University of Southern Queensland

Faculty of Engineering and Surveying

LIFE CYCLE ASSESSMENT OF CSR AUTOCLAVES LIGHTWEIGHT CONCRETE PRODUCTION IN MALAYSIA

A dissertation submitted by

Mr. LAY Wei Kian

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Course ENG4111 and ENG4112 Research Project

towards the degree of

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ABSTRACT

This project is seeks to investigate the product of CSR autoclaves lightweight concrete (ALC) as well as to produce an outline of life cycle assessment (LCA) methodology and lastly to set up a model. In order to achieve the aim of the project, literature review of Life Cycle Assessment related to building and construction industries have been carried. Damage to human health, ecosystem quality and resources will be shown in the LCA model. These results can be used as guidance for future improvement of the CSR ALC products. The improvement also can minimise the occupational health and safety risks in the process.

LCA model is an idea tool to reduce the environment impact and help to achieve sustainable development. It is internationally recognized as a method which complies with international standards (ISO 14040-14049). LCA also is a potentially powerful tool which can assist regulators to formulate environmental legislation. Besides that, LCA helps manufacturers analyse their processes, improve their products, and perhaps enable consumers to make more informed choices.

History of life cycle assessment is introduced in the first section in this chapter. Life Cycle assessment is made of the methodology, data demand and software. These are the three main components to make a Life Cycle Assessment. At the present time, it is used by industry, government and consumers. Last but not least, even though LCA is largely used today, but there are some of limitations encounter during the process. Usually the limitations are due to lack of knowledge, databases, finance and long duration of time to carry out the job.

The inventory results have proved that CSR block is an environmental friendly product. Even though, the most serious impacts on environment are caused by cement, which is up to 79.2 % of the total impacts. The least environmental impact caused by the product or process in each stage its life cycle is the truck (0.249%), Cutting process (0.17%) and the remaining process is 0.146%.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

LAY Wei Kian

Student Number: 0050048321

Signature

Date

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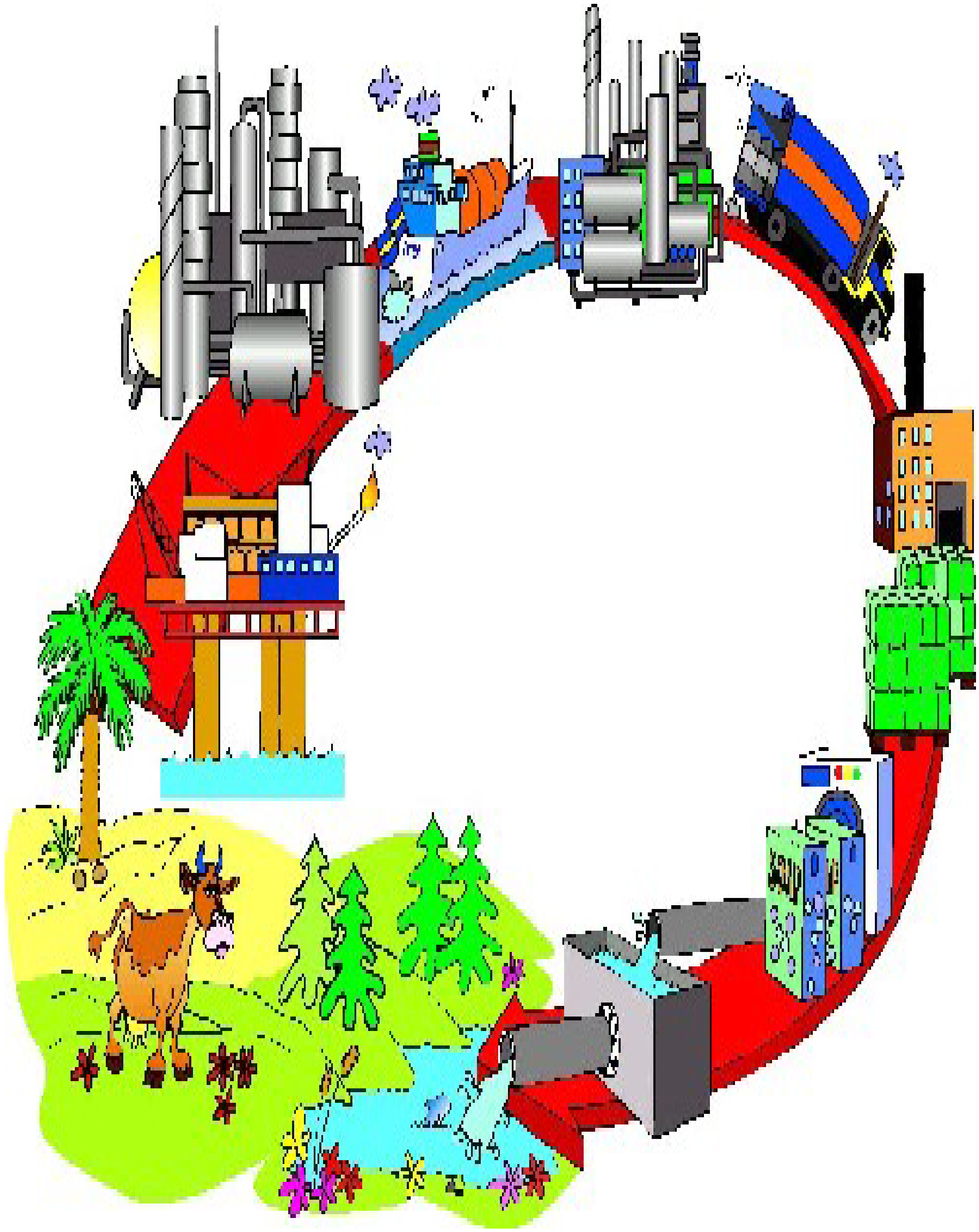
CHAPTER 1

INTRODUCTION

1.1 Introduction

The current issues that touch on pollution and degradation of the environment are related to human activities. The impact on sustainability is from local and global development. Sustainable development has been identified as significant national and international issues. Sustainable development has been defined as balancing the fulfilment of human needs with the protection of the natural environment so that these needs can be met not only in the present, but in the indefinite future. The term of sustainable development also can be defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own need". (Mintzer, 1992)

Life cycle assessment (LCA) is an ideal tool for the first step to achieve the sustainable development of modern industry and society. To achieve sustainable development, understanding and identifying where the environmental impacts and damages occur were essential so that improvement can be made. The process of life cycle assessment can be seen in figure 1.1. In this research project, SimaPro will be used to analyse and quantifier the environmental impacts on the product of Autoclaved Lightweight Concrete (ALC) – a product of CSR Building Material Company (CSR). This product is chosen because it is a popular building material. ALC has been used throughout the world in building due to its speed of construction, excellent thermal properties and ability to provide for versatility in design.



(Source: Dantes, 2005)

Figure 1.1: Life Cycle Assessment

1.2 Objectives

The main objective of this research project is to set up a LCA model for compiling and accessing environmental for the CSR ALC products. A literature review of Life Cycle Assessment related to building and construction industries are needed to be carried out in order to achieve the aim of research project. The literature review and background knowledge will provide a good direction to carry out the research project.

A comprehensive study of the Life Cycle Assessment methodology and the SimaPro software have been used to look for the possible ways to simplify the study and also in order to decrease the complexity of a large system to a smaller model that produces the same results. Moreover, defining the goal and scope of the Life Cycle Assessment of a CSR ALC manufacturing company can be started once the methodology study has been completed. The software of the Life Cycle Assessment methodologies made better chances of understanding the software working with CSR ALC products and in turn to produce better quality products and help to achieve sustainable development. This is followed by the creation of a running model using data from previous studies, reference material and reliable data value available. This process also sets up a functional unit or simply a reference unit for the software analysis and the criteria for data quality. After this model has been established, the correct data can then be simply substituted to the software and came out with relevant results. The results are compared with other studies to make sure it is functioning. A model sensitivity analyses was carried out to find if any small variations completely change the trends shown by the model. After the model has been tested, the results will be evaluated to suggest opportunities to improve the studied CSR ALC manufacturing system. If time permitted, the model can be extended to cover other aspects not included in the basic model such as waste treatment of CSR ALC. Last but not least, comparing the building materials CSR ALC product with cement sand brick or concrete block also can be conducted.

1.3 Conclusions: Chapter 1

The project is seeks to investigate the product of CSR autoclaves lightweight concrete (ALC) as well as to produce an outline of life cycle assessment methodology and lastly to set up a LCA model. Damage to human health, ecosystem quality and resources will be shown in the LCA model. These results can be used as guidance for future improvement of the CSR ALC products. The improvement also can minimise the occupational health and safety risks in the process. Therefore LCA model is an idea tool to reduce the environment impact and help to achieve sustainable development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

What is Life Cycle Assessment (LCA)? LCA is a potentially powerful tool which can assist regulators to formulate environmental legislation. LCA also help manufacturers analyse their processes, improve their products, and perhaps enable consumers to make more informed choices. It is internationally recognized as a method which complies with international standards (ISO 14040-14049). A tendency for LCA to be used to prove the superiority of one product over another has brought the concept into disrepute in some areas. A number of different terms have been coined to describe the processes. One of the first terms used was *Life Cycle Analysis*, but more recently two terms have come to largely replace that one: *Life Cycle Inventory (LCI)* and *Life Cycle Assessment (LCA).* These better reflect the different stages of the process. Other terms such as *Cradle to Grave Analysis*, *Eco-balancing*, and *Material Flow Analysis* are also used.

2.2 History of life cycle assessment

2.2.1 The early years

From the late of 1960s and early 1970s, the first study to look at the life cycle aspects of products and materials were conducted. The main focused was on the issues of energy efficiency, the consumption of raw materials and waste disposal. Cola-cola was one of the leading companies to set up a study to compare resource consumption and environmental releases associated with beverage containers. Meanwhile, in Europe, a similar inventory approach was being developed. At the mean time, the thinking progressed of LCA was a bit slowly. It was not until the mid eighties and early nineties that real wave of interest in LCA swept over a much broader range of industries, design establishments and retailers. (Kim Christiansen, 1997)

2.2.2 Rapid growth and Adolescence

LCA was attempted to assess the resource cost and environmental implications of different patterns of human behaviour. LCA is relative young technique, but there was an obvious extension of the development of methodology was occurred in 1980 to 1992. Initially many thought that LCA would be a very good tool to support environmental claims that could directly be used in marketing. Over the years, it has become clear that this is not the best application for LCA, although it is clearly important to communicate LCA results in a careful and well-balanced way. (Michiel Oele, 2002). The development of standards and guidelines in 1992 also enables the authority to be able to evaluate the manufacturing processes involved, the energy consumption in manufacture and use, and the amount and type of waste generated.

2.2.3 Towards Maturity

The enormous progress of LCA is about the future for life-cycle inventories (LCIs) and about the take-up of life cycle thinking by management generally. The concept integrating LCA into management systems and used for broader environmental objective is a relatively recent one which emerged in response to increased environmental awareness on the part of the general public, industry and governments. Furthermore, a recent survey on the application of LCA is for internal purposes such as the following:

- Benchmarking
- Product improvement
- Support for strategies choices
- External communication

2.3 LCA methodology

According to the ISO 14040, a Life Cycle Assessment is carried out in four distinct phases as following and is shown in figure 2.1.

1. ISO 14041: Goal and scope definition
2. ISO 14040: Life cycle Inventory
3. ISO 14042: Life Cycle Impact assessment
4. ISQ 14043: Interpretation

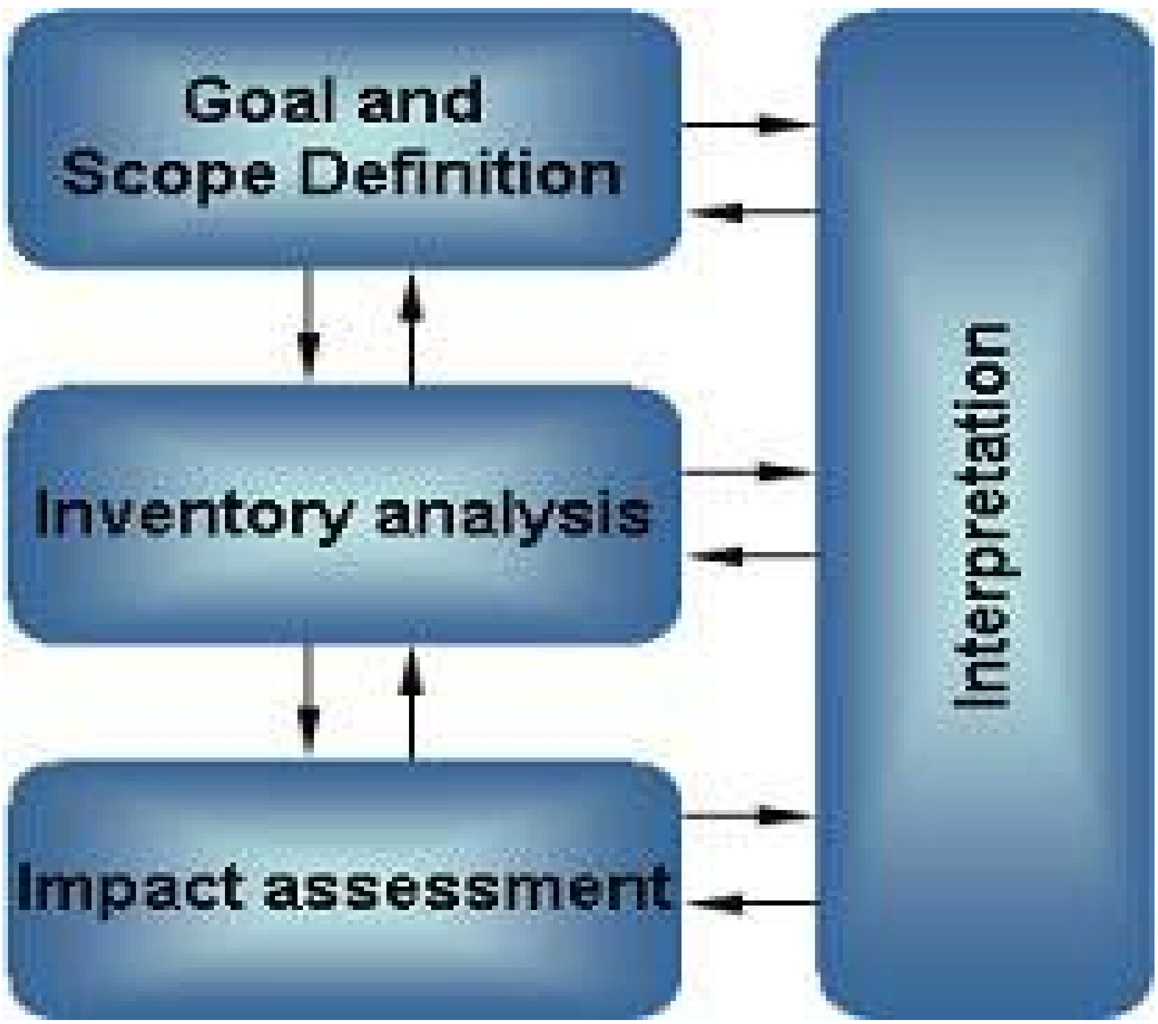


Figure 2.1: LCA methodology

2.3.1 Phase 1 - Goal and scope definition

The goal and scope definition is a guide that helps to ensure the consistency performance of the LCA. It is also designed to obtain the required specifications for the LCA study. The following step must be taken in phase 1 of LCA methodology:

i. Defining the purpose of LCA study, ending with the definition of the functional unit, which is quantitative reference for the study.
ii. Defining the scope of the study, this includes the drawing up of a flowchart of the unit processes that constitute the product system under study, taking into account a first estimation of their inputs from and outputs to the environment.
iii. Defining the data required, which includes a specification of the data required both for the Inventory analysis and for the subsequent Impact Assessment phase.

2.3.2 Phase 2 - Life cycle Inventory

This second phase Inventory involves modelling of product system, data collection, as well as description and verification data. The main technique used on LCA is that of modelling. In the inventory phase, a model is made of the complex technical system that is used to produce, transport use and dispose of a product. This results in a flow sheet or process tree with all the relevant processes. For each process, all relevant inflows and outflows are collected. The inflows and outflows include inflows of materials, energy, chemicals and outflows in the form of air emissions, water emissions or solid waste. Other types of exchanges or interventions such as radiation or landuse should be included. The results are usually a very long list of inflows and outflows that is often difficult to interpret.

The Inventor Analysis collects all data of the unit processes of product system and relates them to the functional unit of the study. The following steps must be taken:

i. *Data collection*, which includes the specification of all input and output flows of the processes of the product system, both products flows and elementary flows.
ii. *Normalization* to functional unit, which means that collected are quantitatively related to one quantities output of the product system under study, most typically 1 kg of material is chosen, but often other units like a car or 1 km of mobility are preferable.
iii. *Allocation*, which means the distribution of the emissions and resources extractions of a given process over the different functions which such a process, for example petroleum refining max provide.
iv. *Data evaluation*, which involves a quality assessment of the data.

The result of Inventory Analysis, consisting of the elementary flows related to the functional unit is often called the "Life Cycle Inventory (LCI) table". (Jacqueline Aloisi de Larderel, 2003)

2.3.3 Phase 3 - Life Cycle Impact assessment

The third phase of Life Cycle Impact Assessment is aimed at evaluating the contribution to impact categories such as global warning, acidification and so on. The first step is termed characterization. Here the impact potentials are calculated based on LCI results. The next steps are normalization and weighting, but these are both voluntary according the ISO standard. Normalization provides a basic for comparing different types of environmental impact categories and the same unit will be shown for all impacts. Weighting implies assigning a weighting factor to each impact category depending on the relative importance.

The mandatory steps to be taken are:

i. *Selection and definition of impact categories*, which are classes of selected number of environmental such as global warning or acidification.

ii. *Classification*, comparing the assignment of the results from Inventory Analysis to relevant impact categories.

iii. *Characterization,* which means the aggregation of the inventory results in terms of adequate factors, so-called categories, therefore a common unit is to be defined for each category, the results of characterization step are entitled the environmental profile of the product system.

2.3.4 Phase 4 – Interpretation

The Interpretation phase aims to evaluate the results from either Inventory Analysis or Impact Assessment and to compare them with the goal of the study defined in the first phase. (Jacqueline Aloisi de Larderel, 2003) The following steps can be distinguished:

i. *Identification* of the most important results of the Inventory Analysis and of the Impact Assessment.

ii. *Evaluation* of the study's outcomes, consisting of a number of the following routines: completeness check, sensitivity analysis, uncertainty analysis and consistency check.

iii. *Conclusions, recommendations and reporting,* including a definition of the final outcome such as:

- A comparison with the original goal of the study
- The drawing up of recommendations
- Procedures for critical review
- Final reporting of the results

The results of the Interpretation may lead to a new iteration round of the study, including a possible adjustment of the original goal. (Jacqueline Aloisi de Larderel, 2003)

2.4 LCA Data demand

LCA requires huge amount of data. A typical life cycle involves several hundred processes like the extraction of copper ore, the production of steel, the transport of chlorine, the manufacture of packaging materials, use and maintenance of the final product. All these processes need to be specified. Besides, each process specification involves a lot of items such as the consumption of electricity, the demand for styrene, the amount of material produced, emissions into the atmosphere and the generation of waste.

If the LCA has been requested by a commercial enterprise, it is usually not too difficult to obtain data on that company's processes. In other cases, it may be extremely difficult to obtain the right data, especially if the organisation does not operate in the commercial sector. Hence, it would be great help if standard databases were developed which contained data on general processes. There is a need to develop the background data of the generation of electricity, the different mode of transport and production of raw materials. (Nico van den Berg, 1996)

2.5 LCA Software

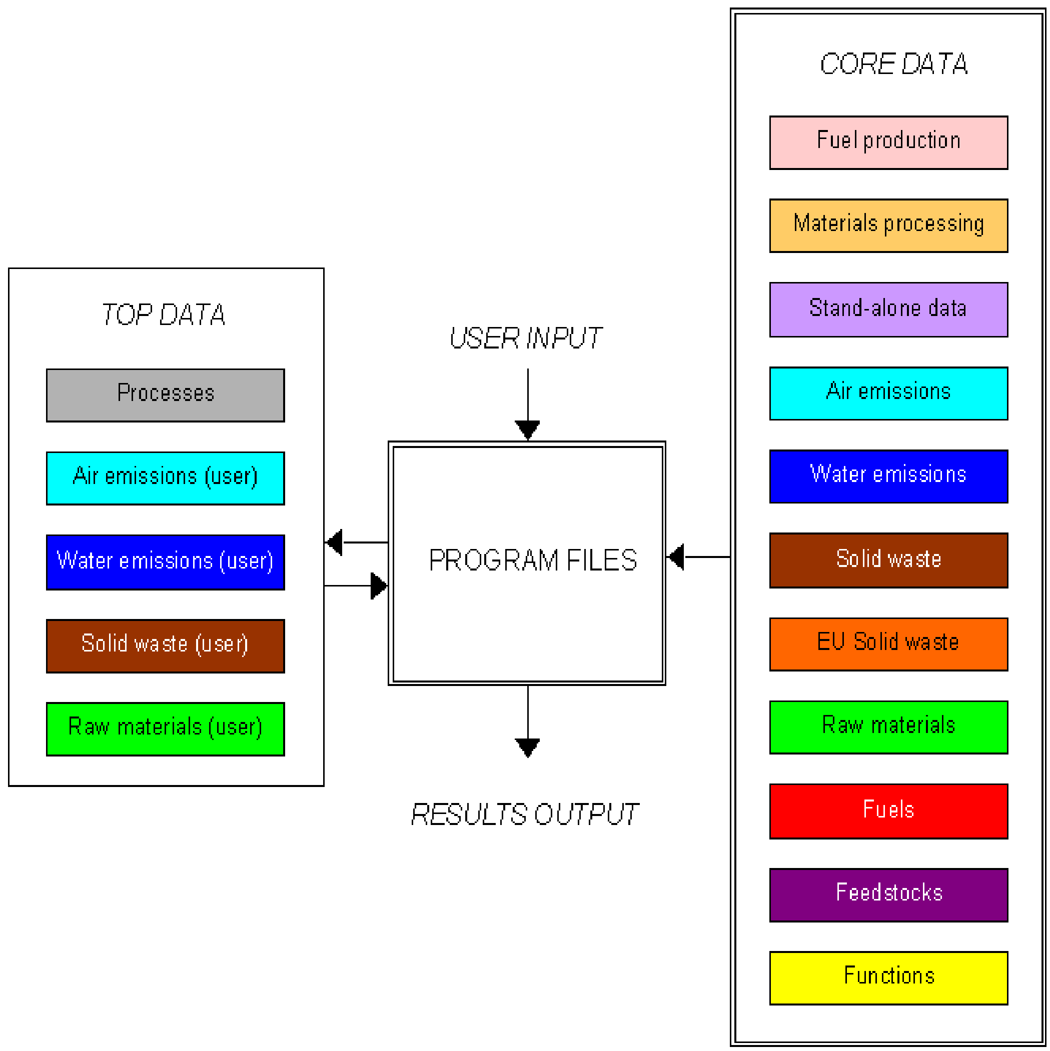
Computer's LCA software is very important because it can handle thousands of figures in carrying out a LCA analysis. Computer programs can handled these data faster, more conveniently and with better quality assurance than human operators. Basically the LCA based electronic tools can be divided into four sections:

LCA tools	LCA Software
1. Life Cycle Inventory tool	The Boustead Model
2. Full LCA	GaBi KCL ECO SimaPro TEAM Umberto
3. Abridge LCA	Eco-indicator
4. Specialised LCA tool	WISARD

Table 2.1: LCA tools and software

2.5.1 The Boustead Model

The Baoustead Model is a computer modelling tool for lifecycle inventory calculations. It is a basic MS DOS based software which is collected from industry. There are three main groups of file which are the programme files, the core data files and the top data file as shown in figure 2.2. (Dr Ian Boustead, 2007)



(Source: Dr Ian Boustead, 2007)

Figure 2.2: Structure of Boustead Model

Advantages:

- Fuel production data covering nearly every OECD/ non-OECD country and over 200 regions.
- Large data base in MS DOS based software package available which makes Bousted a very international oriented tool.

