DOCUMENTATION OF LCWE DATA IN GABI

1 INTRODUCTION

Sustainability is an increasingly used expression and many products are marketed as being sustainable. The definition of sustainability includes ecological, economic and also social aspects, as presented in Figure 1. Currently, for example carbon footprints are highly discussed and therefore environmental and also economic profiles of products, but especially the social aspects are often largely neglected. The challenge for conducting a social assessment along the complete life cycle is the need of plenty – so far not acquired – data. This situation is comparable to the efforts that had to be done at the beginning of Life Cycle Assessment itself in the 1980s.

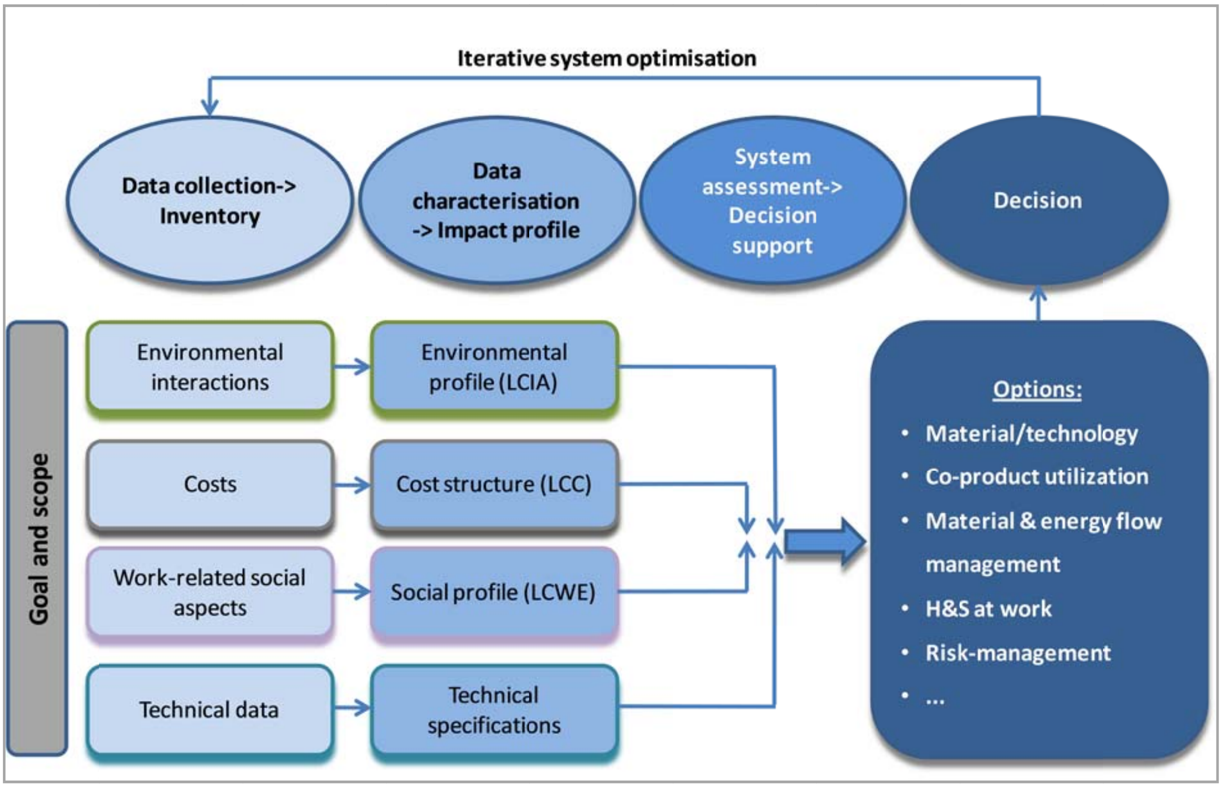

Figure 1: Sustainability: Integration of ecologic, economic, social and technical dimension in a software and database system

In order to fill these existing gaps, statistical sources can be employed to gather socially relevant data. The University of Stuttgart, Chair of Building Physics (LBP), Dept. Life Cycle Engineering (GaBi) developed the method of Life Cycle Working Environment (LCWE) to integrate social aspects into Life Cycle Assessment (LCA). In applying this method, high quality process-specific data concerning social aspects for use in product LCA is obtained by using statistical sources. The following aspects are covered:

- Amount and qualification level of work
- Health and safety.

The next paragraphs will document the method that was applied to generate social profiles for all unit processes in the GaBi database.

