sectors: Industry, Construction Industry, Trade and Services. These annual surveys<sup>39</sup> cover the CNAE sections C (mining and quarrying), D (manufacturing), F (construction industry), G (trade) and H to O (services) and bring data regarding characteristics of the companies, like number of employees, revenues, expenditures with employment, with taxes, investments, etc. The survey covers all companies with more than 30 employees. For smaller companies, a survey based on sampling is conducted. Data is available at class level, i.e. for all classes of the CNAE classification.

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<sup>39</sup>References: [19] PAC (annual trade survey), [20] PAIC (annual construction industry survey), and [21] PAS (annual services survey) and [22] PIA (annual industry survey). All available in Portuguese in [http://www.ibge.gov.br/home/#sub\\_economia](http://www.ibge.gov.br/home/#sub_economia)

For the sectors where annual surveys are not available, i.e. A (agriculture, hunting and forestry), B (fishing) and E (electricity, gas and water supply), information regarding the characteristics of the companies can be retrieved on the Statistics from the National Register of Enterprises (CEMPRE), which is also published by IBGE. The information available in CEMPRE<sup>40</sup> covers all the economic activities on the group level, but is less complete than the annual surveys.

No adaptation measure is needed for Brazil and data is available for all the economic activities.

## **7.6. Professional training**

This indicator presents the expenditures of the companies in professional training. It includes material expenses and external costs for occupational education and advanced training. At present, no information was found regarding these expenditures in Brazil. What was found so far is the percentage of companies that had employees trained according to the average number of training hours per employee, inside or outside the company. For instance, in the chemical industry (CNAE division 24) 13.3% of the companies had 1 to 8 hours of training hours per employee inside the company, 60.0% from 9 to 24 hours, 20.0% from 25 to 40 hours and 6,7% of the companies had more than 40 hours of training hours per employee<sup>41</sup>.

In this case, either more research is necessary to identify the information that fits the measurement unit (costs for professional training in €) used so far, or the way of measuring the indicator in Brazil needs to be changed, in order to adapt to the existing data.

## **7.7. Strikes and lockouts**

In this indicator, BASF considers any labor dispute with minimum of ten or more employees with a loss of working hours of at least one day. There is no consolidated data regarding this indicator in Brazil, at least not

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<sup>40</sup> See reference [18], available in [http://www.ibge.gov.br/home/#sub\\_economia](http://www.ibge.gov.br/home/#sub_economia)

<sup>41</sup> See reference [7], table 38

divided into the economic activities. So far, one general study from DIEESE<sup>42</sup> was found, which brings data regarding the number of lost working hours in the first semester of 2006, aggregating all the economic activities into only four sectors: industry, service, trade and rural. If no more detailed source is found, i.e. presenting data detailed for each CNAE class, group or division, this study may be used as an indication of the number of strikes and lockouts in Brazil.

### **7.8. Child labor**

In Brazil, general employment is forbidden for any person under 16 years old, except for apprenticeships, with the minimum age being 14 years. However, data from PNAD (National Household Sample Survey) 2001 showed an estimation of 3 million children between 5 and 15 years working.<sup>43</sup> There are considerable differences among the regions in Brazil. While in South children work more in agriculture, in other regions, trade and services are the sectors with higher rates of child labor.

The Brazilian secretariat of ILO (International Labor Organization) published in 2004 a report presenting the profile of child labor in Brazil, by regions and activities.<sup>44</sup> The study is based on data from the PNAD 2001 and brings the number of children between 5 and 15 years old working according to seven economic branches: agriculture, trade, construction, industry, services, social and others. Although the data is not classified according to the CNAE classification, it can be used to measure the indicator.

### **7.9. Foreign direct investment**

This indicator reflects the foreign direct investment (FDI) in developing countries, from the perspective of the country where the alternatives are

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<sup>42</sup> See reference [8], table 1. DIEESE is an Inter labor unions department for statistics and socioeconomic studies. DIEESE publishes studies about income, labor unions agreement, strikes and lockouts, economics and other issues of interest for workers.

<sup>43</sup> See reference [24]

<sup>44</sup> See reference [29], table 32

produced. That means, to account how much FDI in developing countries the companies related to the product studied do.