Disadvantages:

- All information is collected from industry through questionnaires which may be inconsistence and incorrect.
- Usually contain large number of operations linked by the flows of materials and energy.

2.5.2 GaBi

This software system is designed to create Life Cycle balances, covering both environmental and economical issues. The structure can be set up to support the ISO 14040 standards.

Advantages:

- GaBi simplifying the communication of LCA results.
- Can directly evaluate alternatives without needing any LCA modelling skills, product developers.
- Updated of the world-wide, unique electronics database, applicable for eco-design and EuP directive.

Disadvantages:

- Database for land use is not included at the current stage and which is considered a very important role regarding to the life cycle impacts of many products or product groups.
- Sustainability assessments are becoming more and more important but the database for social is still under development.

2.5.3 KCL ECO

KCL ECO operates on a process of modules and flows, each flows consists of a number of equations that represent masses and energies moving between two modules. KCL's key competencies are sustainability indicators fort he forest industry's value chain and expertise in life cycle assessment. The picture presents an example of bioenergy in the wood product's value chain (focus on forest and pulp making) undertaken by KCL ECO.

Figure 2.3: Example of bioenergy in the wood product's value chain.

Advantages:

- KCL ECO makes it easy to handle very large systems.
- The software works especially well when applied to small products and has a clear presentation style.
- Eco data contains 300 high quality data modules.

2.5.4 SimaPro

SimaPro is the latest generation of the world's most widely used Life cycle assessment (LCA) software. It was first released in 1990 and is a proven, reliable and flexible tool used by major industries, consultancies and universities. SimaPro is the most successful LCA software worldwide with nearly thousand user licenses sold in 50 countries.SimaPro is a LCA software helps to collect, analyse and monitor the environmental performance of products and services in a systematic and consistency way. Hence, SimaPro assists us to find the best improvement options. SimaPro will be used in this research project to analyse the product of CSR. The SimaPro software is available in multiple versions but SimaPro 5.1 will be used in this research project. This version of SimaPro is included large set of inventory data and impact assessment methods. This allows us to start building life cycle models of the products and services immediately.

Advantages:

- Intuitive user interface following ISO 14040.
- Easy modelling, with powerful wizards available.
- Parameterized modelling with scenario analysis.
- Hybrid LCA with Input Output databases.
- Direct Linking to Excel or ASP databases.
- Direct impact assessment calculation from each stage of the model.

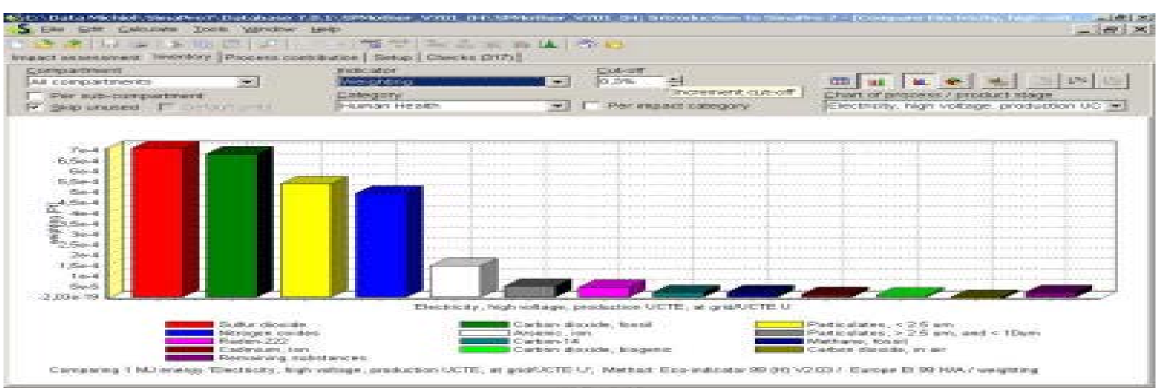


Figure 2.4: Sample of LCA result

2.5.5 TEAM

TEAM is a software package with an extensive database, powerful and flexible structure that supports transparency and sensitivity analyses of studies. Team enable to describe any industrial system and to calculate the associated life cycle inventories and potential environmental impacts according to the ISO 141040 series standards.

Advantages:

- TEAM dramatically speeds up the process of carrying out a LCA compliant with current methodology standards by offering powerful calculation capacities, linked to a comprehensive process and material database.
- Conduct life cycle assessment determinations using any one of the protocols incorporated within the software.
- Perform sensitivity analyses in an automated fashion to identify “data hot spots”.

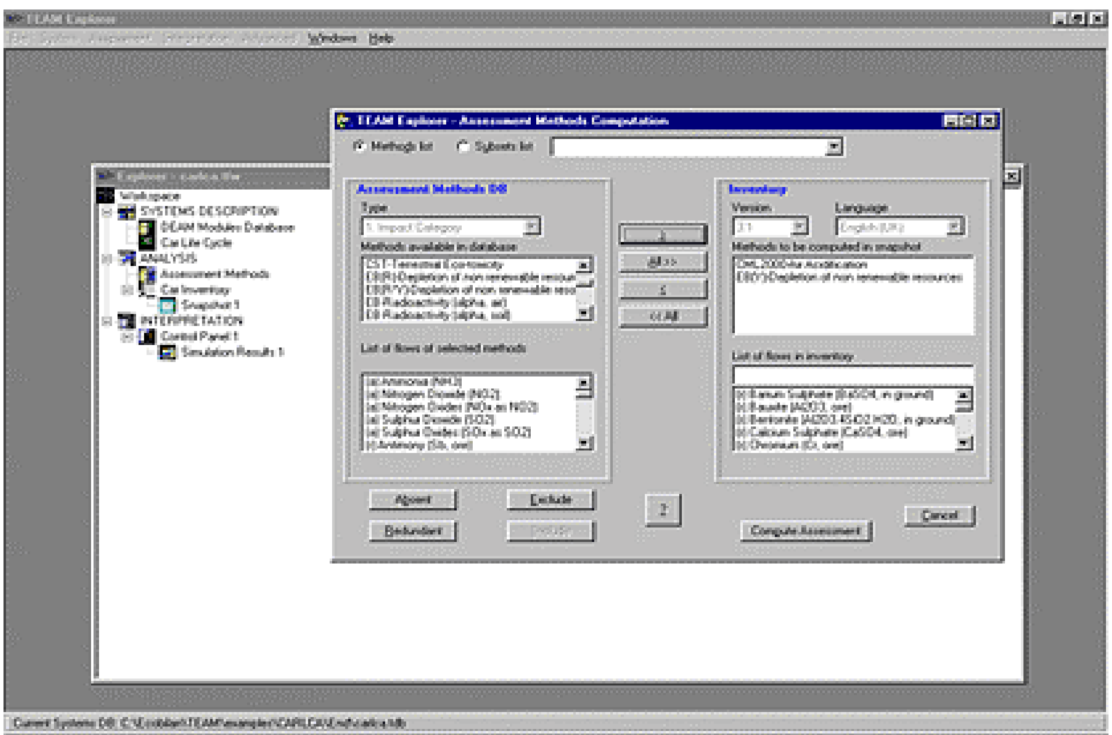


Figure 2.5: TEAM Explorer

In figure 2.6, the TEAM is designed in order to be handled a variety of methodological rules. It lets the user handle these choices, change them during the course of project, and even assess their influence on the end-results.

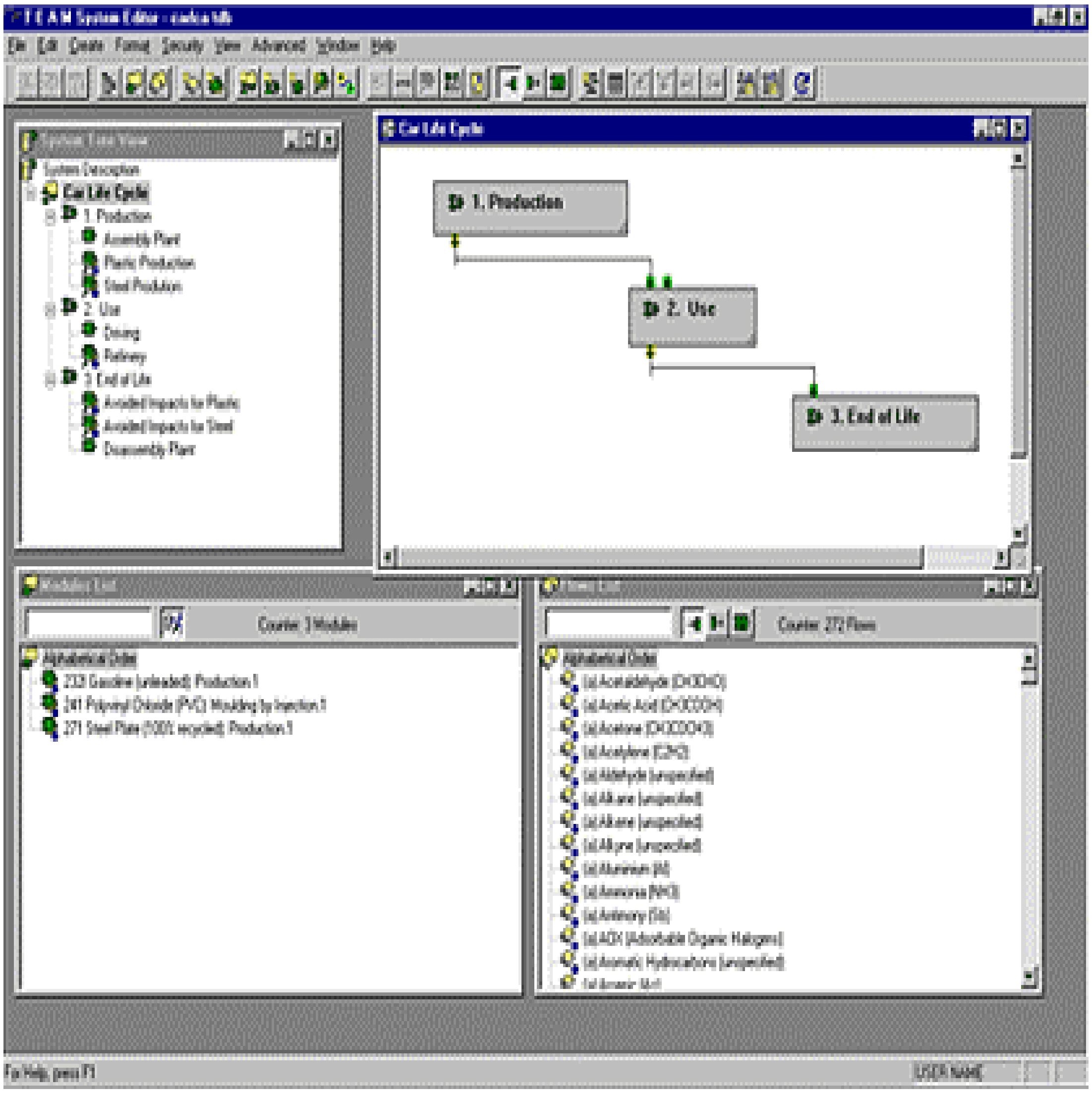


Figure 2.6: TEAM System editor

2.5.6 Umberto

Umberto is a multi-purpose Life Cycle Assessment package capable to calculate material flow networks. It is used to analyse the process systems, either in a plant or a company or along a product life cycle.

Advantages:

- The results can be assessed using economic and environmental performance indicators.
- Cost data for materials and process can be entered to support managerial decision making.
- With its comfortable graphic interface even complex structures can be modelled.

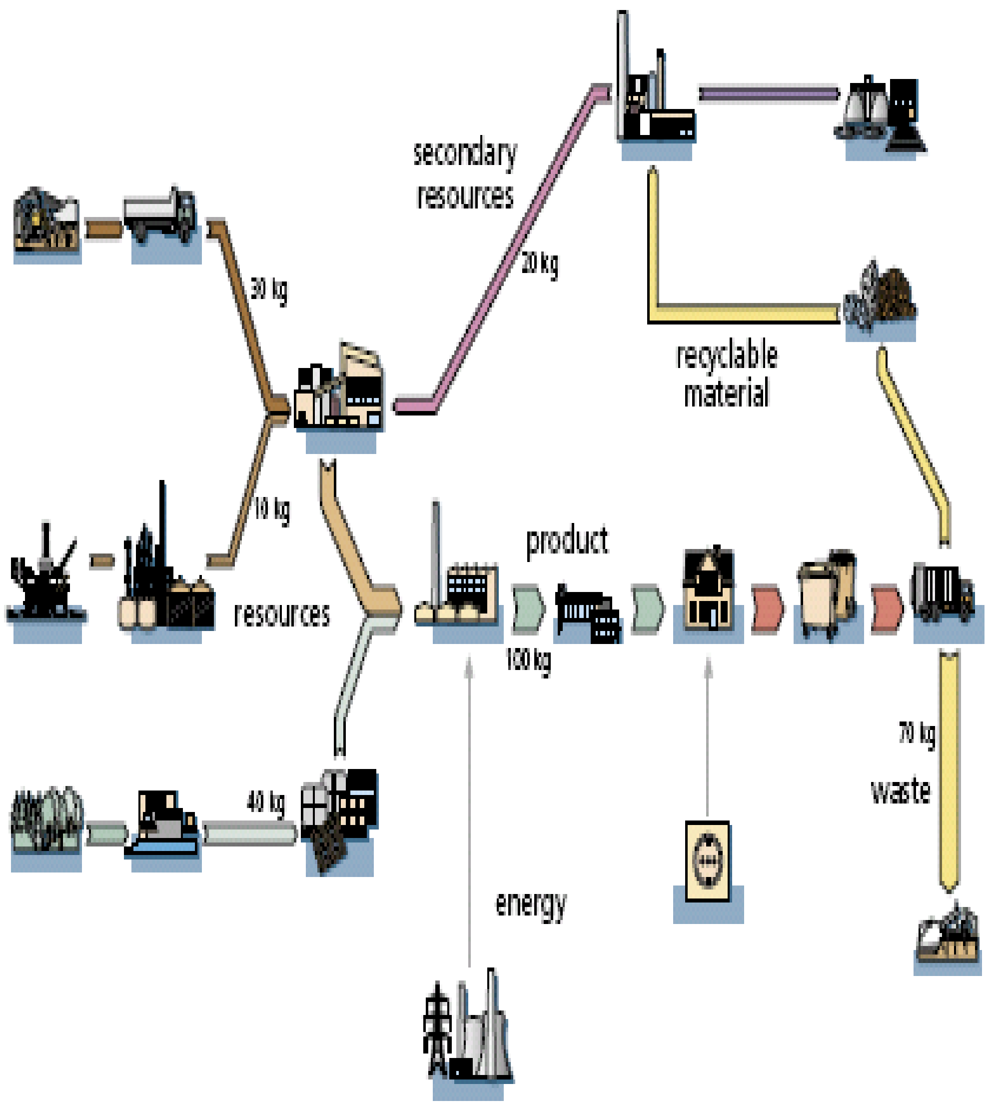


Figure 2.7: Example of a process flow diagram

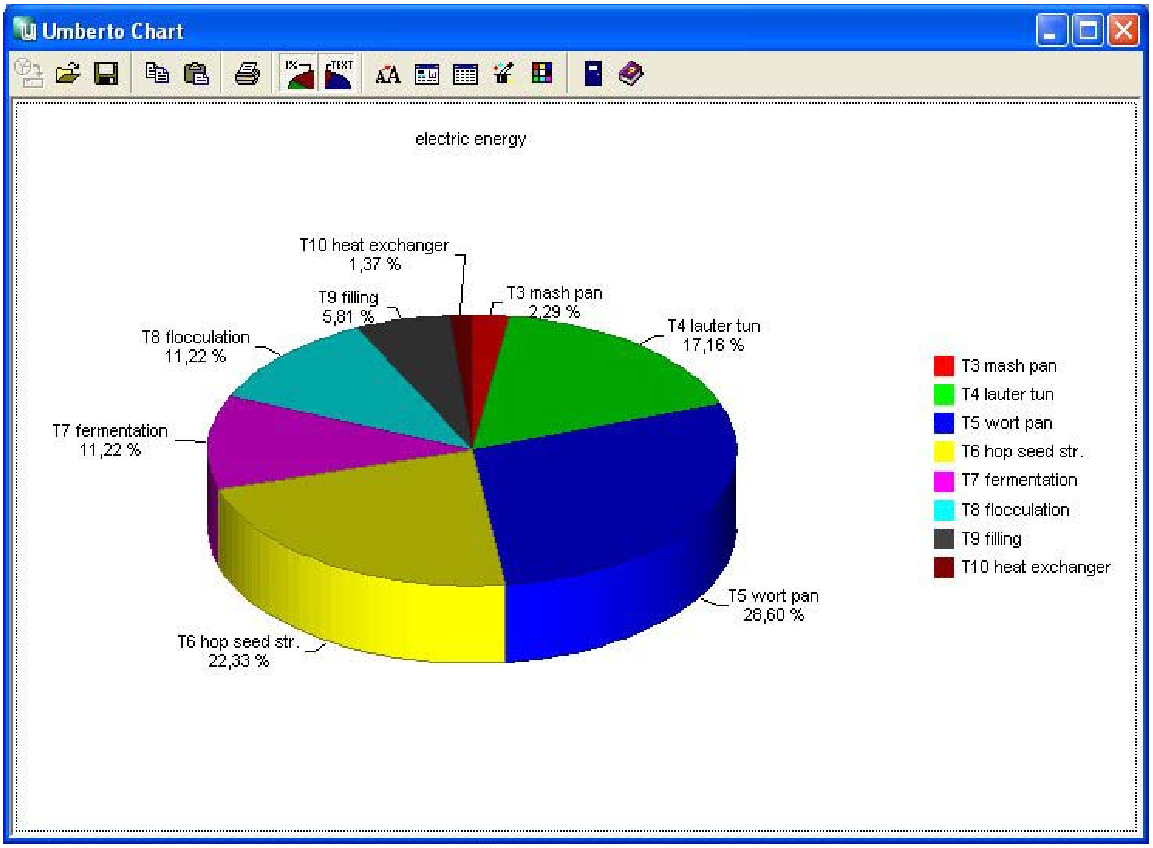


Figure 2.8: Example of Umberto results display as chart

2.5.7 Eco-indicator

It is a manual for designer with background information on life cycle assessment. It contains a limited amount of data but allows simple Life Cycle Impact evaluation studies and helps designers understand the fundamentals of life cycle thinking.

2.5.8 WISARD

WISARD is an LCA software tool combined with waste management priorities. It is equipped with LCI capabilities but also allows comparison of different waste management scenarios.

2.6 Significant of life cycle assessment

LCA is a tool to assess the potential environmental impacts of product systems or services at all stages in their life cycle – from extraction of resources, through the production and use of the product to reuse, recycling or final disposal. LCA can be applied in the area such as strategic development, product development and marketing. (Dantes, 2005)

According to ISO 14040 the application of an LCA can assist in:

- Analysis of the contribution of the life cycle stages to the overall environmental load. Usually with the aim to prioritise improvements on products or processes.
- Identifying opportunities to improve the environment aspects of products at various points in their life cycle.
- Decision- making in industry, government or non-governmental organisations (e.g. strategic planning, priority setting, product or process design or redesign)
- Comparison between products for internal or internal communications.
- Selecting the relevant indicators of environmental performance, including measurement techniques.
- Marketing (e.g. an environmental claim, ecolabeling scheme or environmental product declaration).
- Compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle.
- Assessing the potential environmental aspects and potential aspects associated with a product or service, by compiling an inventory of relevant inputs and outputs, evaluating the potential environmental impacts associated with those inputs and outputs
- Interpreting the results of the inventory and impact phases in relation to the objectives of the study.

2.7 The uses and application of Life Cycle Assessment

LCA is used by at least three types of primary user:

1. Industry and other commercial enterprises.
2. National governments and local, national and inter-government regulative bodies.
3. NGOs, such as consumer organisations, environmental groups and consumers.

2.7.1 Industry

Companies first of all use LCA for incremental product improvements and not for real product innovation. In other words, LCA is barely used for the complete redesign of existing concepts and even less for alternative fulfilment of functionality. LCA is primarily used by companies to support their environmental decision making. The most frequent applications are related to:

- Design, research and development.
- Comparison of existing products with planned alternatives.
- Providing information and education to consumers and stakeholders.
- Formulation of company policy
- Formulation of marketing strategies.

At present, manufacturer of a product is held responsible not only for its manufacturing operations but also for the uses to which the product is put and the way in which it disposed. Companies are increasingly looking at supply chain management as a way to improve environmental performance. Companies therefore need LCA to discharge their chain responsibility. LCA also paly a critical role in helping them to identify and quantify the issues involved. LCA is primarily used by companies to support their environmental decision making.

2.7.2 Government

Governments have a responsibility to help develop LCA because of LCA's potential uses in achieving sustainable forms of development. LCA is one of the few tools that deal adequately with both the economic and environmental reality of a product. At present the main role of LCA in policy development is in environmental labelling and formulation of regulations on product policy and waste management. However, there are high expectations of its future significance in a number of other policy areas such as green government purchasing, eco-management, green design guidelines and awards and sector benchmarking. The significance of LCA will increase when it is a part of a standard decision-making procedure. (Jacqueline Aloisi de Larderal, 2003)

The alternative government applications of LCA are:

- Ecolabelling.
- Deposit-refund schemes.
- Subsidies and taxation.
- General policies.