2 SELECTION CRITERIA FOR INDICATORS

When thinking about social effects, one of the first questions to consider is which criteria should be measured and which indicators should be employed to describe the social implications of a human action. For the method described here, the objective was to integrate social assessment into the already existing methodology of Life Cycle Engineering (LCE). That imposes some restrictions upon the choice of indicators. Therefore, the criteria the employed indicators have to comply with are described in the following.

2.1 Relevance and Consensus

The social goals should have an actual relevance and a broad international consensus. They should if necessary allow for the inclusion of other societal or cultural values.

2.2 Impartiality

The indicators and their ascertainment should be impartial and revisable.

2.3 Completeness and attributability

1. All relevant goals should be addressed.
2. The indicator should cover the respective social goal comprehensively.
3. The indicator should be clearly and completely attributable to the respective product or process.

2.4 Quantitativeness

The indicator should comprise a quantitative measure in order to be aggregated over the whole life cycle.

2.5 Pertinence of indicator sum

The sum of the indicator values of all processes of one site, company, industrial sector or country should accurately describe the overall situation.

2.6 No Overlap

There should be no overlap between the different indicators to avoid double counting and therefore overvaluation of single effects.

2.7 Comparability of targets and indicators

1. The goals and indicators should be comparable in an international context.
2. The goals and indicators should be comparable between different industries.

2.8 Product/Process-relatedness

The goals and indicators should have a direct relation to products or processes or should facilitate to be related to them.

2.9 Average validity

The indicators should remain valid for average modelling, i.e. useful for LCWE databases.

2.10 System boundaries, cut-off criteria, reference system

They are chosen in accordance with the ISO 14040 and 14044 (CEN 2006), whereas the "environmental relevance" is substituted by the "social relevance".

2.11 Temporal stability and time series

The calculation of the social indicators should be repeatable for other years, which means that time series show the actual changes.

2.12 Data availability/effort

The data collection should be viable under justifiable effort.

3 LCWE METHOD DESCRIPTION

The next paragraphs will explain the LCWE method developed at University of Stuttgart, LBP-GaBi.

3.1 Indicators chosen for integration into LCA

Table 1 shows the indicators chosen to be integrated into the Life Cycle Engineering methodology basing on the criteria described above.

Table 1: Social Indicators chosen

Group	Indicator	Unit
Qualified working time	General Qualification level A (GQL A)	[sec]
	General Qualification level B (GQL B)	[sec]
	General Qualification level C (GQL C)	[sec]
	General Qualification level D (GQL D)	[sec]
	General Qualification level E (GQL E)	[sec]
	Total working time	[sec]
Health and Safety	Lethal accidents	[cases]
	Non-lethal accidents	[cases]

3.2 Data acquisition method

In general, both, a bottom-up and a top-down approach for data acquisition do exist. The bottom-up approach would be the separate acquisition of data for every unit process. The top-down approach corresponds to the prorating of aggregate data to single processes.

3.2.1 Separate data acquisition for unit processes

Applying this approach, social indicators have to be collected for each process in the production chain. Here the problem occurs that such data is rarely available at the moment, because a meaningful use and comprehensive approach for such indicators was non-existent so far. The initiation of a continuous ascertainment of this data would be cost intensive and time consuming.

Due to this, for the beginning the top-down attempt is chosen for the LCWE methodology developed at the University of Stuttgart. Nevertheless, the data acquisition for every single process remains the middle-term to long-term goal because of its more precise results.

3.2.2 Proration of aggregated data to single process

Statistical data concerning social issues is available for most of the highly developed countries, for some of them detailed enough to use them in the LCWE methodology.

To prorate this data down to process level, the following assumptions are applied:

1. The social impacts of a process are proportional related to the amount of human labour of the process.

2. The amount of human labour of a process is related to the effort made to add value by processing (which is equivalent to the added-value itself).

The above assumptions are valid within the same industry and in the same country only.

In contrast to the situation for environmental Input-Output tables, the amount of human work is very well correlated with the economic value added of a process. The precision of the results that can be reached is hence high enough to be used as a reasonable starting point for modelling on the product level.

Figure 2 shows the different steps of the approach developed at the University Stuttgart aiming at the calculation of process specific LCWE data.