Since Brazil itself is a developing country, the first issue raised regarding this indicator was its applicability to the country. The discussion is still going on, but a first idea is to keep this indicator, since there are Brazilian transnational companies, which do invest abroad (e.g. *Petrobras*, *Gerdaul*, *Cia Vale do Rio Doce*). The Central Bank of Brazil publishes data regarding outward FDI per country and economic activity of the receptor company<sup>45</sup>. The United Nations Conference on Trade and Development (UNCTAD) also presents data regarding FDI.<sup>46</sup> However, none of the sources presents data concerning the FDI done by Brazil in developing countries, consolidated by the economic activity of the investors, i.e. by economic activity of the Brazilian companies investing abroad. This data, FDI from Brazil in developing countries, divided by economic activity of the investor, is still needed for the construction of the social database. Besides that, no other measure has to be taken in adapting the indicator to Brazil.

### **7.10. Imports from developing countries**

This indicator is not yet included in the German version of SEEbalance®, due to lack of data. In Brazil data was found regarding the imports from developing countries of different products, classified into the NCM<sup>47</sup> code. There is a list of correlations between this NCM code and the CNAE. Therefore, it is possible to know the amount and value of the imports by Brazil from developing countries of products covering the economic activities of sectors A-D (agriculture, hunting, fishing and manufacturing).

However, it is important to notice that the data reflects the economic activity of the origin of the product, and not the destiny of the import. That means it is not possible to know how much was imported by each of the economic activities in Brazil, but from each economic activity in developing countries. Data showing the imports of Brazilian companies from developing countries is still needed. No further adaptation measure is needed.

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<sup>45</sup> See the website of Central Bank of Brazil: <http://www4.bcb.gov.br/?CBERESULT>

<sup>46</sup> See the UNCTAD website: <http://www.unctad.org/Templates/Page.asp?intItemID=3198&lang=1>

<sup>47</sup> NCM (Portuguese) = Nomenclatura Comum do Mercosul [Mercosur Common Nomenclature]

### **7.11. Number of trainees**

Trainees are employees under a contract of apprenticeship in a qualified job. In Brazil, big and medium size enterprises are obligated by law to hire young people between 14 and 24 as trainees.<sup>48</sup> However, there are companies that publish this information on their annual report. So far no data regarding the number of trainees according to economic activities was found. If this kind of data is found, no adaptation measure is necessary to implement this indicator in Brazil.

### **7.12. Research and development (company expenditures)**

This indicator includes all the companies' internal and external expenditures in research and development (R&D). Every two years the IBGE publishes an Industrial Survey of Technological Innovation (PINTEC)<sup>49</sup>, which brings the expenditures with R&D of companies belonging to the sections C (mining and quarrying) and D (manufacturing), group 64.2 (telecommunications) and divisions 72 (Computer and related activities) and 73 (Research and development) of the CNAE. There is no need of adapting the indicator to Brazil, but it is necessary in the future to look for data regarding the economic activities not covered on PINTEC.

### **7.13. Capital investments**

This indicator portrays the value of replacement and net investment, including general repair, purchase of concessions, patents and licenses. As mentioned in the indicator wages and salaries, IBGE publishes annual surveys containing data about companies in Brazil, which includes expenditures with investments. Data regarding the investments for divisions A (agriculture, hunting and forestry), B (fishing) and E (electricity, gas and

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<sup>48</sup> Law 10.097/2000 and decree 5.598/2005 available in Portuguese in <http://www.mte.gov.br/aprendizagem/default.asp>

<sup>49</sup> See reference [23], available in [http://www.ibge.gov.br/home/#sub\\_economia](http://www.ibge.gov.br/home/#sub_economia)

water supply) of CNAE still needs to be found. Regarding the adaptation of the indicator, no measure needs to be taken.

#### **7.14. Social security**

The label of social security covers all compulsory employer contributions to health insurance, unemployment insurance, pensions and similar. The annual surveys conducted and published by IBGE bring information regarding expenditures from companies with social pensions and a warranty fund for working time of the employee (FGTS), which are both compulsory. The company contribution to unemployment insurance is included in the wages and salaries and can not be differentiated to be summed up in this indicator.

Like in the previous indicators that have data coming from these annual surveys from IBGE, there is no data for the divisions A, B and E of CNAE. Besides the lack of data for the economic activities of these divisions (A, B and E), nothing is to be changed on the indicator.