2.7.3 Consumers and consumers organisations

Establishment of a guideline for the consumers are essential to achieve sustainable consumption pattern. Consumers and consumer organisations express their need for environmental information in order to make (ecological) product choices. However, consumers do not make environmental assessment by themselves, but they rely on consumer organisations issuing ecolabels. Consumers also often lack trustworthy and comparable environmental information. This information could be provided by LCA. The use of LCA by consumer organisation is not very widespread due to the limitation of resources and data. However, LCA may indirectly through ecolabeling and comparative publications by consumer organisations, support consumers in their decision making in relation to product and investment.

2.7 Limitation/ issues of LCA

The limitation is the issues of problems encounter when carrying out a LCA. LCA continues to struggle a number of key issues, some of which are strongly linked to nature of the discipline itself.

These include:

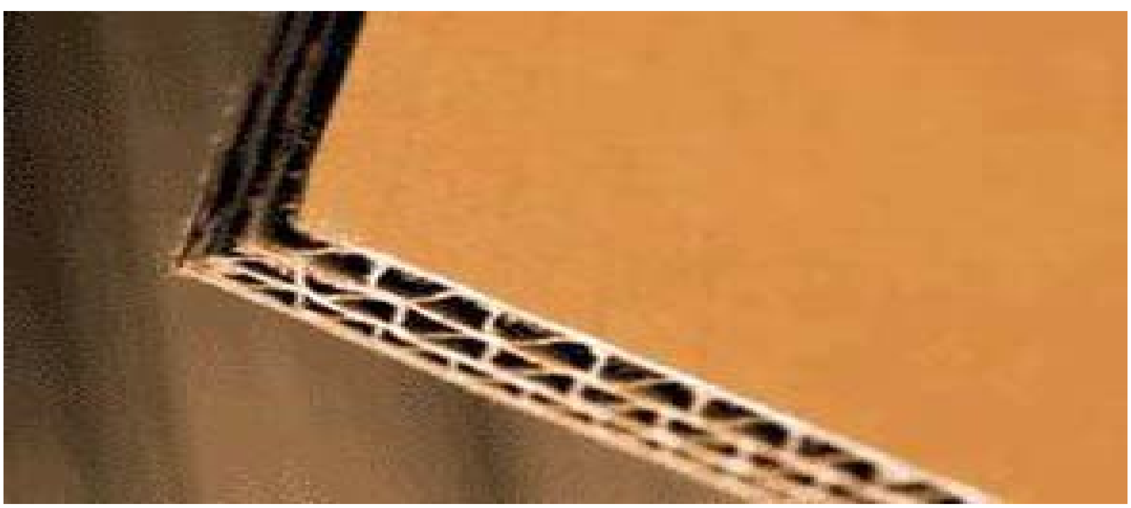
- The complexity of many of the methodologies and processes.
- The lack of accepted international standards although the SPOLD LCA format initiative has been useful and ISO standard is guaranteed.
- LCA can take so long to perform that delay action.
- The high cost although much progress has been made.
- LCA may hinder technological improvements which later turn out to be environmental improvements as well.
- The continuing invisibility of much LCA work, compounded by the above factors.
- Lack of scientific knowledge preventing the production of reliable answer to the questions that needed answering regarding to LCA.
- Ill-defined question and insufficient or poor quality data.
- The necessity of making value judgments in the course of work, judgements which are not always identified in final report.
- Most company has not felt the need for LCA in their regulation decision-making.

2.9 Case studies

The focus of LCA is on the entire life cycle of the product, which is from the extraction of the raw materials through the production of materials and components and the manufacture, transportation and use of the product to the final disposal and possible recycling. There are different types of product has been carried out by life cycle assessment, some of the relevant research is the life cycle assessment of paperboard packaging and life cycle assessment for a men's shirt. Besides that, one of the SimaPro wood tutorials also is conducted in order to get the first experiences with LCA and SimaPro.

2.9.1 Case study 1 - Life cycle assessment of paper board packaging

The use of paperboard is increasing in anywhere there is a need for packaging a delivery's product. Cardboard box is a simple and convenient product used in corrugated cardboard boxes for packaging. This paper boxes are produced from different structures and shape of corrugated board as shown in figure 2.9, 2.10 and 2.11. Unfortunately, the simple product but behind them is a comprehensive series of processes. The processes are organised in a loop with continuous input of virgin material (tree) and continuous output of used material (used boxes). The manufacturing process of the paper board has the potential contributions to environmental impacts such as emissions to the environment, global warming, acidification, oxygen depletion and photochemical ozone formation (smog). (Arunee Ongmongkolkul, 2002)



(Source: Arunee Ongmongkolkul, 2002)

Figure 2.9: Three layers corrugated board

(Source: Arunee Ongmongkolkul, 2002)

Figure 2.10: Paperboard box

(Source: Arunee Ongmongkolkul, 2002)

Figure 2.11: Paperboard sheets

Due to the increasing paperboard consumption in the world and an increasing environmental awareness, many people and organisations have a close look at the environmental properties of the product. The life cycle assessment has been carried out for all production steps from wood production to landfill disposal. The life cycle assessment of the cardboard box has been analysed base on the measurements, estimations, assumptions and simulation. Inventory and impact assessment calculations were performed with SimaPro LCA software package. (Per H. Nielsen, Ph.D, 2002)

Environmental impact of paper board packaging

The table below shows the potential contributions to environmental impacts per functional unit.

Environmental impact categories	Amount per functional unit	Unit
Global warming	7.47	kg CO_2-eq
Acidification	43.1	g SO_2-eq
Eutrophication	20.2	g PO_4-eq
Smog formation	5.64	g C_2H_4-eq
Solid waste generation	0.91	kg
Oxygen depletion	0.57	g COD

(Per H. Nielsen, Ph.D, 2002)

Table 2.2: Environmental impacts per functional unit of paper board

Improvement recommendations

In order to reduce the overall environmental impacts from paperboard in Thailand a number of suggestions have been given below.

- Reuse of the box as many times as possible
- Recycle the paperboard when the box cannot be used anymore
- Do not put paperboard to the landfill
- Implement landfill gas collection and treatment systems
- Reshape the box
- Reduce electricity consumption in paperboard factory
- Avoid N-compounds in sizing additive
- Limit the use of clips and sticky tapes in paperboard boxes
- Establish cleaner paperboard collection systems

2.9.2 Case study 2 - Life cycle assessment for a man's shirt

A project in the Netherlands included an LCA for a man's shirt. The retailer that participated in this project was interested in developing an environmental-friendly range of shirts. The main questions asked were:

1) Which phase in the life cycle of shirt produces the most pollution?
2) Which kind of textile fibre-nature or synthetic is environmentally preferable?

The assessment of the environmental impacts of the shirts included:

1. Production

- cotton growing
- spinning
- weaving

- drying
- finishing

2. Use

- washing
- drying
- ironing

3. Dispose

- reuse
- recycling
- composting
- incinerating

The results of the LCA showed that the most of the environmental impact of the life cycle of shirt is caused by the used phase and by its transport to retail outlet by air. In addition, washing the shirt at 60^0c instead of 40^0c uses twice much energy. Proper washing instruction can therefore reduce the environmental impact. Because of the high impact of the use phase synthetic or mixed textile fibres like cotton and polyester are preferable. These produce shirts that are easier to dry and to iron, further reducing energy consumption.

Conclusion of the research:

1. Environmental benefits and

- Reduction in energy use (10%)
- Reduction in use of detergents (>20%)

2. Economic benefits

- Consumers reduce energy cost by 10%
- Consumers reduce detergent cost by 20%

2.9.3 Case study 3 - Life cycle assessment of a wooden shed

The life cycle assessment of a wooden shed is a guidance to set up a LCA model through the tutorial. This is a simple shed just made of two materials which is the wood and some steel for the nails and the metal parts. Packaging, windows, doors, painting are not included during the process of life cycle assessment. In order to create a LCA model for wooden shed, some of the process like cutting a tree, sawing planks in sawmill will be considered. Several processes must be conducted in order to get the LCA model as following.

Process 1: Felling the tree

The first process describes the feeling of the tree. All the data of feeling tree must be obtained before it can be entered to the SimaPro. The chain saw is needed to cut the tree, so the amount of time required for chain saw will be entered. Besides that, Solid emissions of the branches left in the forest also included in the process. Now, the results will look like the figure below.

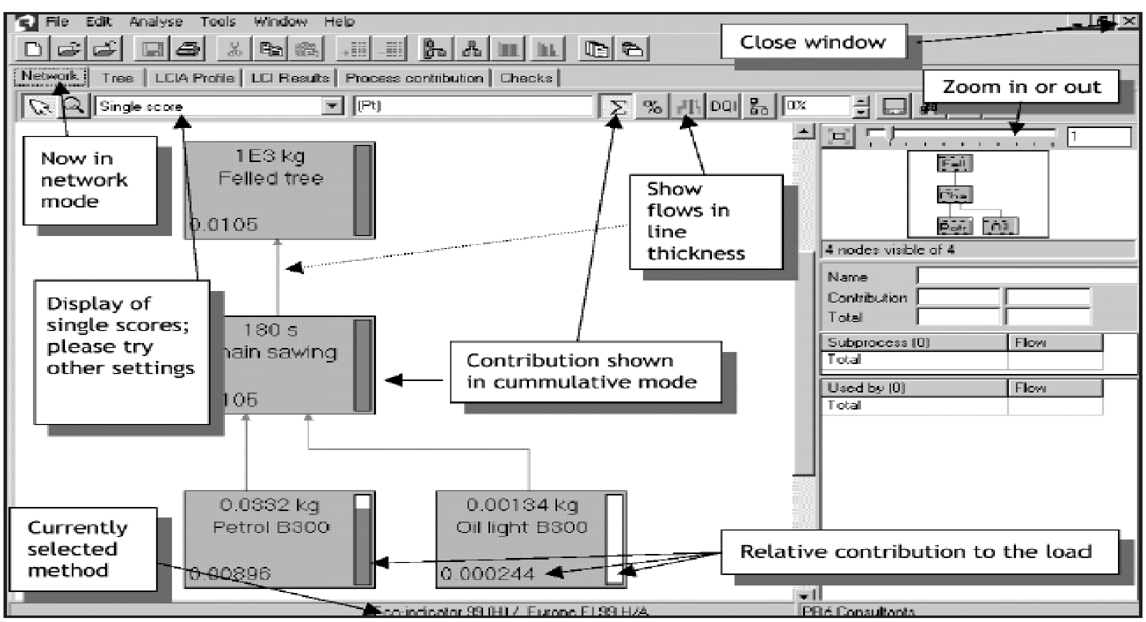


Figure 2.12: Network tree

Process 2: Sawmill

The next aim is to define the sawmill process and in this process will convert the felled trees into three products:

1. Planks, about 50% of the output
2. Sawdust, about 40% of the output
3. Bark, about 10% of the output

Moreover the electricity, water and emissions will be added into this process. Now like the previous record, the result can checked as shown in figure 2.13.

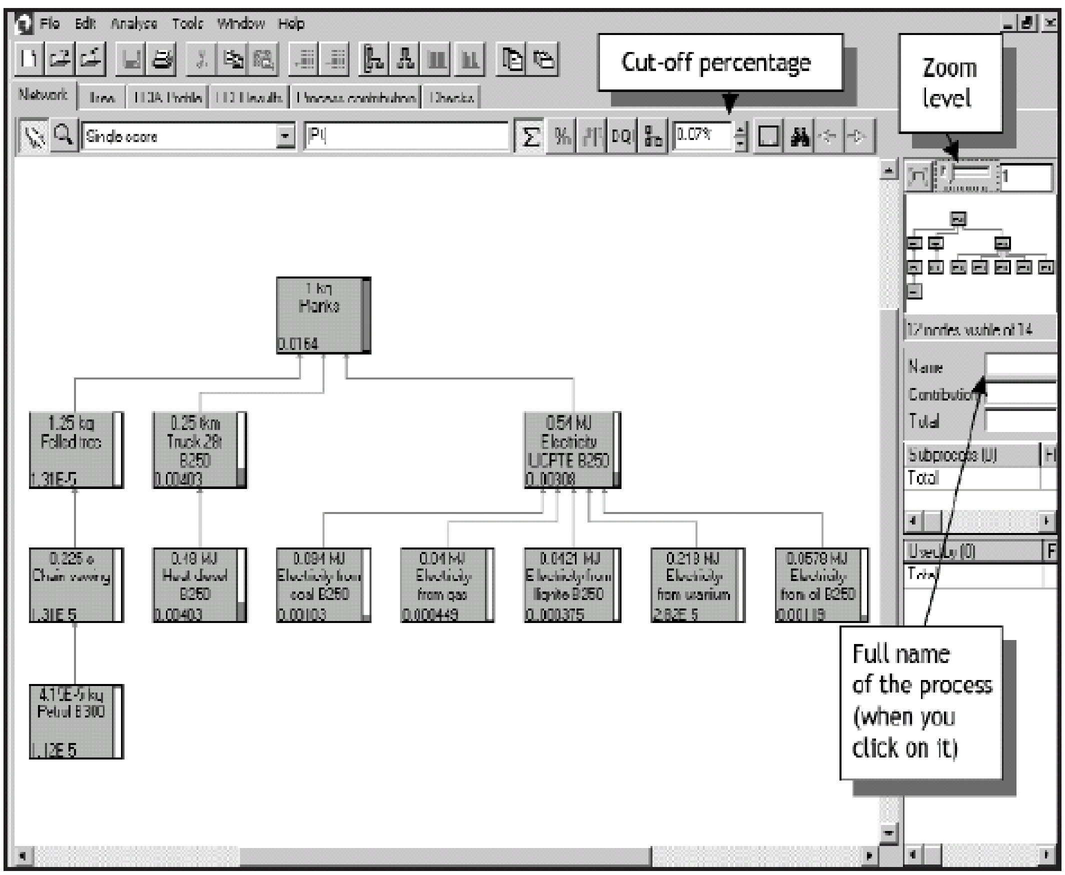


Figure 2.13: Network tree

Process 3: Waste scenario

This scenario describes how mush waste goes to which treatment. There are three scenarios:

1. One for landfill
2. One for the open fire
3. One that splits up the waste between open fire and landfill

Process 4: Results

After getting the correct network tree, the results can be viewed as following figure.

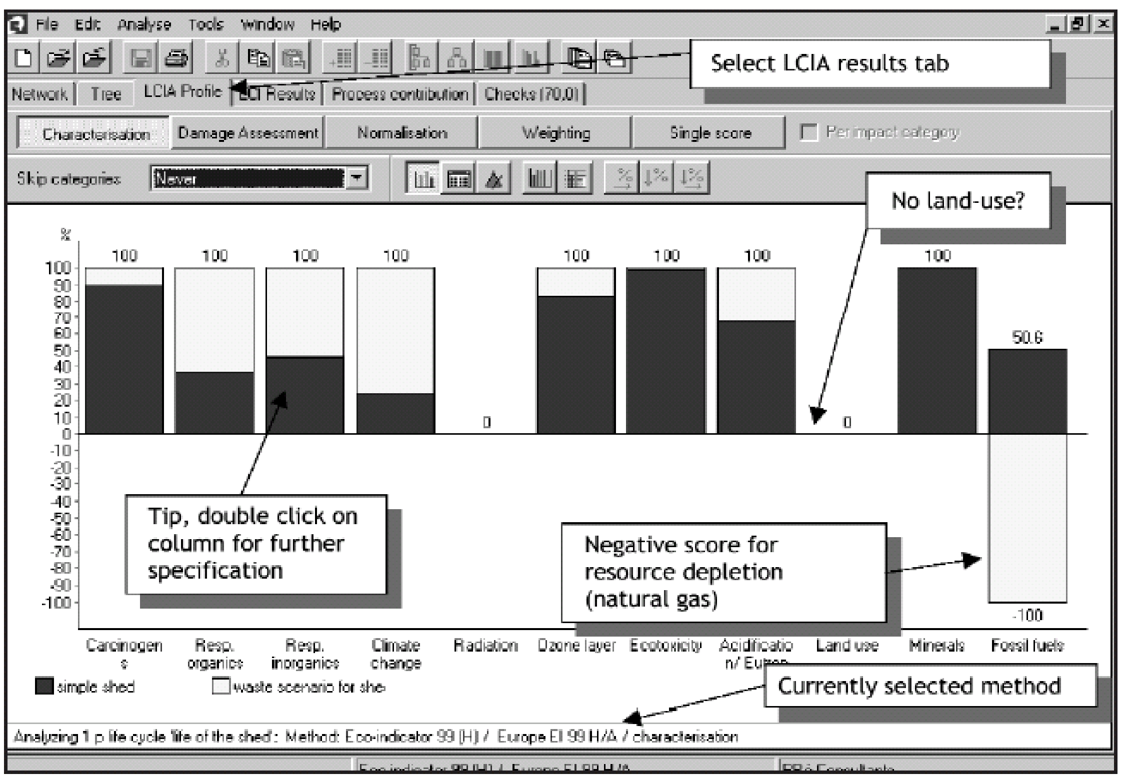


Figure 2.14: LCAI results

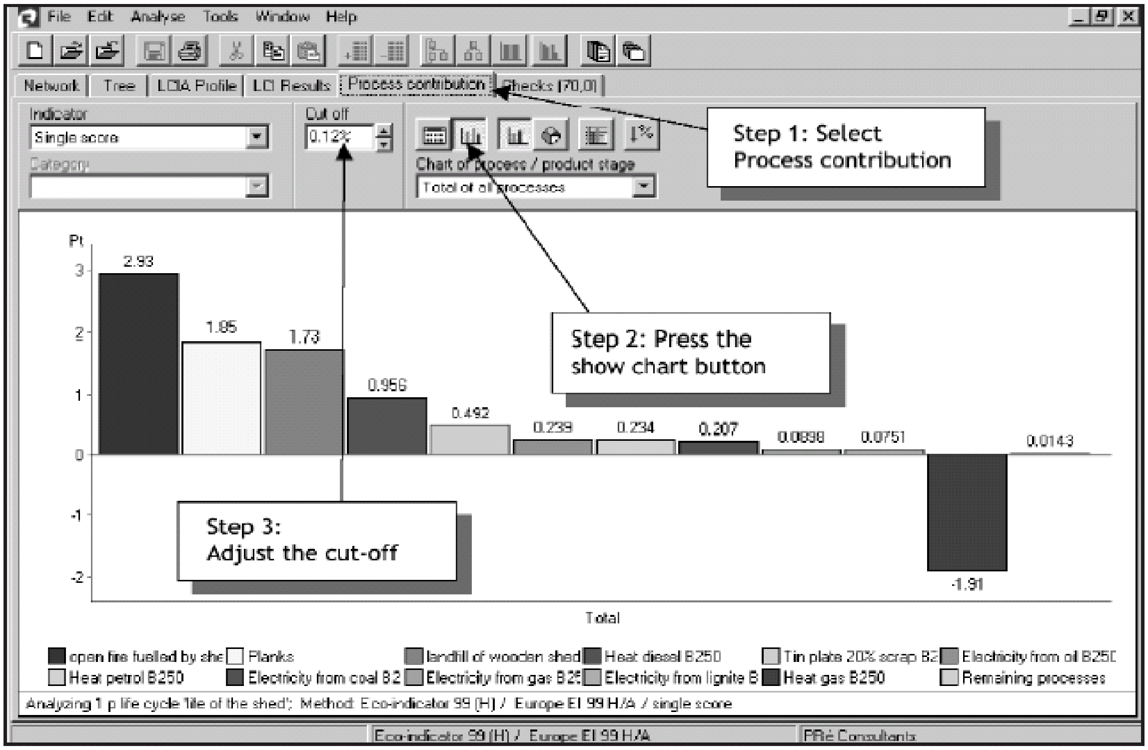


Figure 2.15: Contribution results

2.10 Summary

History of life cycle assessment is introduced in the first section in this chapter. The reviewed of history is indicated that LCA is a process of evaluating the effects that a product has on the environment over the entire period of its life cycle. Life Cycle assessment is made of the methodology, data demand and software. These are the three main components to make a Life Cycle Assessment. LCA is a very important tool helps to achieve sustainable development. At the present time, it is used by industry, government and consumers. The case study of the LCA of men's shirt is included in this chapter. The case is showing that the cost and environment damage have been saved by LCA. Last but not least, even though LCA is largely used today, but there are some of limitations encounter during the process. Usually the limitations are due to lack of knowledge, databases, finance and long duration of time to carry out the job.

CHAPTER 3

Background information

3.1 History of CSR ALC

The Autoclaved Lightweight Concrete (ALC) story began over 45 years ago in West Germany, when a building contractor named Josef Hebel decided to develop a more cost effective building system. Hebel was decided to set up a mixing, moulding and cutting plant at Emmering near Munich. The idea was attributable to the initial success of the first Autoclaved Aerated Concrete (AAC) products, Architects and builders quickly saw the advantages of this strong yet lightweight material, and were soon utilizing its range of properties in all types of construction. CSR is one of the world‘s largest building and construction materials companies. CSR first became involved in the ALC business in 1989 as a licensee of CSR international with the construction of an ALC plant on the NSW central coast just North of Sydney. CSR international is a world leader in technology for production of ALC products. ALC was first commercially used in Europe over 60 years ago. It has since become widely used building material in Australia, Europe, Japan, Taiwan, Korea, South East Asia, North and South America and the Middle East.

3.2 History of CSR ALC in Malaysia

CSR Building Materials (M) Sdn Bhd is a subsidiary of CSR Limited, Australia's leading manufacturer and supplier of the building products with operations throughout Australia New Zealand and Asia. CSR has been involved in the production of insulation products in Malaysia since 1981 under the Bradford name. CSR Building Materials (M) Sdn Bhd was established in 1995 as a joint venture between PFM capital holdings Sdn Bhd, a subsidiary of PNB and CSR Ltd of Australia. In August 1995, CSR ALC was introduced to the Malaysian markets with opening of the state-of-art CSR ALC plant in Senawang, it was located at the southern part of Kuala Lumpur. Since then, the demand for the product has grown quickly and factory extensions were conducted early in 1997, which is two years ahead of the original planning.

3.3 Manufacturing process of CSR ALC

Step 1:

The product of CSR ALC is basically manufactured from the binding agent such as sand, lime and cement to which the gas–forming agent is added during the manufacturing process.

Step 2:

Cement and lime are stored in silos whilst the sand is ground to the required fineness in a ball mill and store.

Figure 3.1: Cement Silo

Figure 3.2: Lime Silo

Step 3:

The raw materials are then automatically weighed and measured in the mixer. The water and aluminium powder acted as the gas-forming agent are added to the mixture.

Figure 3.3: Mixer

Step 4:

After mixing, the cement slurry is poured into a mould. The aluminium powder reacts with alkaline elements in the cement and form gas.