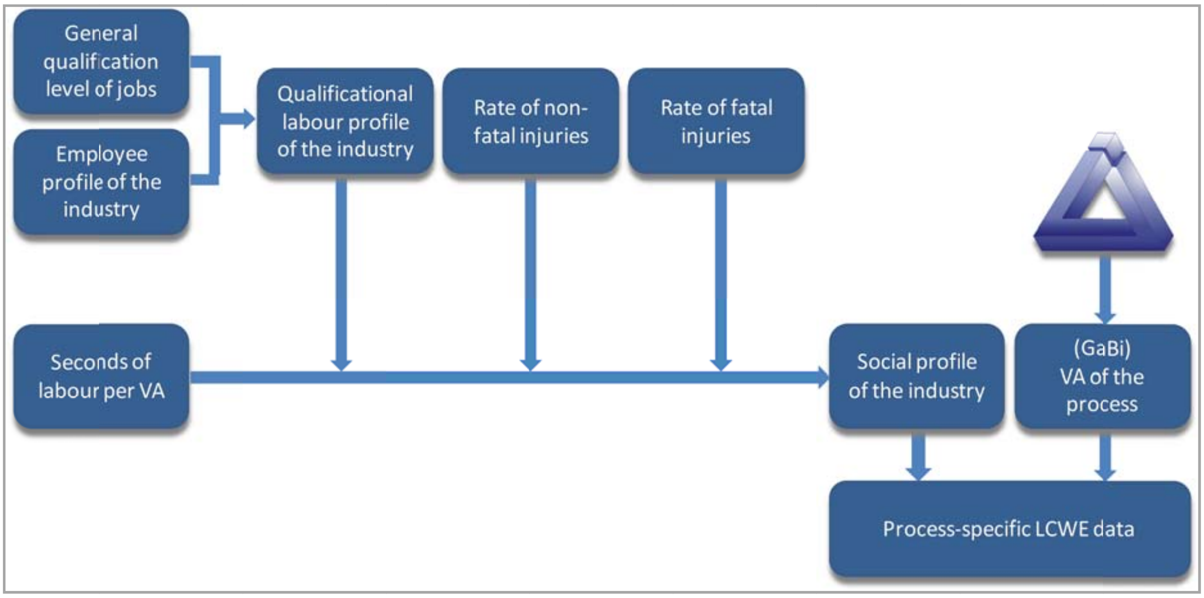

Figure 2: Generation of process-specific social information

In the following paragraphs, the steps shown in Figure 2 are described in more detail.

3.3 General qualification level of jobs

In the first step, single professions are allocated to different qualification levels. The classification is made according to the International Standard Classification of Education (UNESCO INSTITUTE FOR STATISTICS 1997). This classification was developed in 1997 by the UNESCO in order to classify and characterize different school types and school systems. The ISCED addresses the required qualification of a job position rather than the actual qualification of the employees. It classifies seven different qualification levels (Level 0 – Level 6). In the course of the development of this method Level 0, Level 1 and Level 2 were combined to one level. The distinctions made in these levels for the required qualification of a job are not relevant enough to be kept in the classification for the developed method.

3.4 Employee profile of the industry

In the second step, the profession distribution per industry is calculated via a matrix based on the SIC code (OCCUPATIONAL HEALTH AND SAFETY ADMINISTRATION 1992). In the table elements of the matrix, the number of positions of each profession in every single industry is presented. From this, the employee profile of each industry can be identified.

3.5 Seconds of labour per VA

The seconds of labour per value added are derived from the U.S. Economic Census (U.S. CENSUS BUREAU 1997). This statistic gives information about the number of employees, average number of production workers, production workers' hours, cost of contract work and the value added. The value added given in the statistic is calculated from the income through the sale of the produced goods less the expenditures for auxiliary materials, intermediates and/or resources and the expenditures for subcontracting. The value added for the calculation of the seconds of labour per VA – relation is therefore corrected by this number. The working time is only quoted for workers, not for appointees. It is assumed in the methodology, that an appointee works the same hours per year as a worker.

3.6 Qualificational labour profile of the industry

In the next step, the total working time per value added can be broken down with the support of the tables and matrixes generated in the steps before. The result is a qualification profile of each industry per value added generated. This qualification profile shows the amount of working time in each of the five qualification levels to generate one Euro value added. These values, same as the total working to generate one Euro value added, vary between different industries.

3.7 Rate of non-fatal injuries per VA

For the calculation of non-fatal injuries, two kinds of data are available (UNITED STATES DEPARTMENT OF LABOR 1999): The injuries listed as injury rates, as well as absolute numbers of injuries per industry. The injury rates present the numbers of injuries per performed working time. These rates are corresponding with the risk of the employees to get injured in the specific industry. The absolute rates give the total number of injuries without taking the total number of employees in the specific industry into account. In the context of the method described here, the non – fatal injuries have to be related to the total working time and respectively to the value added in order to classify them to the different processes. Therefore, the rate of non-fatal injuries is used.