#### **7.15. Toxicity potential (consumers)**

The same discussion of the indicator “toxicity potential for employees” applies for this one. The BASF method used to calculate the toxicity potential is applied to the consumers, instead of the employees.

#### **7.16. Other risks and functional product characteristics**

In this indicator, all other risks (e.g. failure, break) that are specific to the product or process should be recognized, as well as other relevant characteristics. Since these risks or characteristics depend on the product itself, not on the country, no adaptation is needed to apply the indicator in Brazil.

### **7.17. Number of employees**

The annual survey conducted by IBGE contains detailed information on companies from the CNAE sections C, D, F, G and H to O, as previously explained. For these sections, the number of employees is available for each class of CNAE.

For the other sections, the same as the indicator “wages and salaries” applies, i.e. the source CEMPRES can be used. However, some care is needed when evaluating the number of employees coming from this source. Since the CEMPRES takes into consideration only the legal companies, inconsistencies may appear in sectors like agriculture, for instance, where the major part of the labor force is informal. For example, the CEMPRES estimates the number of employees in the agriculture sector as around 420.000 people. The PNAD 2006<sup>50</sup> estimates 17.832.000 people occupied with agriculture. “Occupied people” includes formal and informal employees, people working for themselves, or for their own consumption, employers and non-remunerated people. Even if only the parcel of formal employees is taken (1.575.000), there is a difference of almost 4 times to the number in CEMPRES.

Besides this decision on which source to be used, there is no other measure be taken to apply the indicator in Brazil.

### **7.18. Number of qualified employees**

So far, no definition of qualified employees in Brazil was found. The first step to apply this indicator in Brazil is to clearly define what “qualified employees” means and to look for data regarding this issue.

In the Ministry of Education of Brazil, there is a secretariat for professional and technological education (SETEC). This secretariat publishes the PAER (regional economic activity survey), which has the purpose of being the statistical reference concerning professional education. Despite of the fact that PAER brings some data regarding the qualification of employees, this data can not be directly used, due to the regionalization of

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<sup>50</sup> See reference [24]. tab 4.18, available in [http://www.ibge.gov.br/home/#sub\\_economia](http://www.ibge.gov.br/home/#sub_economia)

the surveys, i.e. there is one survey for each state of Brazil. There isn't a national consolidation of the results. Besides, the surveys are conducted differently in each state, covering different aspects. Therefore the number of qualified employees may be investigated in one state and not in another, which makes impossible a national consolidation.

Regarding the way the results are presented, the best indication of the number of qualified employees comes from the PAER conducted in the state of São Paulo. The results present the absolute numbers of qualified employees and the percentage of the totality of qualified employees working in each economical activity. For instance, from all qualified employees working in the industrial sector in São Paulo in 2001 (394.751 employees), 7,51% (29.648) work in the chemical industry.<sup>51</sup>

The adaptation of the indicator to Brazil, therefore, passes through a better understanding of the definition of employment qualification in the context of the country. Besides, the data sources found so far need to be consolidated and handled in such a way that a national figure of the number of qualified employees can be seen.

### **7.19. Gender equality**

In this indicator, the number of women in management positions is to be expressed. In Brazil, some companies publish these data on their annual report. However there is no statistical data about female managers in Brazil, what to say divided into economic activities. The PNAD and surveys from the DIEESE present data regarding the total number of women employed per economic activity, but there is no distinction on which kind of position they work.

Therefore, to apply this indicator in Brazil, the search for data has to continue, or an estimation of women in management positions has to be done based on companies that publish such data.

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<sup>51</sup> In São Paulo, the responsible for publishing the PAER results is SEADE (Fundação Sistema Estadual de Análise de Dados). See reference [36] PAER/SP, downloadable file "MOD\_6TAB29\_1.xls".

## **7.20. Integration of handicapped people**

Following the same idea of gender equality, this indicator expresses the concern of the companies regarding discrimination issues. In this indicator, the number of handicapped people is to be counted. In Brazil, there is no consolidated data about the issue, and the same discussion for “women in management positions” applies here. Some companies publish on their annual report data about the number of handicapped employees. Therefore, to apply this indicator in Brazil, either the search for data sources continues, or an estimation based on companies’ reports has to be done.

## **7.21. Part time work**

Part time workers have shortened working hours compared to full time employees. This indicator expresses the number of employees that work under a part time contract. Data on this indicator is not yet found and the same arguments used on “gender equality” and “integration of handicapped people” can be applied here. Data sources are to be found, or estimations are to be done.