Figure 3.4: Casting

Step 5:

The product will stay for few 1 hour for expansion and 2 hours for hardening.

Figure 3.5: Expansion

Figure 3.6: Hardening

Step 6:

The product is removed from moulds after a few hours and transported to a cutting machine. The cutting machine cuts the moulds using high tensile cutting wires, into the required size building elements.

Figure 3.7: Travel to cutting machine

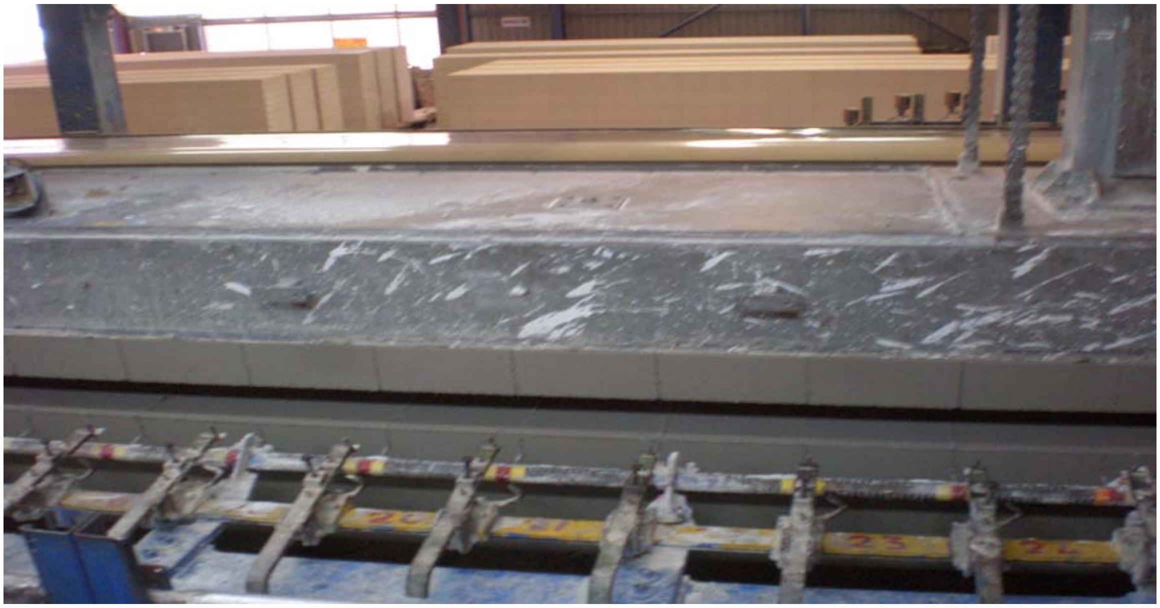


Figure 3.8: Cutting into 250 pieces of ALC blocks

Step 7:

The final curing of the product takes up to 12 hours under high stem pressure in an autoclave.

Figure 3.9: Autoclaving

Step 8:

The blocks panels and lintels are removed from the autoclaved and are packed, ready for transport to site.

Figure 3.10: Products are ready for travel to site

Step 9:

The process is the same as for un-reinforced products.

In figure 2.13 is showing the overall manufacturing process of CSR ALC

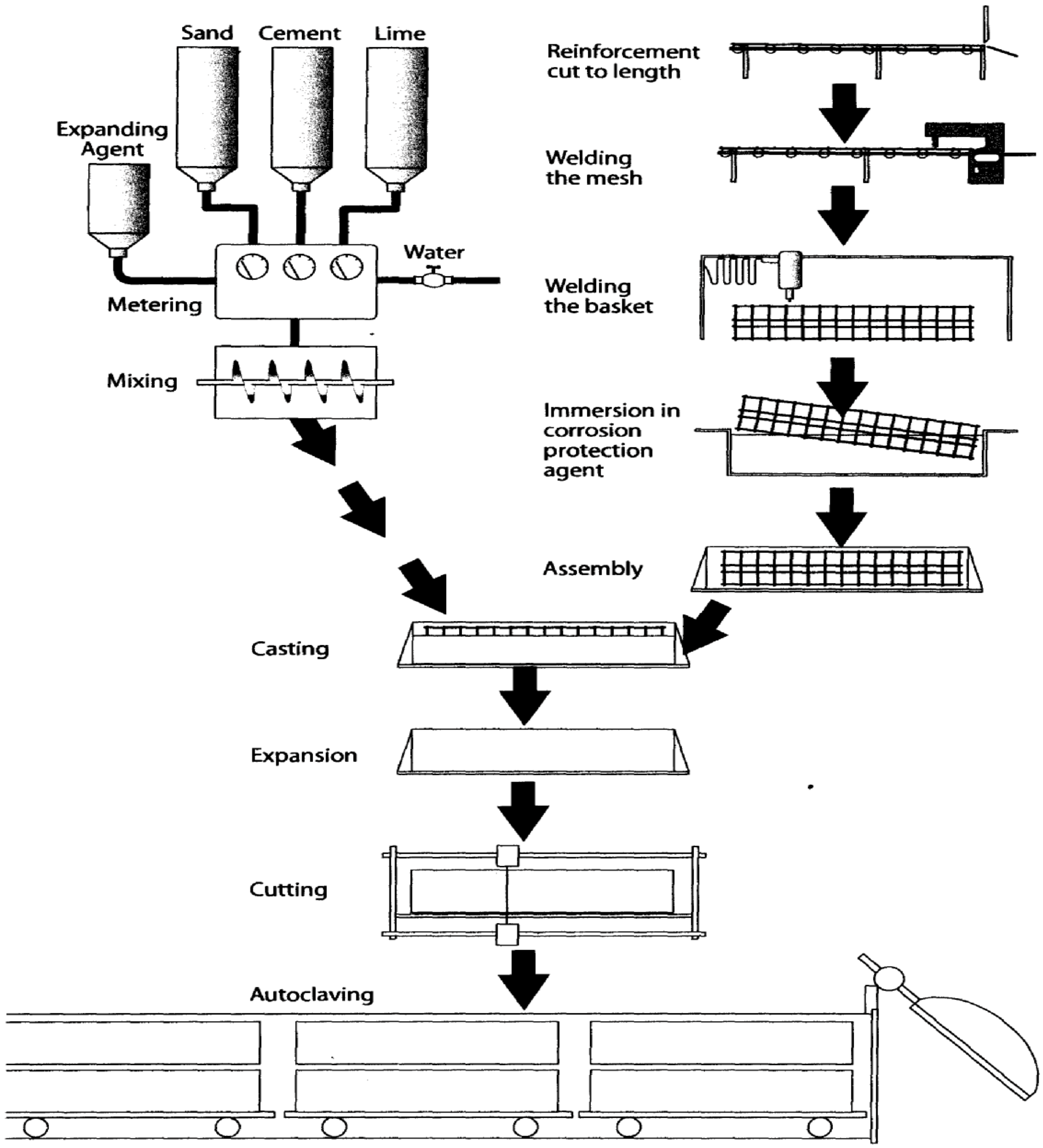


Figure 3.11: CSR ALC manufacturing proce

3.4 CSR ALC BLOCK

CSR ALC has been available in Malaysia since the early 90's and has been used in Europe for over 60 years. Today, the product is extensively used throughout the world. Its products are available in a range of size and strength grades as un-reinforced blocks and reinforced panels, lintels and stair treads.

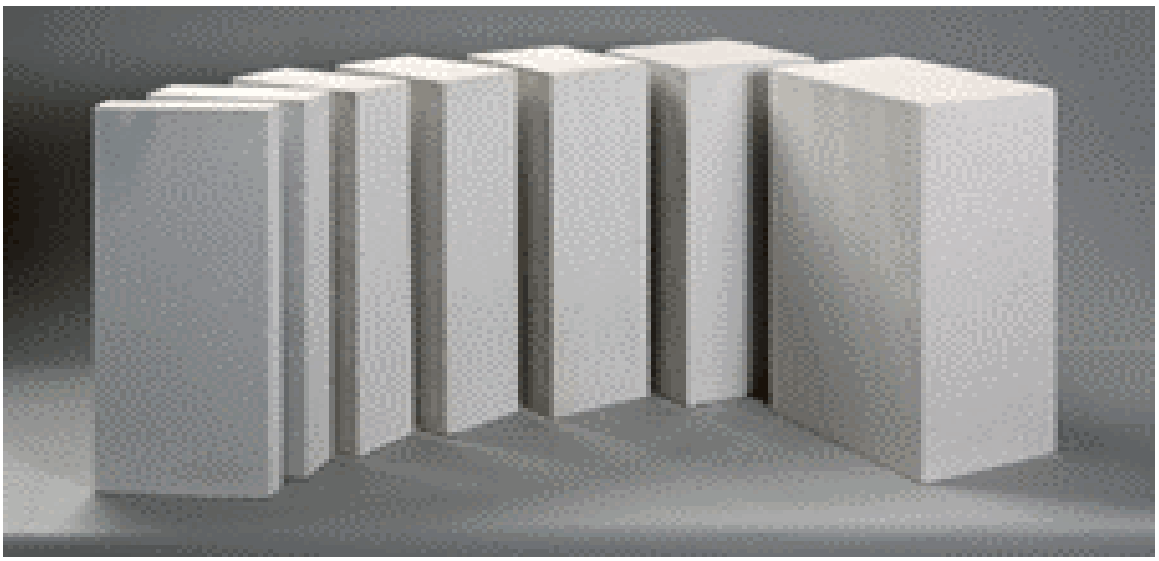


Figure 3.12: ALC blocks

The blocks are produced with a normal face dimension of 600mm x 200mm and in a thickness range of 50-250mm. there are 8.33 block per square meter of wall area. CRS ALC blocks can be used for external and inter load-bearing and non load-bearing walls. Due to their dimensional accuracy, the blocks are easily laid in CSR ALC thin Bed Adhesive with 2-3mm joints. The first course is laid in regular mortar to take out irregularities in the slab. A DCP is required between the slab and CSR ALC Blocks on the ground floor and in wet areas. It is essential that the first course is laid accurately so that speed is achieved in subsequence courses. Subsequent courses are then glued together using thin bed adhesive. This method makes for rapid and easily constructed walls. Wastage is minimized as blocks can be cut size using a tungsten tip handsaw.

Property	Value	Units
Length	600	mm
Height	200 or 400	mm
Thickness	50-250	mm
Nominal Dry Density	490	kg/m^3
Working Density Range	495-650	kg/m^3
Compressive Strength, f'_c	2.8	MPa
Minimum Compressive Strength, f'_m	2.5	MPa
Modulus of Elasticity, E	1500	MPa
Modulus of Rupture, f'_{ut}	0.44	MPa
Ultimate Tensile Strength, f'_{mt}	0.44	MPa

Table 3.1: Block properties

Standard Nominal Length (mm)	Standard Nominal Height (mm)	Nominal Block Thickness (mm)	m^2 per pallet	No. pf pieces per pallet
600	200	100	21.6	180
600	200	125	17.28	144
600	200	150	14.4	120
600	200	200	10.08	84

Table 3.2: CSR ALC Standard Block Size Rang

3.5 Benefits of CSR ALC

The CSR ALC material has a number of unique properties which will transform the Malaysian building industry. The benefits are shown as following:

2.8.1 Manufacturing Accuracy

All CSR ALC panels and blocks will be checked to ensure it produces to required tolerance before leaving the factory. This result in less on-site trimming and reduced quantities of mortar and finishing materials required.

2.8.2 Rapid on- site assembly

The product’s light weight and easy workability enable to quick install on site.

2.8.3 Energy saving

Supplementary insulation can be avoided due to the remarkably good insulation properties of CSR ALC.

2.8.4 Fire resistance

CSR ALC is totally inorganic and is incombustible as a result it is especially suited for fire-rated applications.

2.8.5 Versatility

CSR ALC building products can be used for wide variety of applications including walls, roofs, floors and balconies, in both loadbearing and non-loadbearing applications

2.8.6 Non toxic

CSR ALC products do not contain any toxic gas substances. The product does not harbour or encourage vermin.

2.8.7 Lightweight

The weight for normal block is up to 5 kg and which is produced in easily handled sizes.

2.8.8 Long life

The weight for normal block is up to 5 kg and which is produced in easily handled sizes.

CHAPTER 4

METHODOLOGY

4.1 Research method and data collection

At the beginning stage, a lot of research and studies are carried out. Life cycle assessment is introduced in the first part of the project and continued with the background information of CSR ALC. A lot of case studies of Life cycle assessment also conducted as a guideline for this research project.

Life cycle assessment was performed in accordance with methodology presented by Wenzel et al. (1997) that complies with the general principles of ISO14040 (ISO, 1997). SimaPro is used in this project to perform the inventory and impact assessment calculations. Data related to CSR ALC production will be collected and the data is primarily from the CSR plant in Malaysia through measurements and laboratory analysis. Moreover, the raw material consumption and electricity consumption are partly determined by measurements in the CSR plant and partly derived from the plant's records.

After getting all the data information, the data will be applied in SimaPro software. The life cycle assessment software SimaPro will help to determine and weigh the associated impacts then to set the stages for improvements. If time permitted, comparison will be made between the result of CSR ALC product and concrete block.

To carry out a LCA study, there are four basic steps:

1. First step is to seek to define the goal and scope of the study.

2. Second is to create a model of the product life with all the environmental inflows and outflows by using LCA software. This is usually referred as the life cycle inventory (LCI) stage.
3. Considering and Understanding the environmental relevance of all the inflows and outflows, this is referred as the life cycle impact assessment (LCIA) phase.
4. Finally will be the interpretation of the study.

4.2 Defining the goal

The aim of this research is to set up a LCA model for compiling and accessing environmental information for the CSR ALC products. It is obviously that LCA should have a goal. The goal is to seek for future improvement of the CSR ALC product and minimizing the occupational health and safety risks in the process. The result of the study is aim to applied internal use and there will be a comparison between two products. The reason for carried out the LCA for Autoclave lightweight concrete is intended to provide information only. Besides that, the goal of the study is to determine:

- Future improvement of the product or process so that can reduce the environmental impacts.
- The most environmental impacts caused by the product or process in each stage of its life cycle.
- The least environmental impacts caused by the product or process in each stage of its life cycle.
- The most important factors that decided the environmental load of CSR ALC production.

4.3 Defining the Scope

The scope of this project included the production of the CSR ALC in Malaysia. This included the transportation of raw material to CSR factory, the manufacturing process and waste treatment. This project disregard life time of the product but one of the waste scenario is included which is the waste product will be transported for landfill.

1) Raw materials (the materials are transported to the CSR factory)

- Sand
- Cement
- Lime

2) Manufacturing process

i. Ballmill – sand and lime are mixed then turn to become slurry, where most of the electricity is used in this process.
ii. Batching – Slurry sand is added with cement where energy of electricity will be used.
iii. Cutting – The mould will be cut into 250 pieces of block which the
iv. Autoclaving – the drying process of the block where gas and electricity is used.

3) Waste treatment

- Landfill – the waste product will be moved for landfill.

4.3.1 Functional unit

The functional unit in the project is defined as the production of 4000kg of CSR ALC block which is the mould weight in manufacturing. The other functional unit must be standardised as in table 4.1.

Name	Unit
Raw material	kg / ton
dust	kg
CO2	kg
Gas	kg
transportation	tkm
electricity	kWh
Water	m^3

Table 4.1: Unit standardised

The details of goal and scope definition will be entered to SimaPro as shown in figure 4.1.

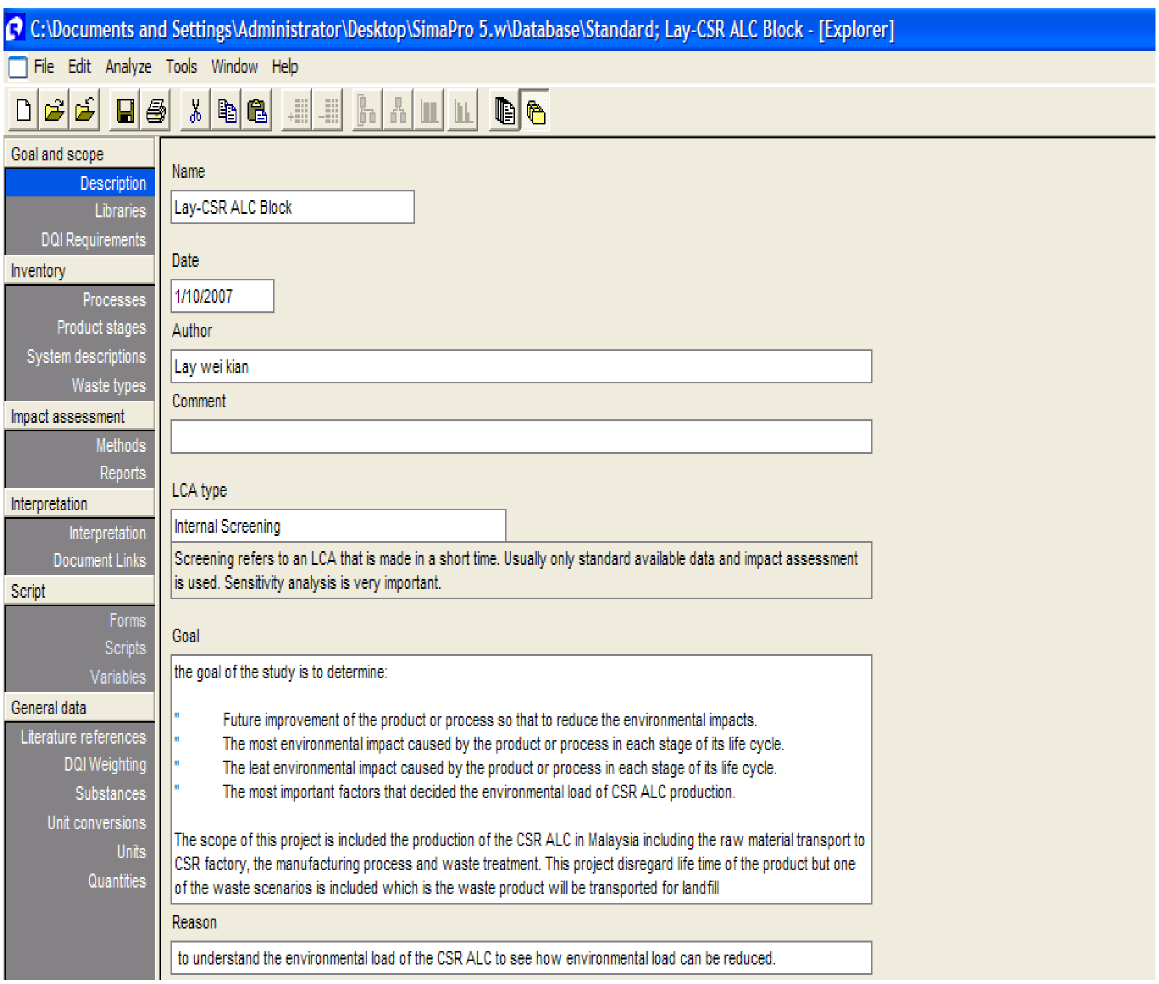


Figure 4.1: Screenshot of goal and scope definition in SimaPro.

4.4 Inventory

In the Inventory phase of an LCA, all emissions and raw material consumption data are collected, all the inputs and outputs data must be calculated before making a model of the product life cycle. In order to perform a Life Cycle impact assessment with SimaPro, There are three major activities:

1. Collect the data is not available in the database, and then enter the data in process records.
2. Link process records to each other form a process tree.
3. Link process records in product stages to model the life cycle.

The process of LCA has a number of fixed main categories as following:

- Materials
- Energy
- Transport
- Processing
- Use
- Waste scenario
- Waste treatment

4.4.1 Material used to produce CSR ALC BLOCK per year

The data that is not available in SimaPro will be collected through books, internet resources and interview. The most important data of the product is provided by the CSR building material company. Factory visit and an interview with the production manager have been conducted in order to get all the data. The following data and information are provided by the CSR building materials company production manager Mr. K.Paneersilvam.

Input Material per year

Material / energy source (inputs)	Quantity
Sand	52361 ton/ year
Cement	23000 ton/year
Lime	7600 ton/year
Gypsum	4800 ton/year
Aluminium powder	59 ton/year
Natural gas	3000 m^3
Diesel (ford lift)	3000 litre
Diesel (production)	1163 litre
Water	5203 m^3
Electricity	304000 kWh

Table 4.2: Input materials per year

Output Material per year

Material / energy source (outputs)	Quantity
Production of block per year	16000 m^3
5 % of waste production	800 m^3

Table 4.3: Output materials per year

4.4.2 Material used to produce 1 mould of CSR ALC BLOCK

Figure 4.2 Picture of mould size

As mentioned previously, the materials will be used for production in one year. Now, the materials used to produce 6.24 m^3 or 4000 kg (1 mould) of CSR ALC block is needed to be figured out. These figures will be used in SimaPro as the functional unit in this project. Therefore, in table 4.4 shows that 4271.8 kg of material is needed to produce 6.24 m^3 or 4000 kg of CSR ALC block (1 mould).

Material (inputs)	Quantity (kg)
Sand	2257.2
Gypsum	200.64
Water	466.16
Lime	206
Cement	602
Aluminium powder	1.8
Waste slurry	538
Total	4271.8

Table 4.4: Input for 1 mould of CSR block.

4.4.3 Actual production of CSR ALC BLOCK after cutting.

Figure 4.3: Production after cutting

The mould of the production will be transferred to the cutting machine. It will be cut into 250 pieces of blocks. After the cutting process, the waste material will be recycled. The waste material is known as waste slurry. The volume of waste slurry is expected up to 538kg in each mould after cutting. The calculation of the production after cutting is showing as following:

Actual production in weight = original weight – waste slurry in kg

= 4000 – 538

= 3462 kg

Actual production in m^3 = original volume – waste slurry in m^3

= 6.24 – 0.84

= 5.4 m^3

To find the density = weight / volume

= 3462 / 5.4

= 641 kg/ m^3

This is to show that the total of block can be produced by 1 mould.

4.4.4 The dimension of 1 piece of block

1 piece of block = 0.06 x 0.2 x 0.1 = 0.012 m^3

To find the weight of 1 piece of block = volume x density

= 0.012 x 641

= 7.68 kg

No of block = 5.4 / 0.012

= 450 pieces

Therefore, 1 mould can produce **450 pieces** of blocks

4.4.5 Non material used to produce of 6.24 m^3 or 4000 kg (1 mould) of CSR ALC block

All the materials like lime, sand and cement are already included in the previous state. Now, non-material such as electricity and water consumption will be determined. Table 4.5 shows that the percentage and amount of electricity and water consumption during the manufacturing process.