3.8 Rate of fatal injuries per VA

The fatal injuries are also collected and published by the U. S. Department of Labor (UNITED STATES DEPARTMENT OF LABOR 1999). For the fatal injuries only absolute numbers are available. A statement concerning the risk of fatal injuries in the different industries therefore is not possible.

In order to relate the fatal injuries to the total working time and hence to the value added, the working time for every industry has to be available. For the reasons explained in the last paragraph, values should not be drawn from different sources. So values from different tables, generated based on the source mentioned above on non-fatal and fatal injuries, are used: The total working time for each industry is derived from the non-fatal injuries rate and from the absolute number of non-fatal injuries.

3.9 Social Profile of the industry

The social profile for each industry includes the working time in different qualification levels, the non-fatal and the fatal injuries, each related to one Euro of value added generated in the respective industry.

3.10 Prices for GaBi-Flows

For relating the social data to LCA process data, the value added of each LCA process has to be identified. This is done by calculating the delta of prices between the output and the input flows of each process. Therefore, for all materials, intermediate products or products, as well as various energy fluxes, which go in and out of processes, prices have to be determined and assigned. Since the product prices depend on a dynamic market, the same reference period for both the prices and for the identification of the value added of the industries should be selected. In this case the calculation is made with annual average values of the same reference period. A foreign trade statistic is used to provide consistent price data (U.S. CENSUS BUREAU 2002A, U.S. CENSUS BUREAU 2002B).

For most of the flows, prices can be calculated regarding quantities and total value of exported commodities. In cases where this is not possible, prices are estimated per expert judgement using the assumptions that there are no negative value addeds and that price ranges can be estimated on the basis of the lower price of a preliminary product and the higher price of a subsequent product. This kind of estimation has an impact on the result if

1. the according flow passes from one industry into another industry and
2. the social profile of both industries varies.

3.11 Value Added of GaBi-Processes

In order to calculate the value added of a single process, the total value of the incoming flows is subtracted from the total value of the outgoing flows of a process. The total value is calculated by multiplying the amount of the flow with its price and then by summing up the values of all flows.

This step requires an access to a life cycle model on a unit process level of the particular product. Furthermore, as consistent as possible data are necessary for all economically relevant material and energy flows, which flow in and out the unit processes.

3.12 Process Data Sets

To generate a LCWE process data set, each individual process must be classified to one of the various industries. Subsequently, the social profile of the industry is multiplied with the value added of the individual process. In doing this, the reference to one Euro of value added is lost and the industry profile is scaled on a unit process.

3.13 Evaluation

In the course of the balance calculation, the values of unit processes are summarized along the value chain according to the summarization of LCA inventory data and can thus be evaluated equally.

3.14 Processing of Data(-sets) in the Software

In the classic LCA the particular processes are scaled according to their connections over input and output flows. Besides, the elementary flows, which exceed the system boundaries and thus cause an impact, are scaled with the factor of their original process. In this way, the contribution of each individual process to the function of the total system is weighted correctly. By including social data into LCA datasets, the same weighting principles apply, thus leading to correct results that can be evaluated in accordance to LCA results.

3.15 Generation of Indicators and Evaluation

In classic LCA methodology, the summation is followed by classification and characterization. In contrast, the indicators for the social aspects are chosen the way that they each build its own class. The step of the classification as relation of particular contributors to a potential kind of impact therefore is superfluous. Within each class, there are no contributors that have to be valued differently. Compared to a consideration of ecological values, a characterization therefore is not necessary. This can be seen as a fundamental difference between ecological LCA and social aspects consideration within LCA; in case of the ecological LCA the interim balance of mass and energy flows is drown. These flows are then miscalculated in respect to their various environmental impacts. However, when examining social aspects, the indicators are selected so that they correspond directly with a social aspect. The evaluation of indicators however can be done in analogy to the classic LCA-method: Each indicator receives its own impact category (or rather for each impact category a described indicator is to be found) and each characterization factor gets the value one.

3.16 Validity

As explained above, a respective validity of a result depends on the selection of the social indicators, on their ability to be summed up, on an ability to be weighted that can be compared with material and energy flows and, of course, on the availability of data for the unit processes. All these conditions are given for the working time values in different qualification levels, the non-fatal and fatal injuries presented above. If there is a possibility to relate them to the basic value working time, also for other social factors to be developed, the criterias of summing up and weighting can be accomplished. The availability of data is to be proved separately, and a general validity or rather reasonableness should be used as primary selection criterion.