## **7.22. Family support**

The indicator family support in Germany expresses the companies’ expenditures with parental leave and other bonus for marriage, benefits for diseases, birth and death. In Brazil, the annual surveys conducted by IBGE (PIA, PAIC, PAC, PAS) bring data regarding “benefits granted to employees, such as: meal vouchers, transportation, medical and hospital expenses, kindergarten, education, etc. This data is available for the economic activities related to industry, construction, trade and services (CNAE divisions C, D, and from F to O), on a detailed level, i.e. for CNAE classes. There is also data about complementary pensions, which is not a compulsory expenditure for the company, but many enterprises grant as benefits as well.

Therefore, to use this indicator in Brazil, no adaptation measure is needed, except for a clear definition of which benefits it would include. Data

regarding the sections A (agriculture, hunting and forestry), B (fishing) and E (electricity, gas and water supply) of CNAE is still needed.

### 7.23. Summary list of adaptation of indicators

Table 1 contains a summary of the discussion of all indicators of SEEBalance®.

Stakeholder	Indicator	Influence	Adaptation measure?	Data source found?
WCE	Working Accidents	Negative	Nothing to change	Yes
WCE	Fatal Working Accidents	Negative	Nothing to change	Yes
WCE	Occupational Diseases	Negative	Nothing to change	Yes
WCE	Toxicity potential (employees) + transport	Negative	Nothing to change	Not necessary
WCE	Wages and Salaries	Positive	Nothing to change	Yes
WCE	Professional Training	Positive	Adapt indicator to data source found or look for other data sources	Yes
WCE	Strikes and Lockouts	Negative	Look for more detailed data source or adapt the data found to the CNAE classification	Yes, but not detailed
IC	Child Labor	Negative	Adapt the data found to the CNAE classification	Yes
IC	Foreign Direct Investment (in developing countries)	Positive	Look for data sources or adapt the indicator to the data found	Yes, but not as expected
IC	Imports from developing countries	Positive	Look for data sources or adapt the indicator to the data found	Yes, but not as expected
FG	Number of Trainees	Positive	Look for data sources or use estimations based on companies annual reports	Yes, but not as expected
FG	R&D (company expenditures)	Positive	Nothing to change, but look for more data	Yes, but not for all economic activities
FG	Capital Investments	Positive	Nothing to change, but look for more data	Yes, but not for all economic activities
FG	Social Security	Positive	Nothing to change, but look for more data	Yes, but not for all economic activities
C	Toxicity potential (consumers)	Negative	Nothing to change	Not necessary
C	Other risks and functional product characteristics	Negative	Nothing to change	Not necessary
LNC	Employees	Positive	Decide on which source to be used for some economic activities	Yes
LNC	Qualified Employees	Positive	To define "qualified employees" in Brazil and look for more detailed data	Yes, but not as expected
LNC	Gender Equality	Positive	Look for data sources or use estimations based on companies annual reports	Yes, but not as expected
LNC	Integration of Handicapped People	Positive	Look for data sources or use estimations based on companies annual reports	Yes, but not as expected
LNC	Part-time Workers	Positive	Look for data sources or use estimations based on companies annual reports	Yes, but not as expected
LNC	Family Support	Positive	Nothing to change, but look for more data	Yes, but not for all economic activities

Legend:  
WCE: Working Conditions for Employees  
IC: International Community  
FG: Future Generation  
C: Consumers  
LNC: Local & National Community

**Table 1: Summary of adaptation measures of SEEBalance® indicators. Self-prepared.**

## 8. Summary

During the last years, sustainable development has dominated the attention of the whole society. This kind of development passes through a cleaner way of production and a wiser behavior of consumers, the so called sustainable consumption and production. The business sector can contribute by producing more eco-efficient products.

One environmental tool that has been frequently for this purpose is the Life Cycle Assessment. LCA is a tool designed to assess the environmental impact of a product, process or service during its whole life cycle, from the “cradle to the grave”. Nevertheless, LCAs can also be used by government, NGOs and consumers.

The business sector benefits from the use of LCA by being able to know deeply the impacts of the products it makes. Therefore, improvements in the design of new products are possible, as well as in technological processes, in the acquisition of raw materials, in determining logistic routes or even in defining new strategies.