Note: - Total electricity consumption per year = 304000 kWh

- Total water per year consumption per year = 5203 m^3
- Total production per year = 16000 m^3
- 1 piece of block = 6.24 m^3

Electricity used to produce of 6.24 m^3 or 4000 kg (1 mould) of CSR ALC block
= (304000 kwh x 6.24) / 16000
= 118.56 kwh

Water used to produce of 6.24 m^3 or 4000 kg (1 mould) of CSR ALC block
= (5203 m^3 x 6.24) / 16000
= 2.03 m^3

Non material / Process	Electricity (%)	Water (%)	Electricity (kwh)	Water (kg)
Ball mill	50	20	59.28	0.4060
Batching/ Mixing	10	20	11.856	0.4060
Cutting	10	-	11.856	-
Autoclaving	20	50	23.712	1.0150
watering	-	5	-	0.1015
others	10	5	11.856	0.1015
Total	100	100	118.56	2.03

Table 4.5: Electricity and water consumption

4.5 Conducting a Sima-Pro Analysis of CSR ALC block

Step 1: **Data Quality Requirements**

Select the Data Quality Requirements in the SimaPro as shown in the figure 4.4, 4.5 and 4.6.

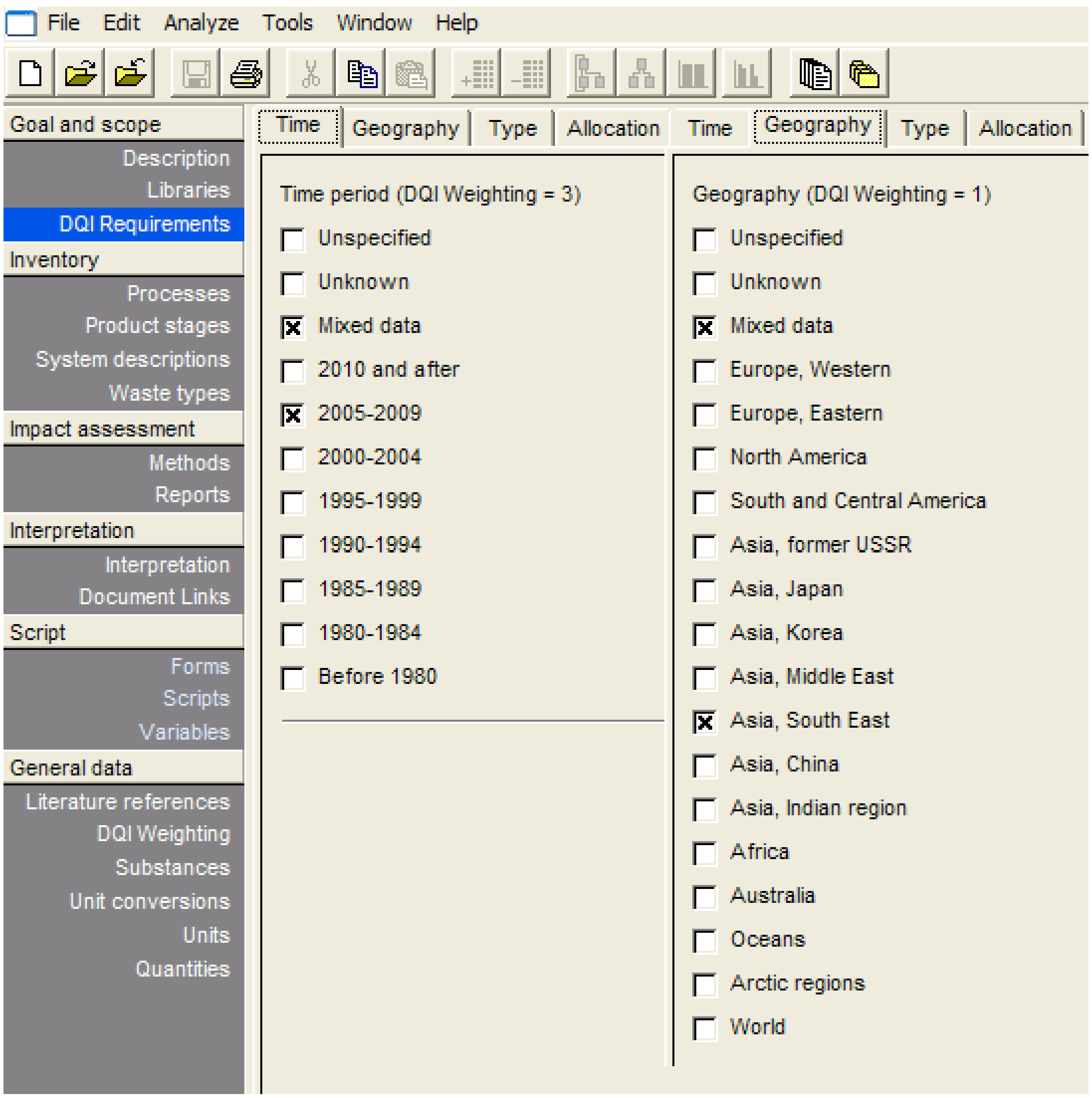


Figure 4.4: Data Quality Requirements 1

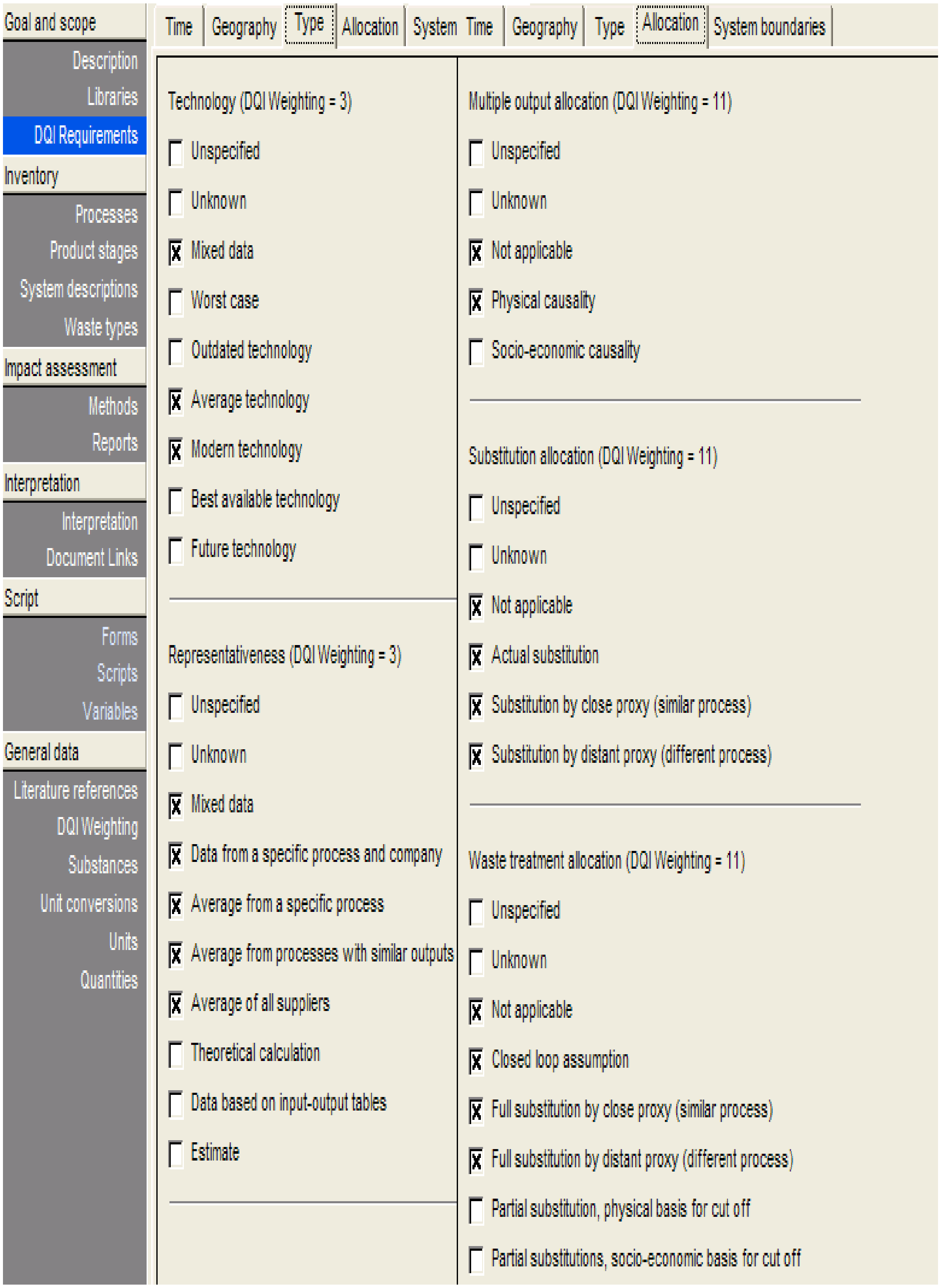


Figure 4.5: Data Quality Requirements 2

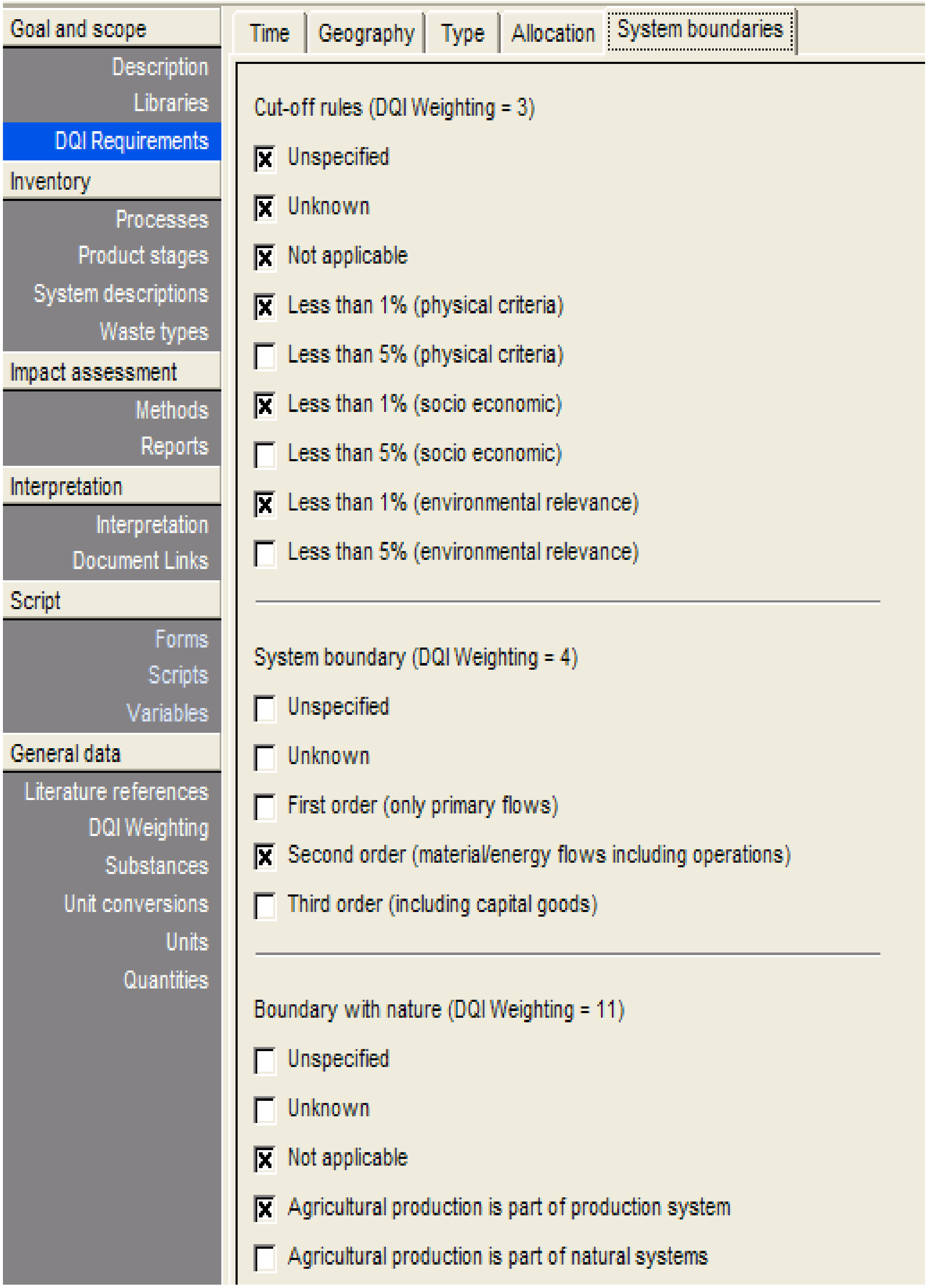


Figure 4.6: Data Quality Requirements 3

Step 2: **Analyse the Ball mill process**

The first step of the manufacturing process is to ground the sand to the required fineness in the ball mill. For Ball mill process, it needs water = 0.406kg, gypsum = 200.6 kg and sand = 2257.2kg for the overall process. During the process, only the electricity from hydropower will be used. The total of 0.3 kg natural gas and 0.2 kg of dust respectively will cause emission to air. All the data will be entered into the LCA SimaPro inventory input and output screen as shown in figure 4.7.

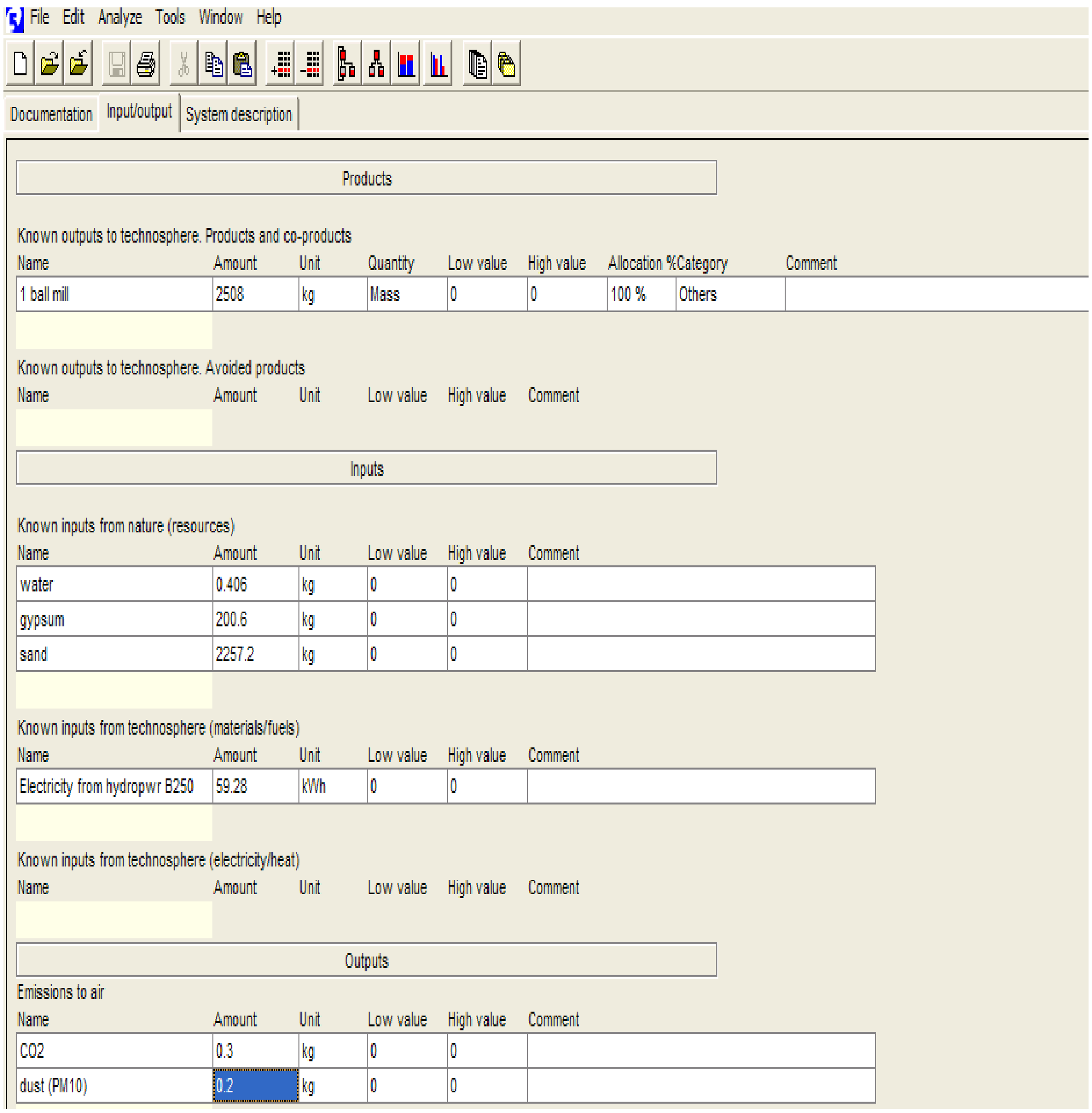


Figure 4.7: SimaPro inventory input and output screen for ball mill process

Step 3: Slurry Sand

The out come of the ball mill process is known as Slurry sand, which the sand is mixed with the water and gypsum. SimaPro inventory input and output screen for slurry sand will be shown in figure 4.8. In Figure 4.9 is the Sima-Pro's Tree of the slurry sand.

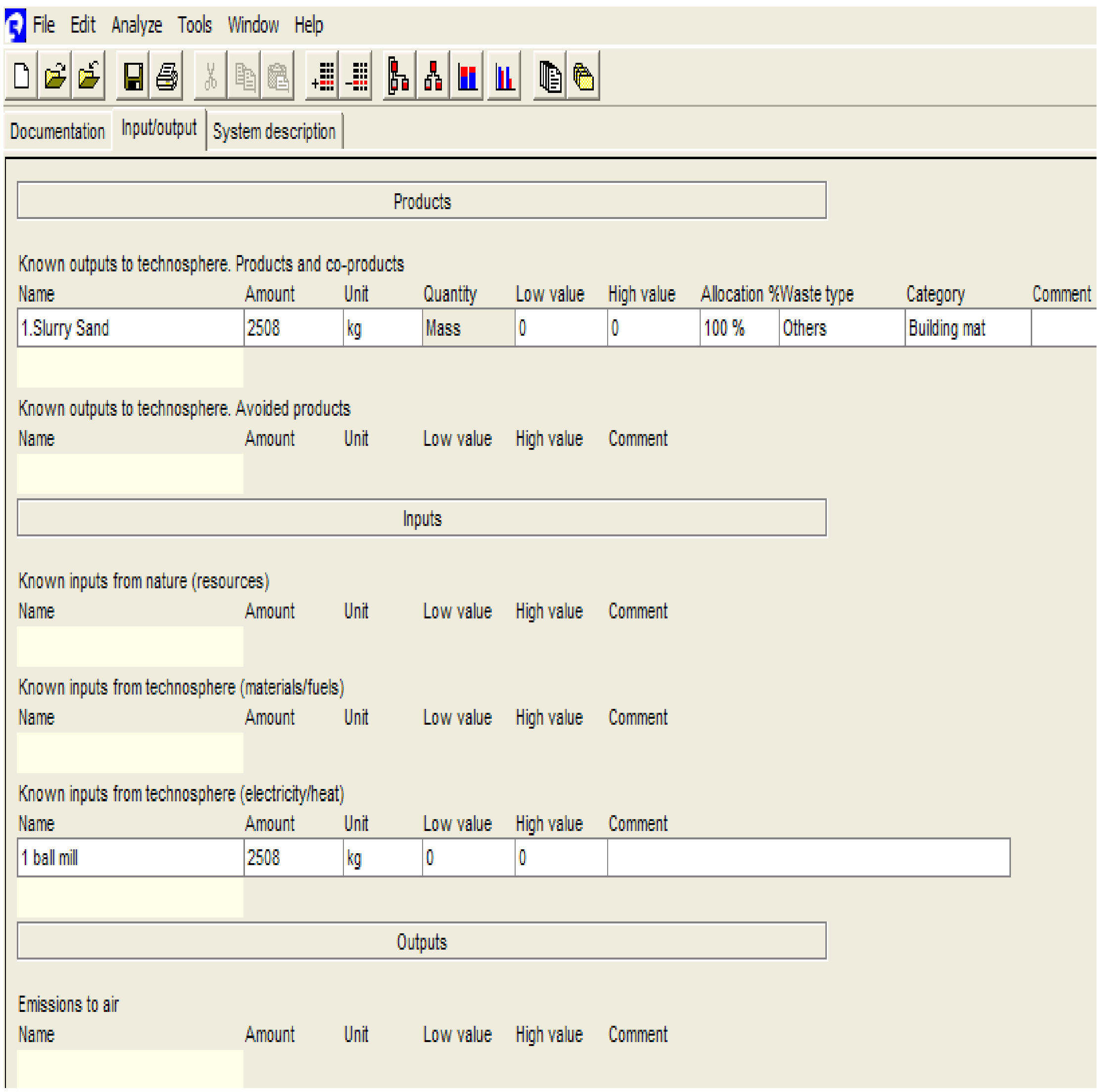


Figure 4.8: SimaPro inventory input and output screen for slurry sand

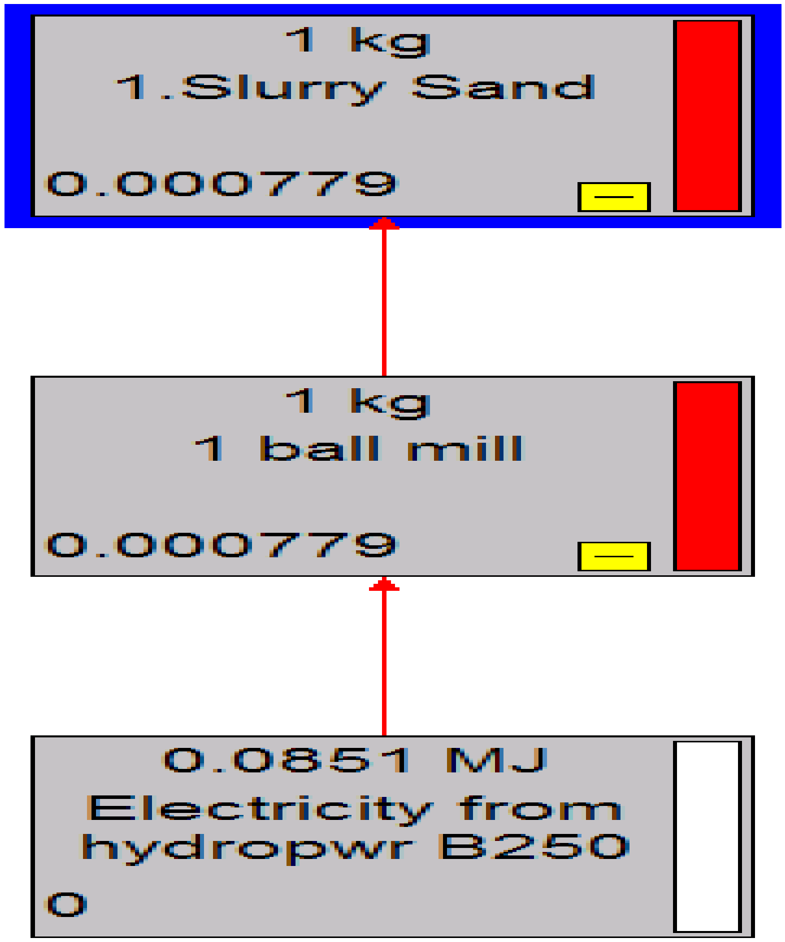


Figure: 4.9: SimaPro's Tree for slurry sand

Step 4: **Analysing cement**

The product of CSR ALC is basically manufactured from the binding agent such as sand, lime and cement to which the gas–forming agent is added during the manufacturing process. The manufacturing required 620 kg of cement and this is usually provided by YTL Company. The travel distance from YTL cement plant to CSR factory is around 10 km. The relevant information about cement can be obtained from the Sima-Pro software itself. Sima-Pro inventory input and output screen for cement is shown in Figure 4.10 and figure 4.11 is the SimaPro's tree analysis for cement.