4 EXAMPLE

To show the potentials and validate the feasibility of the assessment method, it was applied in several projects so far. There are principally two possibilities to use the LCWE method:

1. Use of the comprehensive and consistent background database. The data was calculated as explained above.
2. Gathering of own, project and process specific data. The data can be inserted directly in the LCWE tab, when creating a new process.

For the example, data from the background database is used in order to show the application of the method. Two different kinds of plastic are compared.

4.1 Description of the assessed system

Concerning the social implications, the whole production phase of the different alternatives is assessed including all upstream value chains (production and supply of all precursor substances, operating supplies, auxiliary materials, energies etc.).

In the following, the results for the assessment of two routes will be shown exemplarily: Polyethylene fibres production and the production of Polyethylene terephthalate (PET) fibres.

4.2 Results

Table 2 shows the working time distribution into the general qualification levels (GQL) in seconds, that is related to jobs with the respective qualification level as requirement. Jobs with a GQL A do have the highest qualification as prerequisite, Jobs with a GQL E relate to work with low qualification requirements. The total working time, being the sum of the numbers listed under the different GQLs, is the sum of all human labour employed in the production of 1 kg plastic.

As Table 2 and Figure 3 present, the plastic PET production requires considerably more human labour than PE production. This is caused by the more complex manufacturing process for PET than for PE.

Table 2: Working time and accidents for the production of 1 kg PE and 1 kg PET

Qualification Level	PE	PET
GQL A [s]	1.4	9.9
GQL B [s]	11.0	61.1
GQL C [s]	14.4	72.5
GQL D [s]	15.1	59.4
GQL E [s]	7.6	27.2
Total working time [s]	49.5	230.1
Lethal accidents [cases]	3,23E-07	1,06E-06
Non-lethal accidents [cases]	5,45E-10	1,03E-09

The graphics also show that in industrial process chains rather few jobs without qualification and with a very high qualification can be found. Industry requires a minimum level of qualification and only few people with a very high qualification on the management level. A higher share of workers without qualification is rather found in the service sector (sales, direct services etc.).

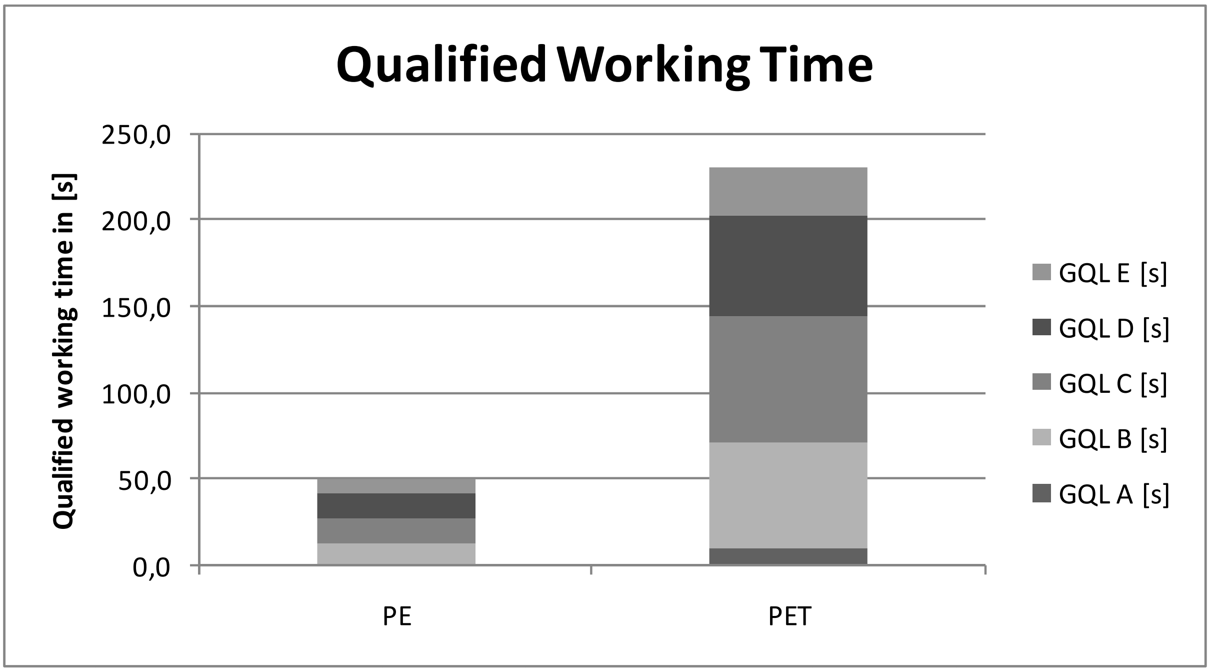

Figure 3: Qualified working time for the production of 1 kg PE and PET

Figure 4 and Figure 5 show the amount of non-lethal and lethal accidents for the production of 1 kg PE or PET. The numbers are very small as they are related to the functional unit of 1 kilogram.