Comparing to other environmental tools, LCA is much more complete. It is not time or location dependant, like environmental impact assessment or risk assessment.

An LCA is composed of four phases: goal definition and scope, inventory analysis, impact assessment and finally interpretation of results. All the phases are interdependent and LCA is an iterative method, which means goals and scope have to be consistently checked.

After performing an LCA, it is possible to know all impacts of a product during its whole life cycle. This knowledge brings a holistic perspective of the influence of a product on the environment, facilitating the decision making process.

BASF is the leading chemical company in the world and is committed to the “Responsible Care”, which is a voluntary initiative of the chemical industry to improve its health, safety and environmental performance. Based in the LCA methodology, BASF developed a tool to compare environmental and economic aspects of a product, the eco-efficiency analysis.

The eco-efficiency analysis by BASF was applied in more than 300 studies worldwide and is certified by an external accreditation body. The economic part of the analysis considers the total costs of the product, whereas the environmental part follows the entire ISO 14040, including the non-mandatory steps normalization and weighting. The environmental impact is assessed according to six main categories: energy consumption, emissions, material consumption, toxicity potential, risk potential (also hazard potential) and land use.

The results of an eco-efficiency analysis can be presented in two main graphs: the ecological fingerprint and the eco-efficiency portfolio, which makes easier the visualization of a very complex analysis. The first graph is the result of the comparison of the studied products (alternatives) regarding the six main categories of the analysis. The worst alternative receives the value of 1 in the axis of the category, and all other alternatives receive proportional values. The second graph, the eco-efficiency portfolio, presents the results of both assessments (economic and environmental) together, each axis representing one of them. For that, the results of the inventory are weighted and aggregated according to a weighting scheme based on relevance and social factors. Alternatives more eco-efficient are plotted on the top right side of the portfolio and the less eco-efficient ones on the bottom left side.

BASF improved the eco-efficiency analysis with the inclusion of a social evaluation, creating the SEEBalance® method. By doing so, the third pillar of the sustainable development, which was lacking in the eco-efficiency analysis, could be taken into account. The method is the result of cooperation between the business (BASF) and the academic sector (universities) supported by the German government (German Federal Ministry of Education and Research).

The SEEBalance® follows the same structure of an eco-efficiency analysis, comparing products during their whole life-cycle. The social evaluation is divided into five main categories, represented by the affected groups of people: employees, international community, future generations, consumers and local and national communities. Each category is composed

by several indicators, such as number of employees, working accidents, child labor, social security and toxicity potential for the consumers.

The inventory of these indicators is normalized, weighted and aggregated using the same scheme as in an eco-efficiency analysis. The results are then plotted in two graphs: the social fingerprint and the SEEcube®. The social fingerprint is equivalent to the ecological fingerprint. Each axis represents one category (stakeholder) and the best alternative receives the value of 1. The SEEcube® is the aggregation of the eco-efficiency portfolio and the socio-efficiency portfolio, creating a tridimensional graph.

Whereas the eco-efficiency analysis is already worldwide used, the SEEbalance® is relatively new and is applied only in Germany. The Brazilian subsidiary of BASF, through the *Fundação Espaço Eco*, is studying how to adapt the SEEbalance® to apply it in Brazil. Since the method was conceived in Germany, there are some particularities that need to be taken into consideration, such as social factors, the construction of a database and the definition of the indicators.

The determination of social factors for the weighting scheme depends on public opinion survey and is not yet done. The construction of a social database and the indicators were discussed above. While for some indicators data was not yet found, for others only partial data was found, i.e. data covering only part of the economic activities of the database. It also happened that, in some cases, data was found but it is not ready to be used as an indicator. As a consequence, either the definition of the indicator needs to be changed, or the data has to be processed to express what is expected.

The adaptation of the SEEbalance® for Brazil will continue, with the participation of a multidisciplinary team, which includes eco-efficiency specialists from Brazil and Germany, sociologists and managers. This master thesis was the result of previous research and an assessment of what needs to be done to apply SEEbalance® in Brazil.

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## **Declaration of Integrity**

Hereby I declare that I have completed the present master thesis without the improper help of any third parties and without the use of other means than the ones stated. Any thoughts and ideas incurred directly or indirectly from external sources are marked as such.

Freiberg, October 31<sup>st</sup>, 2007

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