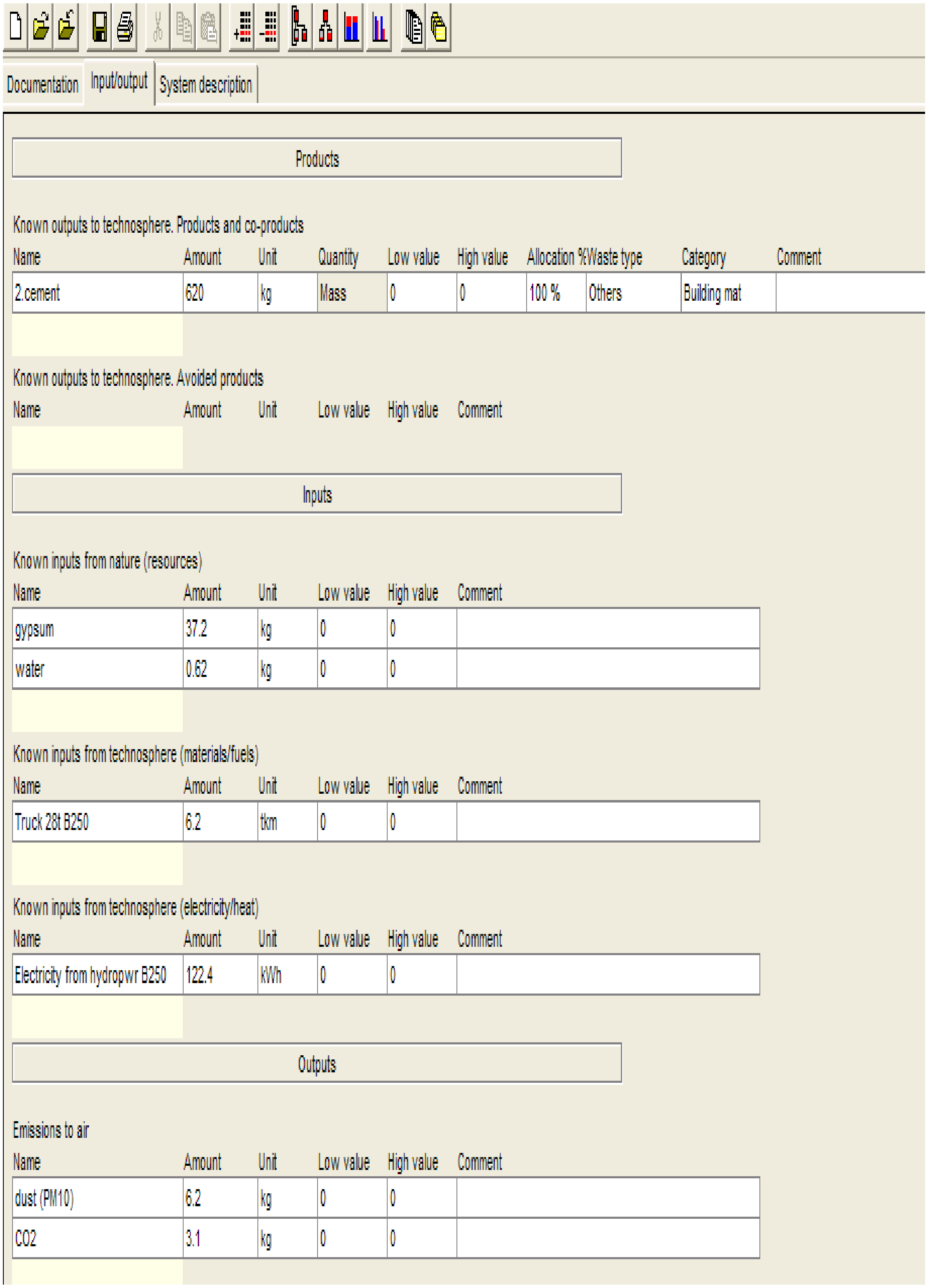


Figure 4.10: SimaPro inventory input and output screen for cement

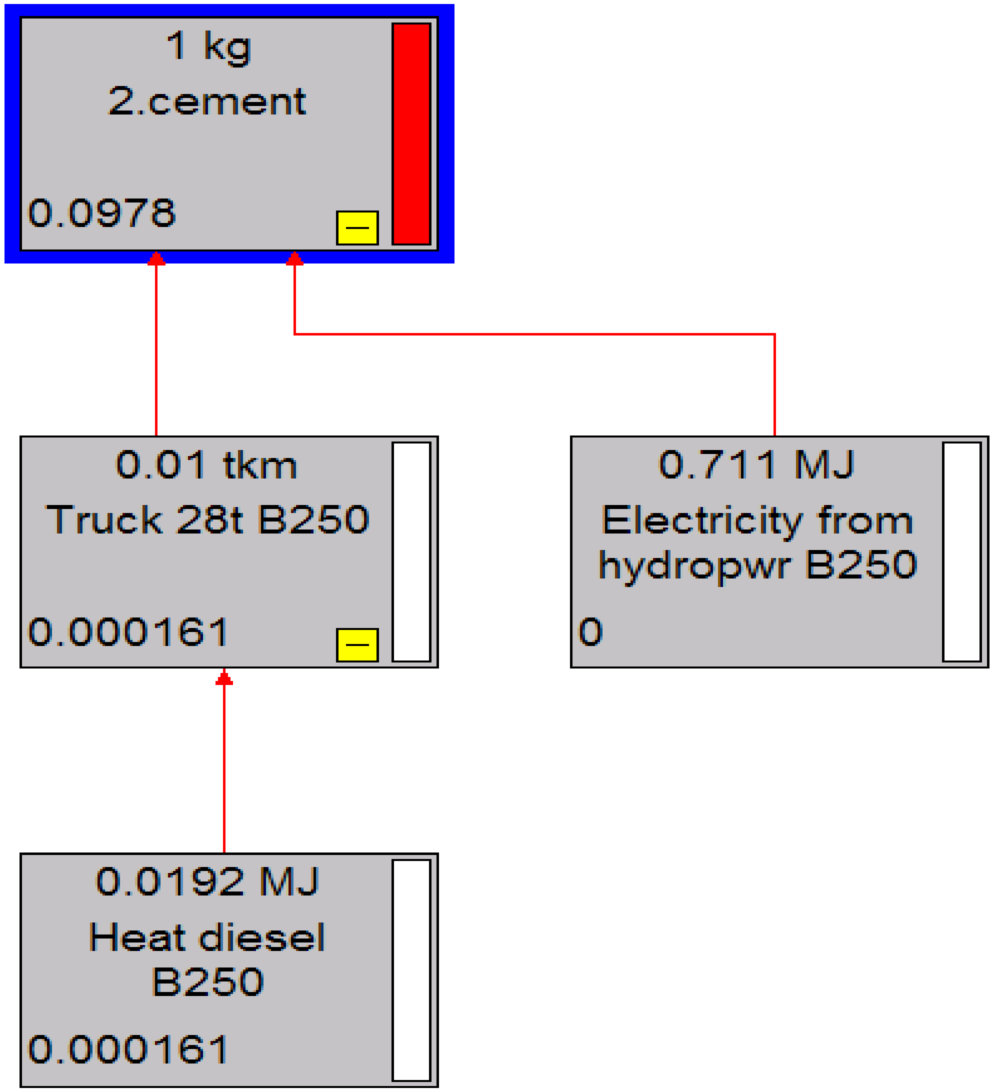


Figure 4.11: SimaPro's Tree for Cement

Step 5:

Next, the lime is imported from Ipoh which is a state in Malaysia. The distance to transport 206 kg of lime is around 300 km. The detail information of lime also can be obtained from the SimaPro software. The results are shown in figure 4.12 and figure 4.13.

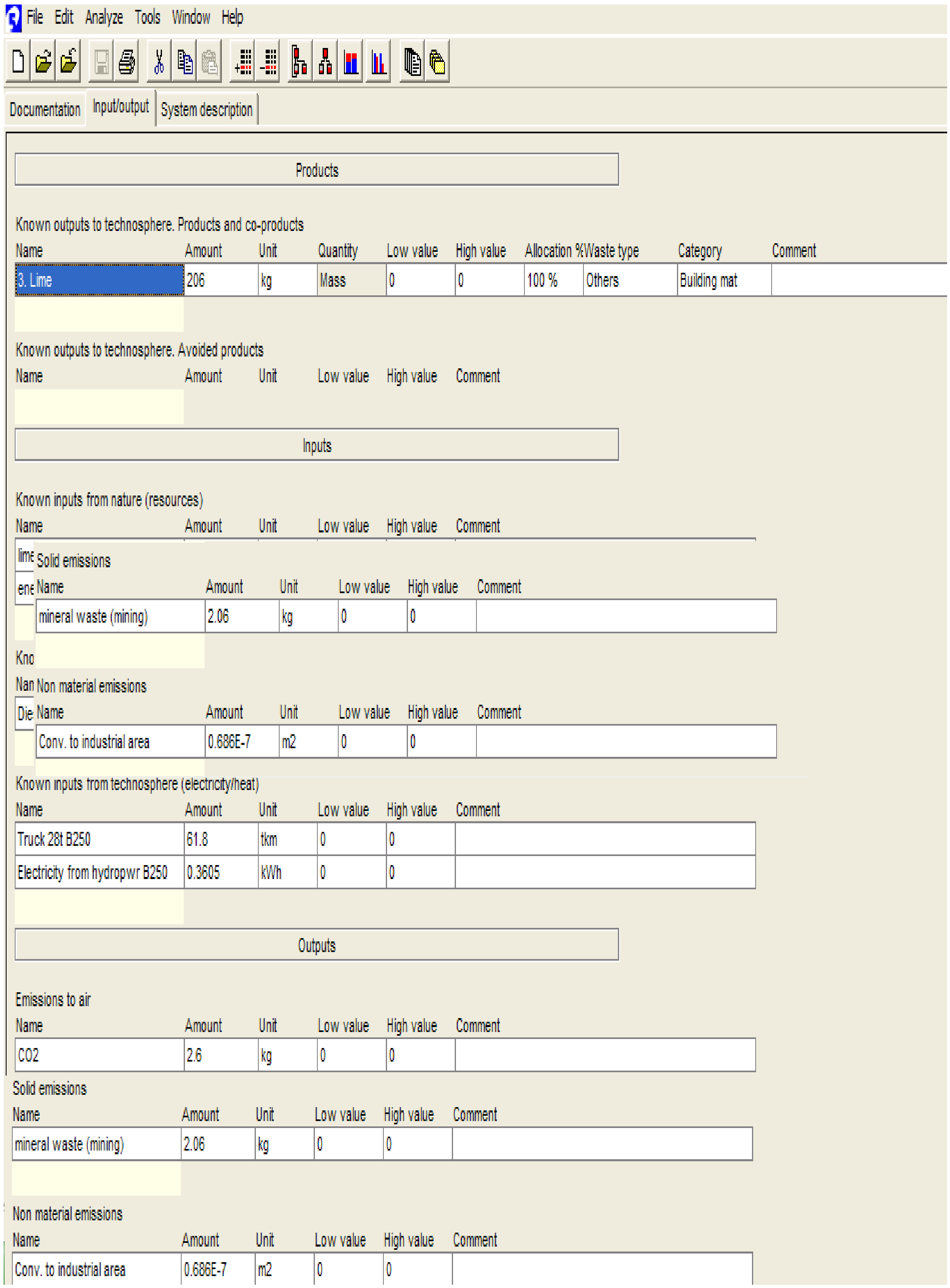


Figure 4.12: SimaPro inventory input and output screen for Lime

Analysing lime

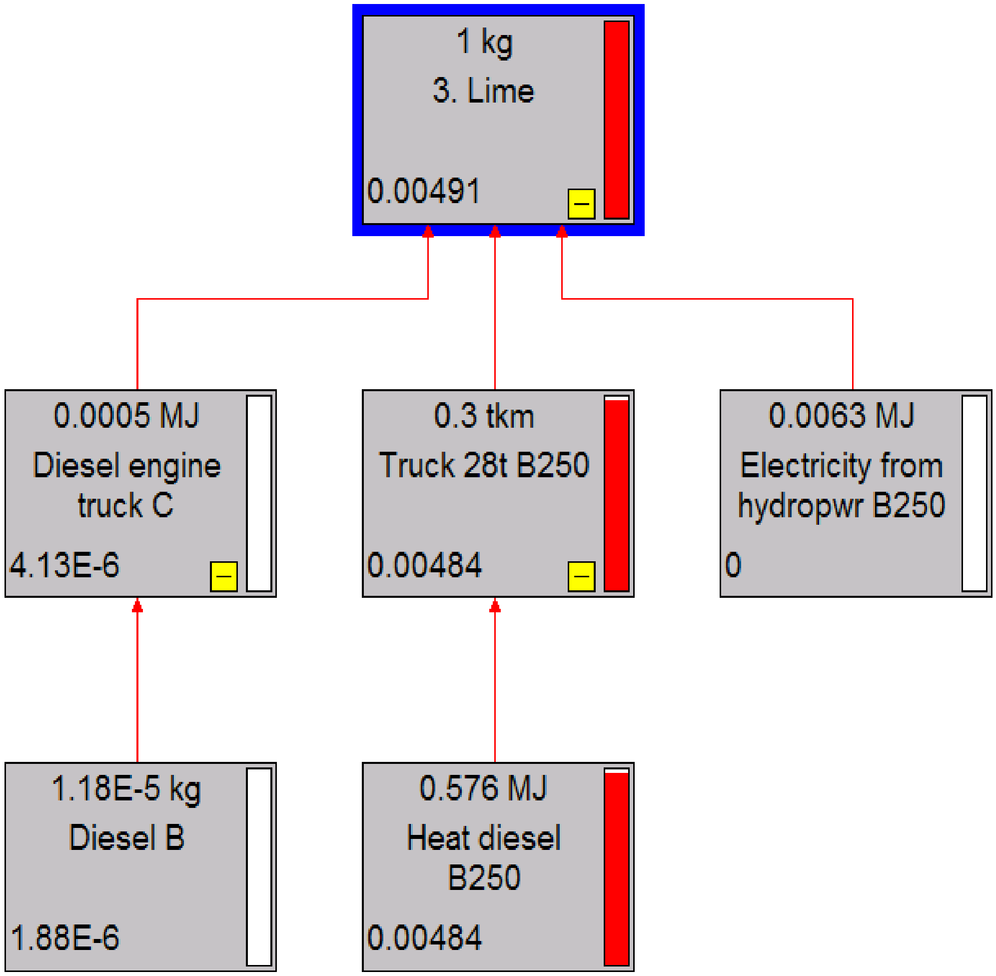


Figure 4.13: SimaPro's Tree for Lime

Step 6: **Analysing the batching process**

The following stage is the batching or mixing process, which the raw materials are then automatically weighed and measured in the mixer. During the process, water and aluminium powder acted as a gas-forming agent are added to the mixture. All the data also entered into SimaPro as shown in figure 4.14 and figure 4.15 is the SimaPro's tree for batching.

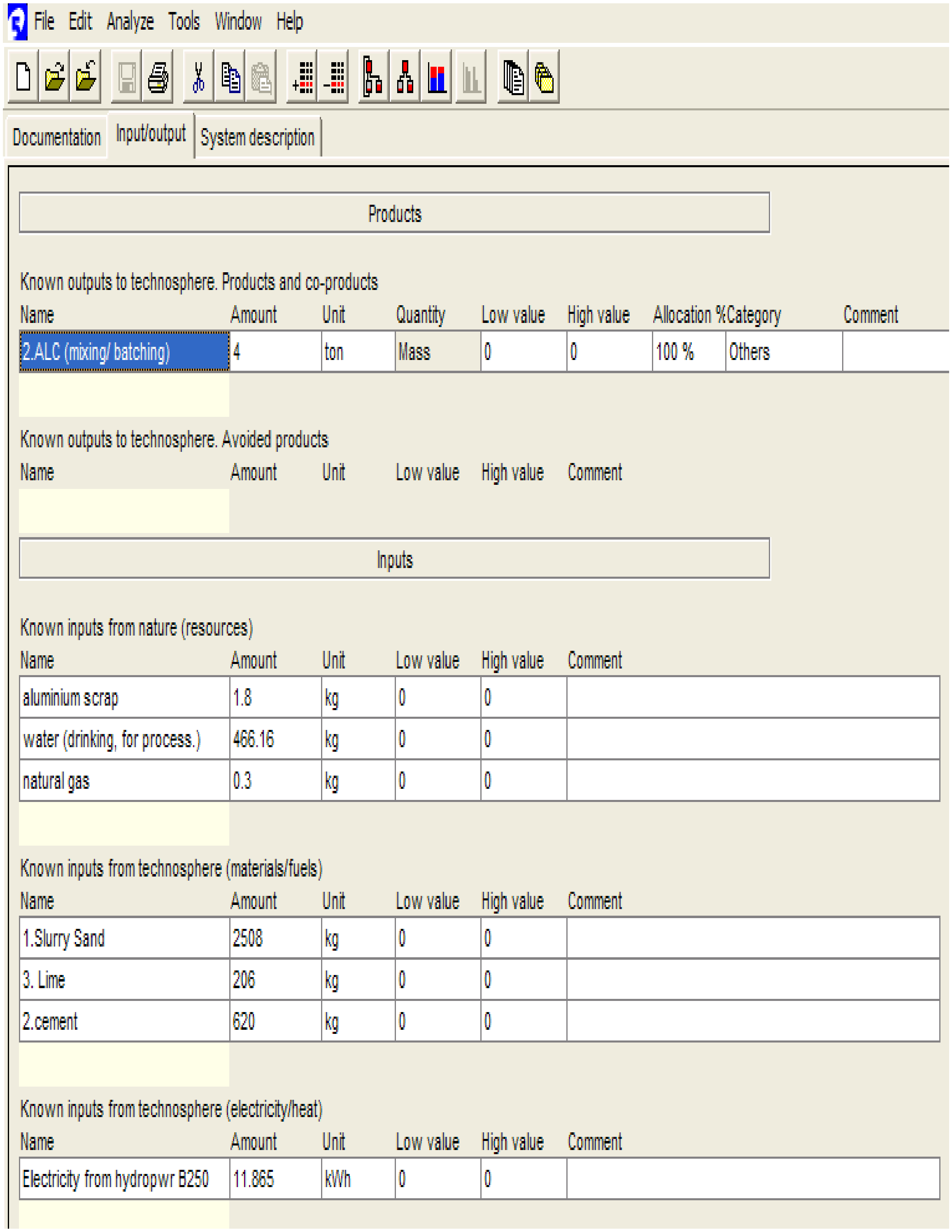


Figure 4.14: SimaPro inventory input and output screen for batching

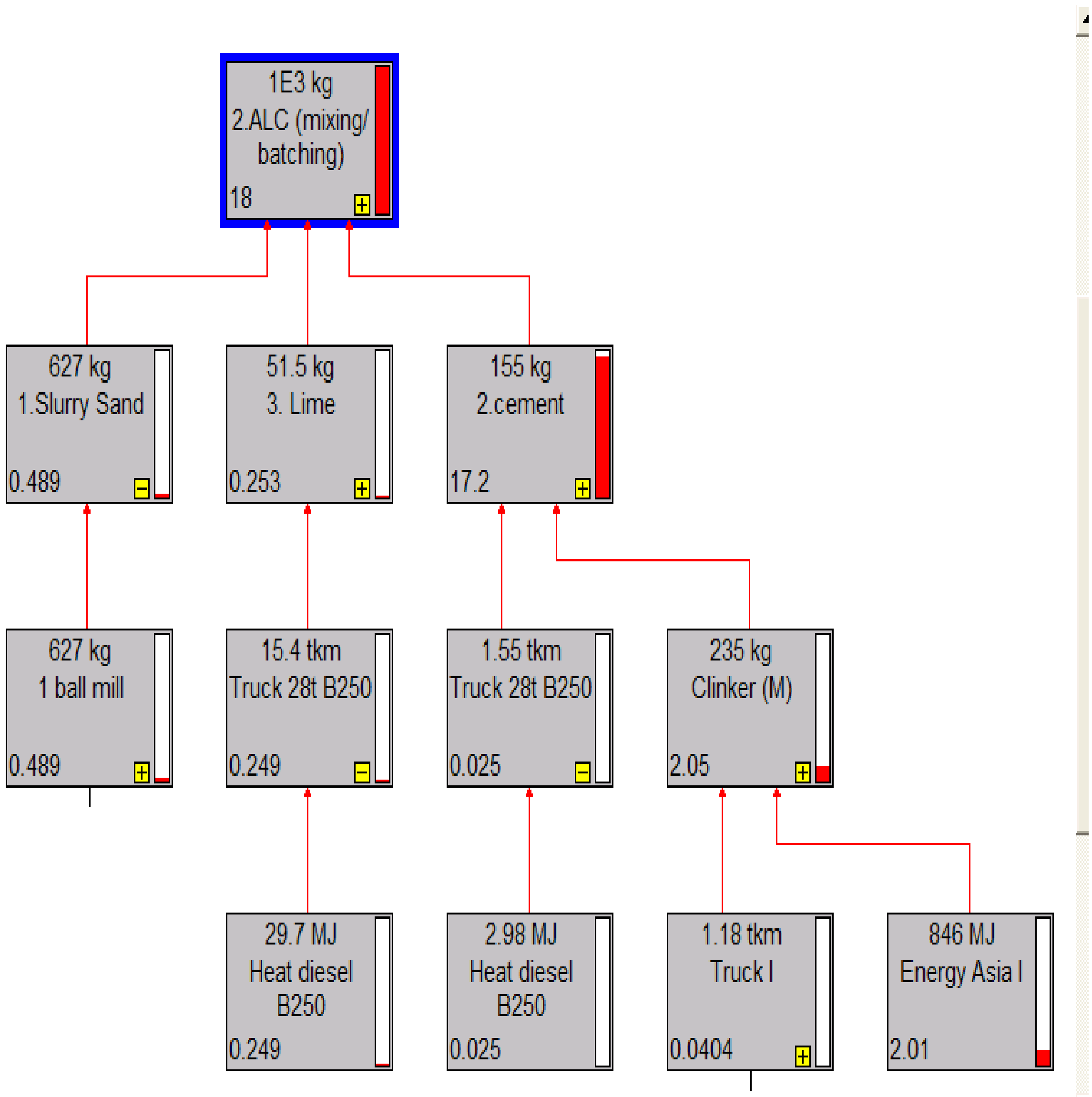


Figure 4.15: SimaPro's Tree for batching

Step 7: **Analyse the cutting process**

The product is removed from mould after a few hours and transported to a cutting machine. The cutting machine cuts the mould into the required size using high tensile cutting wires. Figure 4.16 is the input and output screen and figure 4.17 is the SimaPro's tree for cutting process.