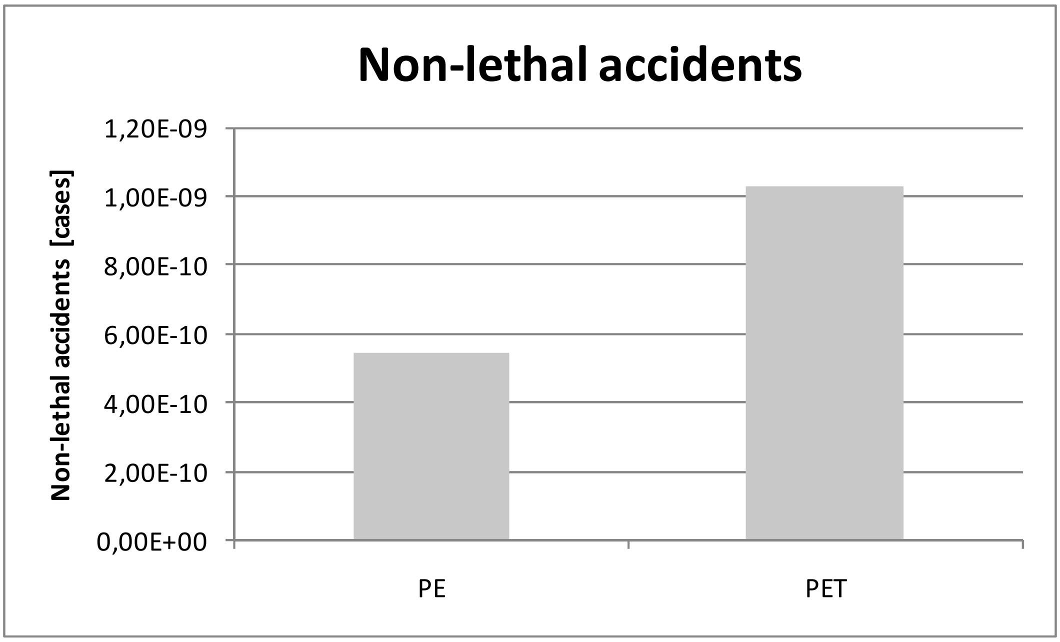

Figure 4: Non-lethal accidents caused by the production of 1 kg PE and PET

The general results are similar to qualified working time: There are significantly more accidents when producing a kg of PET than PE. Again this is due to the more labour intensive and more complex manufacturing process of PET.

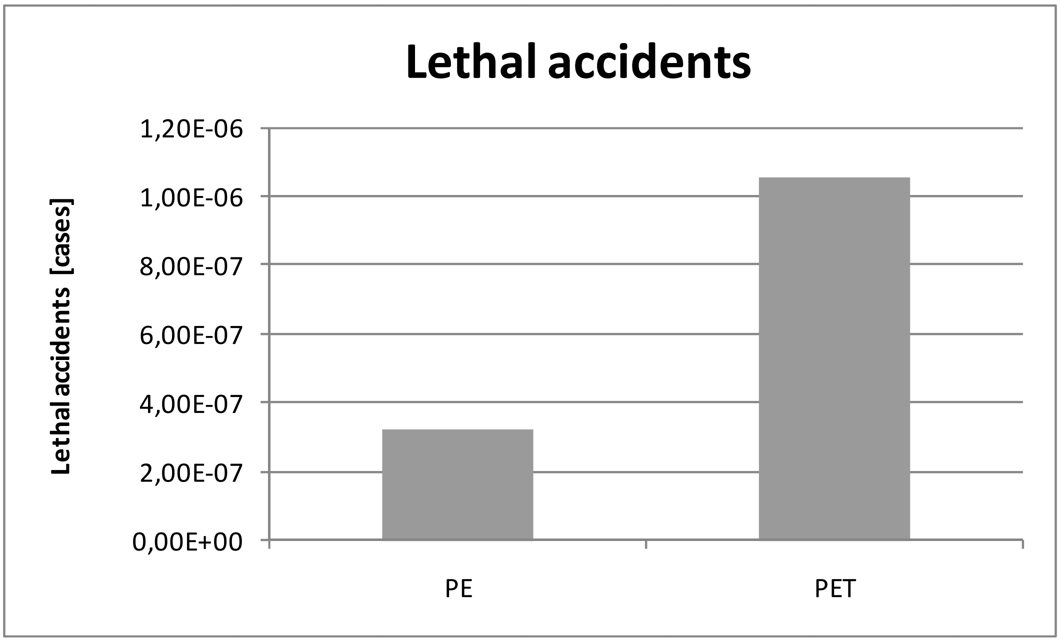

Figure 5: Lethal accidents caused by the production of 1 kg PE and PET

6 Discussion and outlook

Holistic and forward-looking decisions must be based on a broad basis of all relevant information. The social dimension of human actions clearly must be considered.