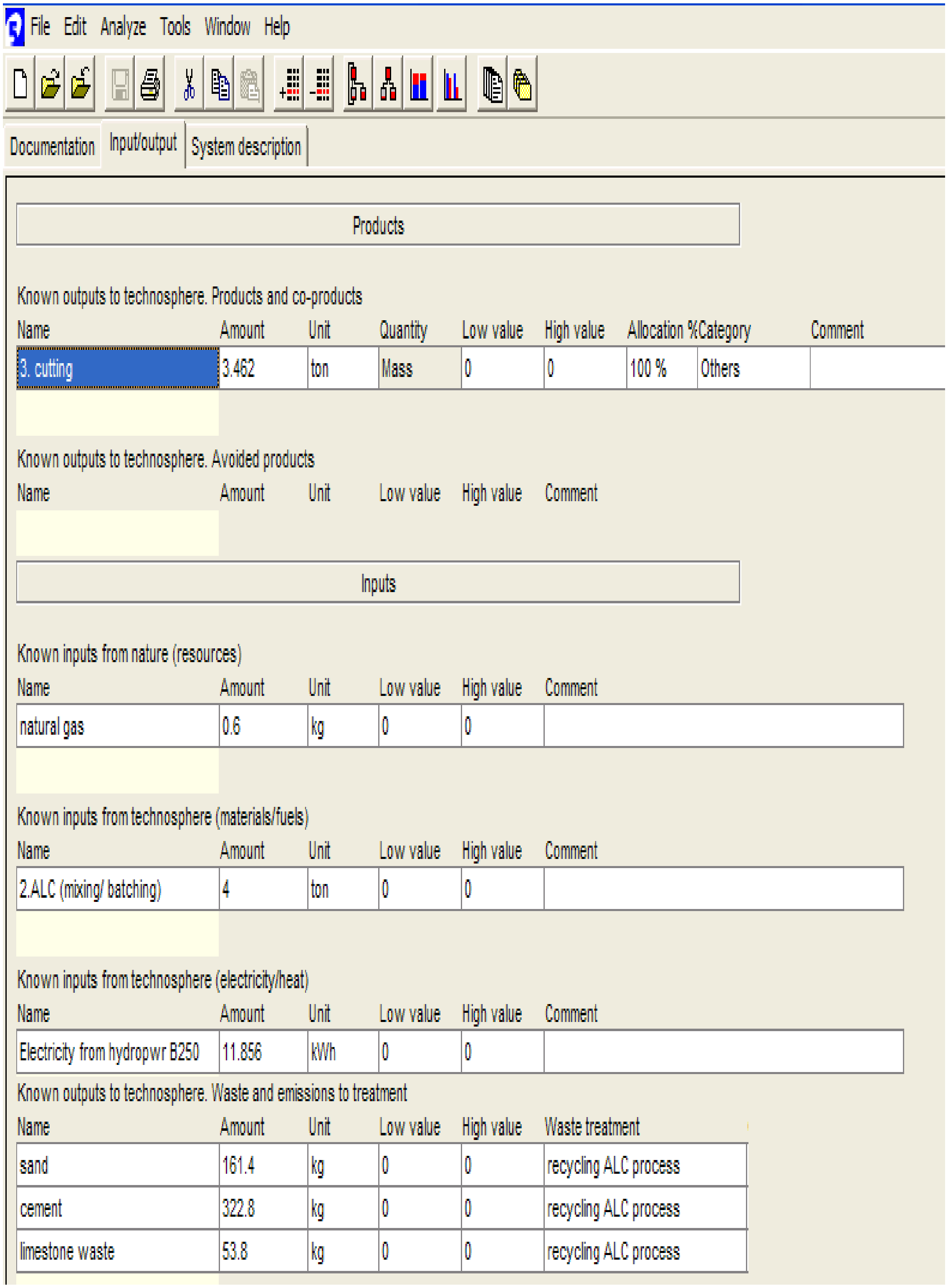


Figure 4.16: SimaPro inventory input and output screen for cutting

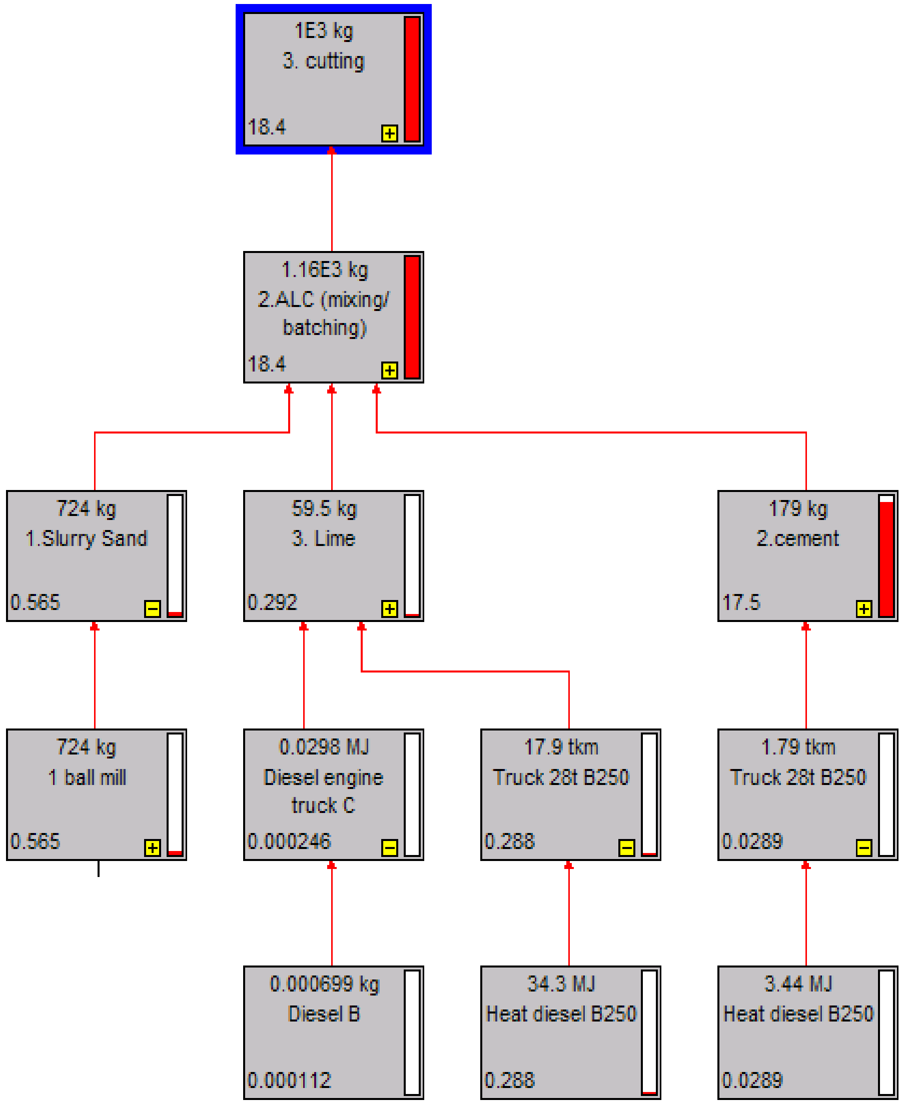


Figure 4.17: SimaPro's Tree for Cutting process

Step 8: **Analyse the autoclaving process**

The final curing of the product takes up to 12 hours under high stem pressure in an autoclave. The results are shown in figure 4.18 and figure 4.19.

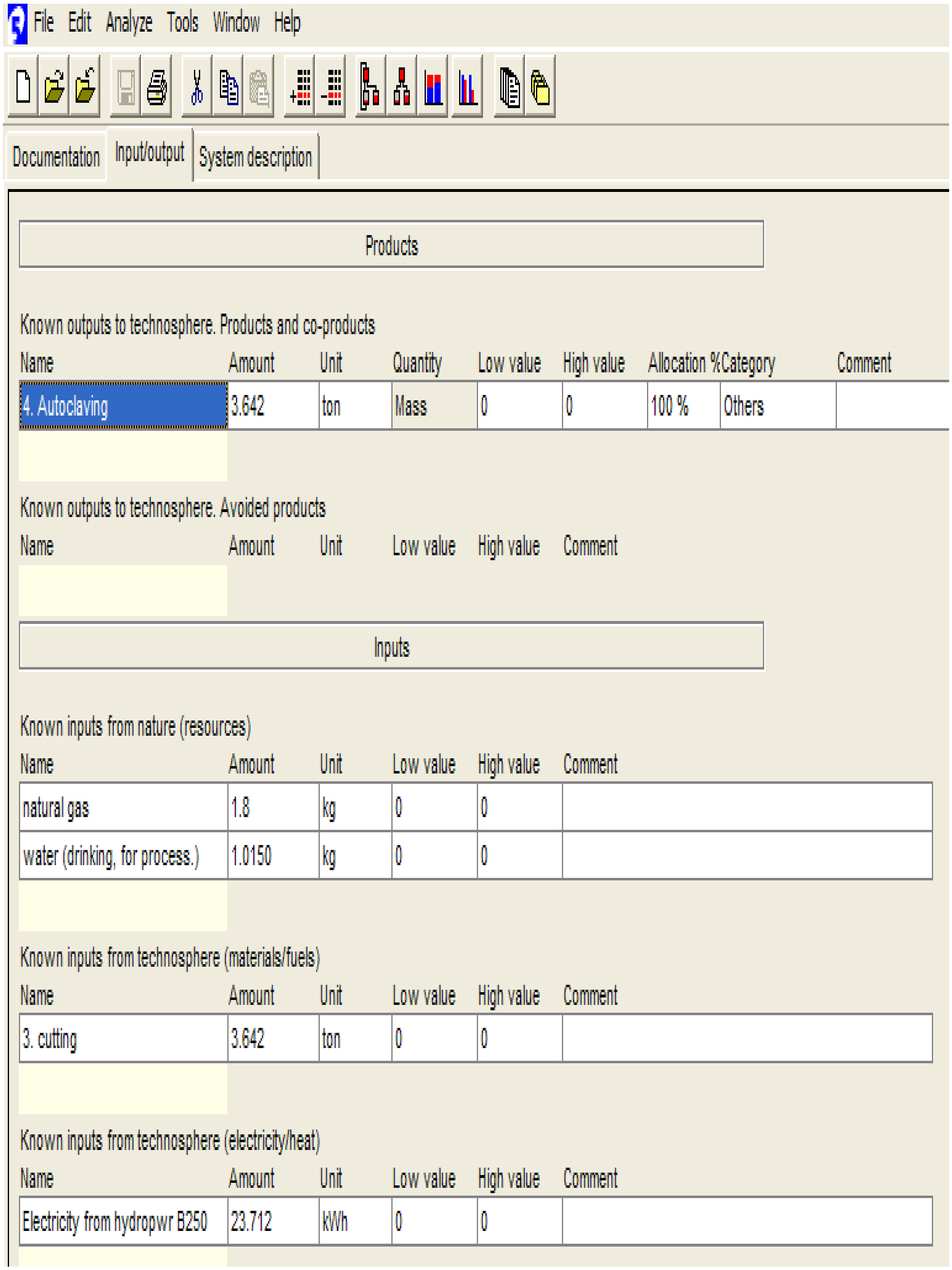


Figure 4.18: SimaPro inventory input and output screen for autoclaving

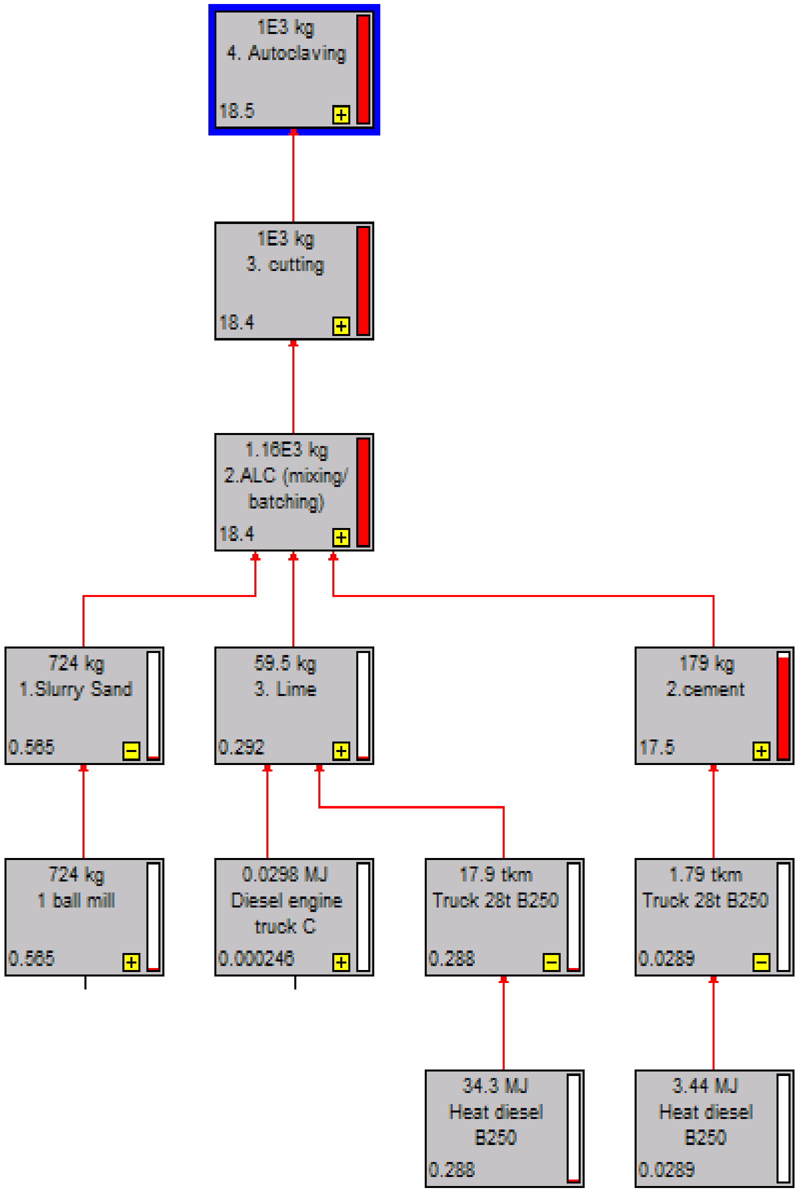


Figure 4.19: Tree for autoclaving

Step 9: **Analysing the CSR ALC block**

The block is removed from the autoclaved and is packed, ready for transport to the site. Figure 4.20 is the final input and output screen and figure 4.21 is the final SimaPro's tree for the ALC block.

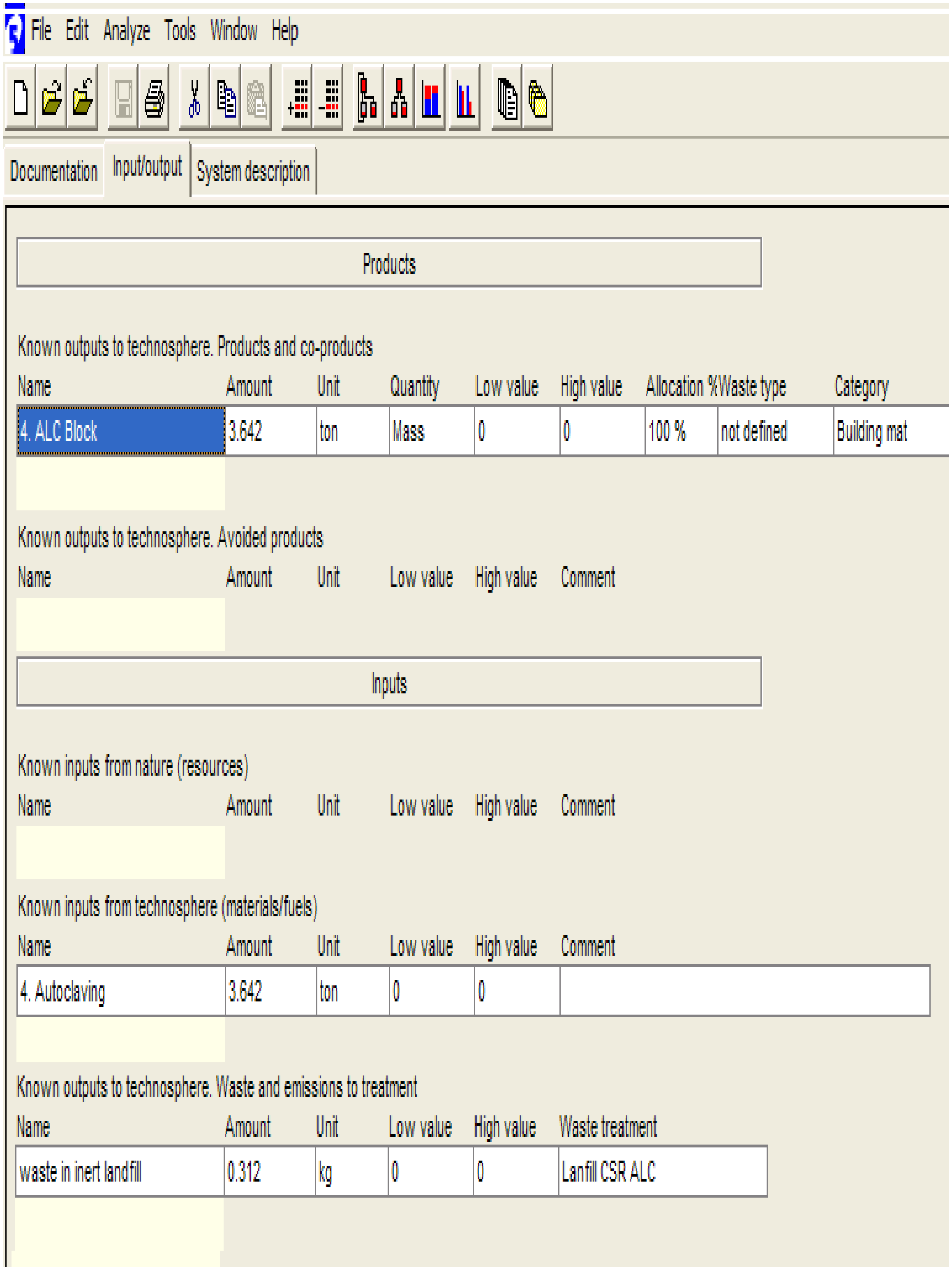


Figure 4.20: SimaPro inventory input and output screen for block.

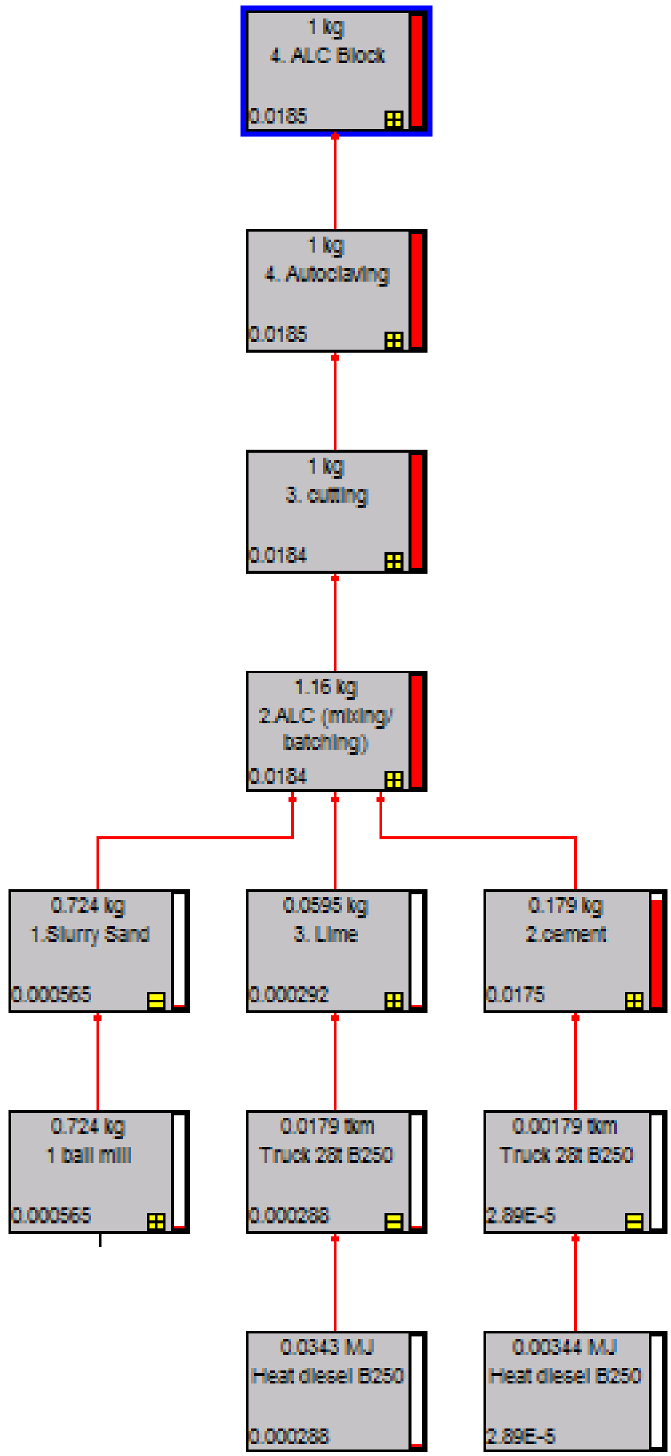


Figure 4.21: SimaPro's tree for ALC block

CHAPTER 5

Life Cycle Impact Assessment

5.1 INTRODUCTION

In this chapter, the materials and manufacturing process will be analysed by SimaPro. The results of impact assessment method such as single score, normalization and damage assessment will be included in this project. CSR ALC block is made of cement, lime and slurry sand. Comparison of the material between cement, lime and slurry sand will be conducted. After that, the result of manufacturing process will be carried out.