The method developed and the respective background database is a first, promising attempt to address the social pillar of sustainability in the scope of the well established method of Life Cycle Assessment and Life Cycle Engineering. Social effects that would have been neglected by an LCA can be included and show remarkable results. Problem shifting from the environmental realm to the social field can be avoided.

The example shows, that the results of the LCWE method can be used similarly to the results of an LCA: Information is presented on a unit process level and also project or process specific information can be inserted. Information about social issues is summable and scalable as the LCA user is familiar with from the environmental LCA. In the comprehensive background database, information for all unit processes regarding the qualified working time and lethal and non-lethal accidents is available. Additionally, information concerning the following indicators can be inserted in the GaBi software in the LCWE tab by the user:

- Actual women employment
- Child labour
- Discrimination in job access
- Forced labour
- Hazardous child labour
- No collective bargaining
- No right to organise
- Unequal remuneration

All information has to be in relation to working time in seconds.

However, it has to be stated that due to the above mentioned restrictions for indicators, not all relevant social information can be accounted for by this method, so far. Additional social effects have to be considered in future development of the methodology.

As all LCWE data currently present in the GaBi database is derived from US statistics, it can be regarded valid for all countries holding similar economic and socio-economic conditions than the US.

Using the LCWE data for decision making, it has to be considered that as the data is derived from statistics, it does not represent exact site specific situations and should only be used to compare for example general product options. For the comparison of social aspects of different suppliers, company-specific data has to be used.

To conclude with, the social database can be used as a hotspot database in order to examine the main contributors to social profiles along the process chains of products. For these main contributors, site specific social data can be gathered in a second step in order to get a more precise picture of the social implications of a product.

6 LITERATURE

NATIONAL CROSSWALK SERVICE CENTER (1997)	NATIONAL CROSSWALK SERVICE CENTER (1997): *NOICC Master Crosswalk, Version 4.3.* National Crosswalk Service Center. Online: http://www.xwalkcenter.org/index.php.
OCCUPATIONAL HEALTH AND SAFETY ADMINI-STRATION (1992)	OCCUPATIONAL HEALTH AND SAFETY ADMINISTRATION (1992): *Standard Industrial Classification (SIC) system.* United States Department of Labor; Occupational Health and Safety Administration. Online: http://www.osha.gov/pls/imis/sic_manual.html; http://www.census.gov/epcd/www/sic.html.
UNESCO INSTITUTE FOR STATISTICS (1997)	UNESCO INSTITUTE FOR STATISTICS (1997): *International Standard Classification of Education ISCED 1997*. UNESCO Institute for Statistics. Online: http://www.unesco.org/education/information/nfsunesco/doc/isced_1997.htm ; http://www.uis.unesco.org/ev_en.php?ID=7433_201&ID2=DO_TOPIC.
UNITED STATES DEPARTMENT OF LABOR (1999)	UNITED STATES DEPARTMENT OF LABOR (1999): *US Fatal and Non-Fatal Injuries and illnesses.* United States Department of Labor and Bureau of Labor Statistics. Online: http://www.bls.gov/iif/oshwc/osh/os/ostb0641.pdf; http://www.bls.gov/iif/oshwc/osh/os/ostb0642.pdf.
U.S. CENSUS BUREAU (1997)	U.S. CENSUS BUREAU (1997): *1997 Economic Census. General Summary Mining and Manufacturing, Industry Summary Construction*. U.S. Census Bureau. Online: http://www.census.gov/prod/ec97/97m31s-gs.pdf; http://www.census.gov/prod/ec97/97c23-is.pdf; http://www.census.gov/prod/ec97/97n21-gs.pdf.
U.S. IMPORTS OF MERCHANDISE (2002A)	U.S. IMPORTS OF MERCHANDISE (2002A): *History DVD-ROM*. U.S. Census Bureau. Online: http://www.census.gov/foreign-trade/reference/products/catalog/imphistory.html.
U.S. EXPORTS OF MERCHANDISE (2002B)	U.S. EXPORTS OF MERCHANDISE 2002B: *History DVD-ROM*. U.S. Census Bureau. Online: http://www.census.gov/foreign-trade/reference/products/catalog/exphistory.html.

APPENDIX

In this chapter the data sources are addressed, which serve as a basis for the method developed at the University Stuttgart. The particular statistics should meet various criteria to be used in this method. These criteria are as well specified in the following paragraphs.

U.S. Economic Census

The "U.S. Economic Census" (http://www.census.gov/) is a comprehensive data collection, that gives a detailed review of the American economy. It is fulfilled by the "Census Bureau", the American demographic agency. The results are gathered every five years, whereas the collected basic data include to a large extent the statistics of all US companies. At the same time, the data collection for the agriculture and the authorities takes place in parallel. The data collection is based on a clear structured classification of the whole economy into a strictly hierarchical system of industrial sectors and subsectors – the so called North American Industry Classification Standard (NAICS). It is important that not the companies as a whole, but the single location of these companies as minimum unit are listed. It allows both a better spatial resolution and a better resolution according to activity, as a company can be active in different sectors. The NAICS classifies 1179 various industries, 1070 of which are covered in the U.S. Economic Census.

The data is provided for free and is supposed to serve several purposes. The following fields of application exemplify this:

- Companies can compare their sales figures with those for their whole industry. It allows them to calculate their market share in order to check their performance or to define new targets.
- Companies can also compare their business ratio with average numbers from the U.S. Census as a benchmark to assess their performance with those of the concurrent organizations.
- Companies which sell their goods or services to other companies can find in the U.S. Census new target industries. Besides, producers learn from the material consumption statistics more about the industries that consume their products.
- Companies can use the data to determine their sales areas, to place a target advertisement and to find the best locations for their new establishments.
- Important key figures about the economic development as monthly retail sales or the gross domestic product are based on the data of the U.S. Census. Associations and the press analyze the data to identify economic circumstances and to forecast developments.
- The legislative body uses the data for the preparation and assessment of new laws. The state and local authorities monitor the Census data to understand economic basics and to decide whether they should settle new businesses or keep the already existing ones.

- Consultants and researchers make use of the data to analyze the changes in the industries' structure or in the spatial resolution. These data are not explicitly collected for the use in the method. Nevertheless they work well for the developed method because of the level of detail and their basis on the clear hierarchical structure of the industries' classification.

In the 2002 U.S. Economic Census the data for the year 2002 are collected. In December 2002 data collection questionnaires were sent to more than 5 million companies, the deadline was set on the 12th of February 2003. Due to adaption of the data entry forms to the individual industries, there exist now more than 600 different versions. Only some very small companies do not receive questionnaires. For them the data already available at the federal authorities' are used. These authorities provide basic data as location and kind of business, sales figures, wages and salaries, number of employees and form of organization. The U.S. Economic Census is enshrined in title 13 of the United States Code. The law commits organizations to send back the filled forms and awards penalties in case companies omit this. Besides, the law swears the Census Bureau to secrecy. No data are published, which disclose the identity or activity of an individual or a company.

Standard Industry Classification (SIC)

The Standard Industry Classification (SIC)-Code is a four-digit numerical code assigned by the U.S. government to the business establishments to identify the primary business activity of the establishment (http://www.osha.gov/pls/imis/sic_manual.html). The classification was developed to facilitate the collection, presentation and analysis of data; and to promote uniformity and comparability in the presentation of statistical data collected by various agencies of the federal government, state agencies and private organizations. The classification covers all economic activities: agriculture, forestry, fishing, hunting and trapping; mining; construction; manufacturing; transportation; communications, electric, gas and sanitary services; wholesale trade; retail trade; finance; insurance and real estate; services; and public administration.

The Bureau of Labour Statistics is a unit of U.S. Department of Labour. This unit is in charge for the fact-finding for the federal government in the wide field of occupational economy and occupational statistics.

US Import/Export History

The data about "U.S. Exports of Merchandise" (U.S. CENSUS BUREAU 2002B) and "U.S. Imports of Merchandise" (U.S. CENSUS BUREAU 2002A) are gathered and provided by the U.S. Census Bureau. The export statistics contain data about the value and the quantity of 9.000 various goods, which were exported from the USA; the import statistics provide this information for 17.000 different imported goods. Depending on the unit the quantity is specified in, an average price of the goods can be calculated based on these data. The data are also available for the past years. For the method described here, data from the reference year 2002 was used.