The impact potentials are calculated according to the LCI results. Impact assessment methods hold data on:

1. Characterisation
2. Damage assessment
3. Normalization
4. Weighting
5. Single score

1.0 Characterisation

This is the first result display at LCIA. This factor reflects to the relative contribution of an LCI result to impact category indicator result.

2.0 Damage assessment

Damage assessment shows the damage to human health, ecosystem quality and resources. Some impact assessment method allow for adding impact category indicators that have a single unit.

3.0 Normalization

Normalization provides a basic for comparing different types of environmental impact categories (all impacts get the same unit).

4.0 Weighting

Weighting implies assigning a weighting factor to each impact category depending on the relative importance

5.0 Single Score

Single scored is the total impact of each process of product being analysed and compared to human health, ecosystem quality and resources.

5.2 LCAI result 1- Comparing the raw materials

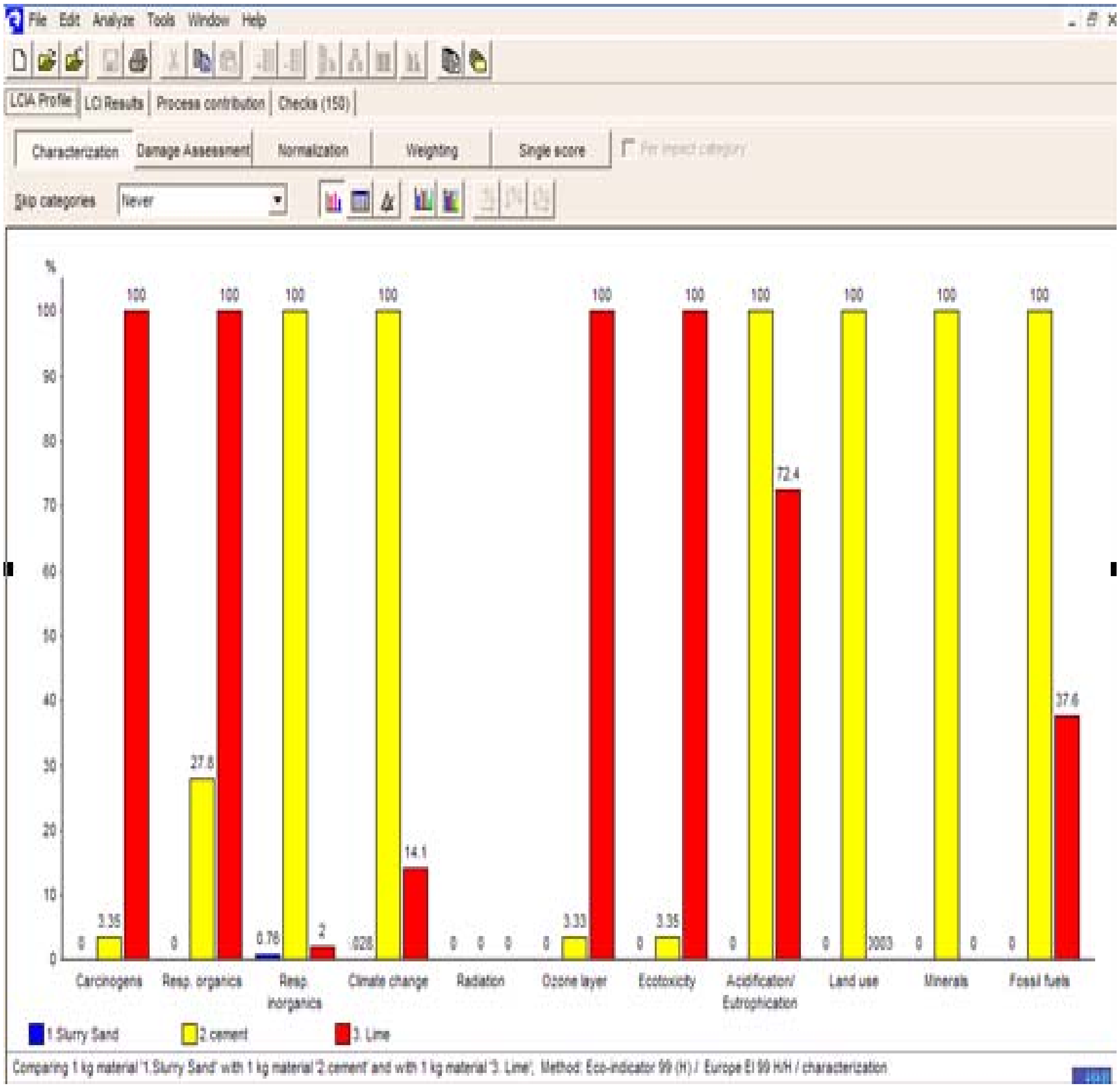


Figure 5.1: Characterization output for Cement, lime and slurry sand.

Characterization

Figure 5.1 is the first result displayed in LCIA which is characterization. From the result, radiation is not affected by slurry sand, lime and cement. The result also shown that Slurry sand is only contributes to Resp. inorganic.

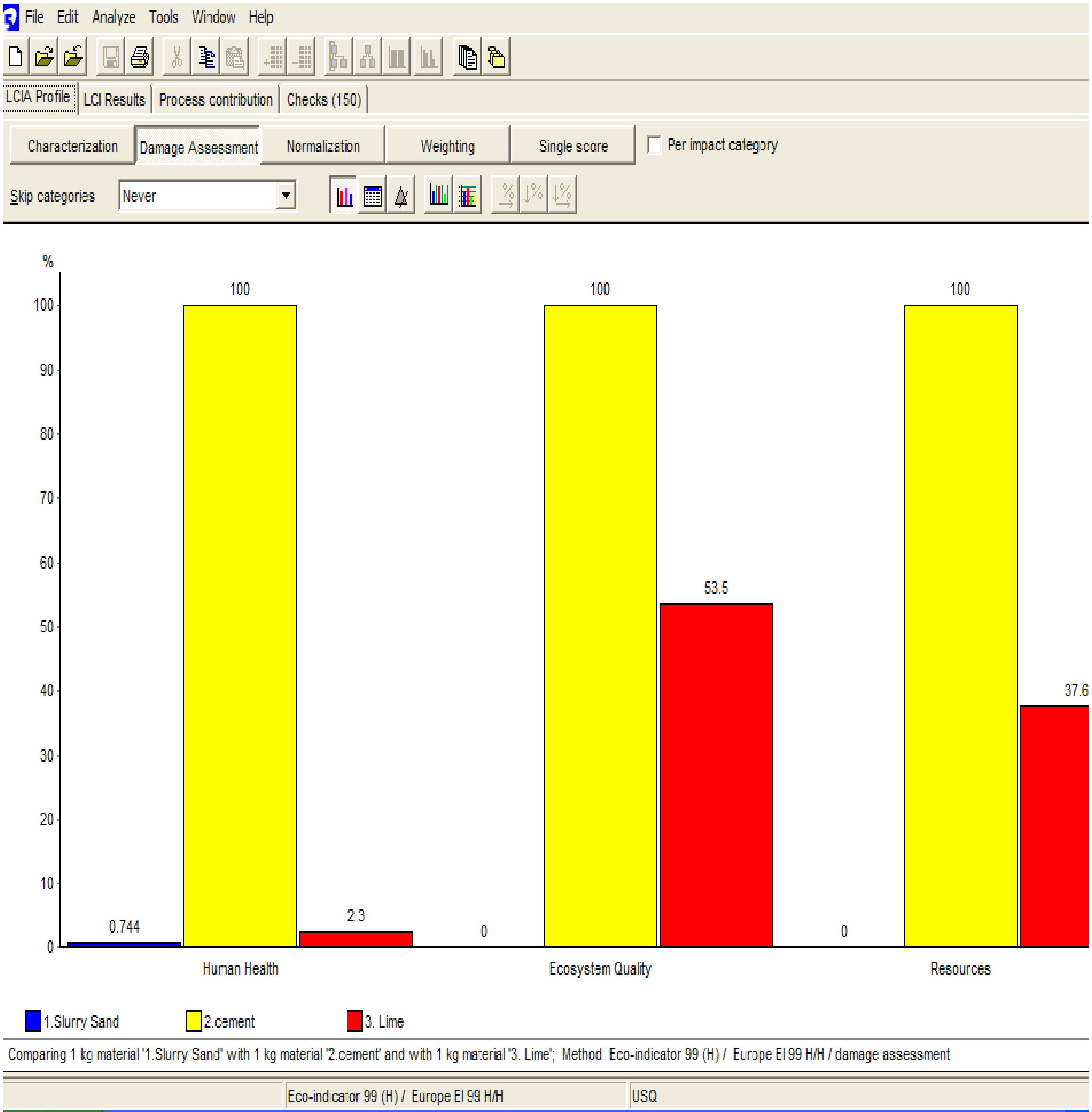


Figure 5.2: Damage assessment output for Cement, lime and slurry sand.

Damage assessment

Figure 5.2 shows that cement caused maximum environmental impact on human health and ecosystem quality. This is due to the clinker process of cement and the fossil fuel used for transportation.

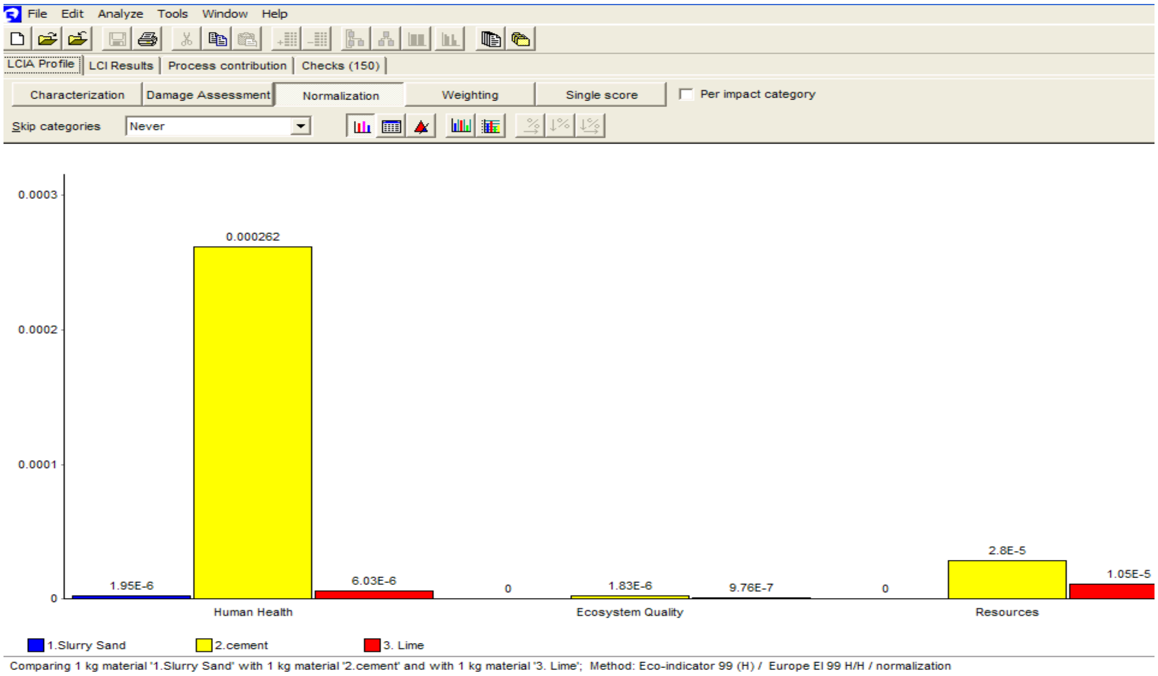


Figure 5.3: Normalization output for Cement, lime and slurry sand.

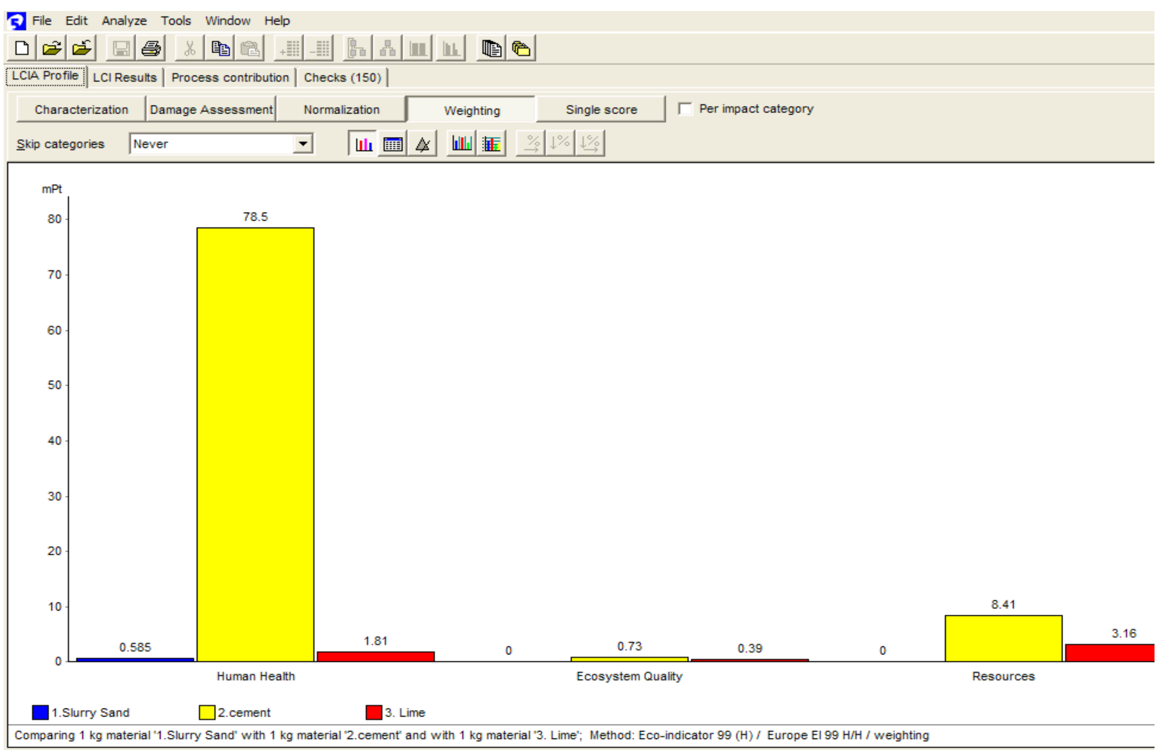


Figure 5.4: Weighting output for Cement, lime and slurry sand.

Normalization and Weighting

Figure 5.3 and figure 5.4 are showing the same result for the materials. The results indicated that cement is causing the most severe damage to human health.

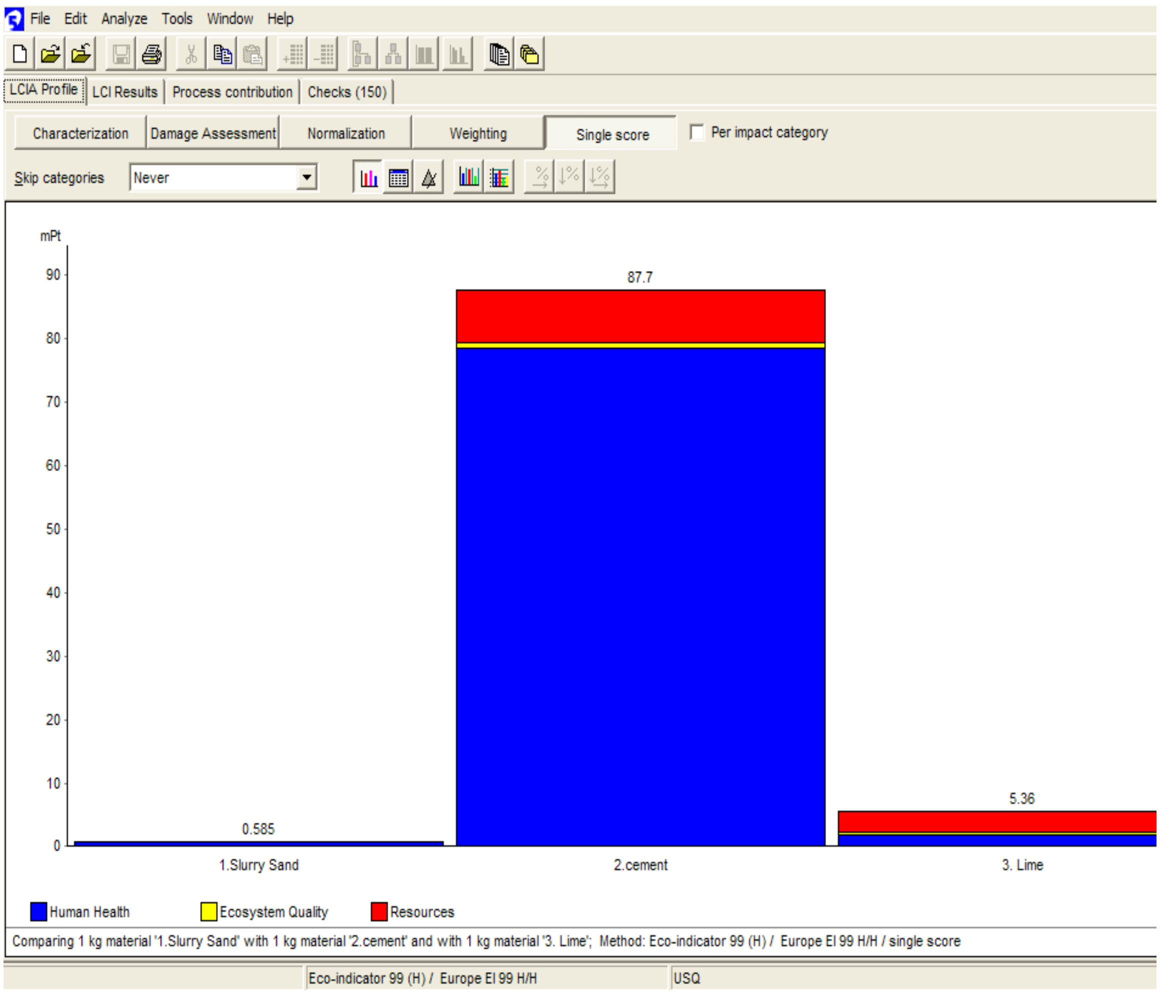


Figure 5.5: Single score output for Cement, lime and slurry sand.

Single score

The environmental impacts are created by cement, which caused the greatest impacts to human health, resources and follow by ecosystem quality.

5.3 LCAI result 2- Manufacturing process of CSR ALC block.

5.3.1 Process 1 – Ball mill

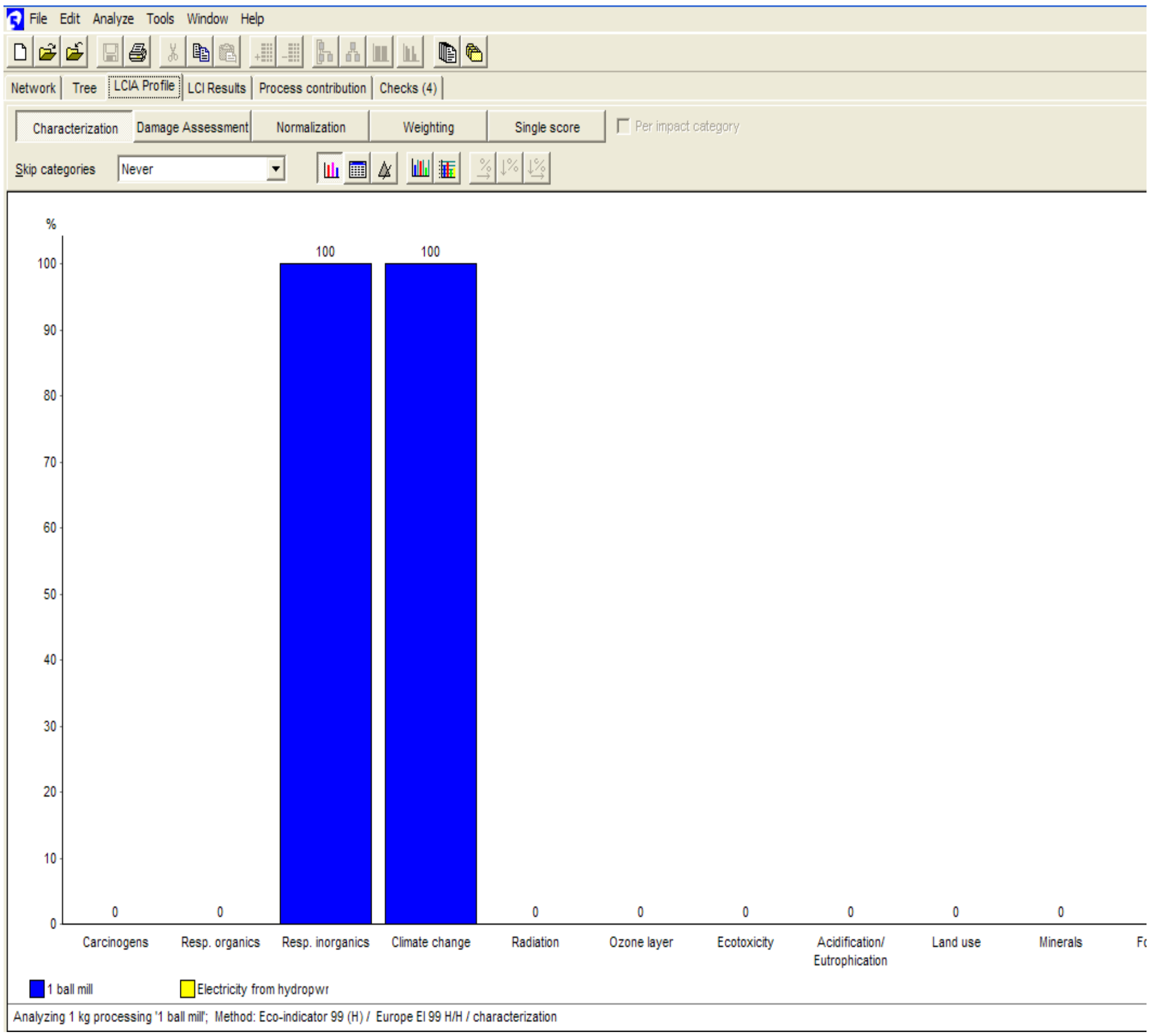


Figure 5.6: Characterization output for Ball mill.

Characterization

Ball mill is the first manufacturing process. Raw materials such as sand and gypsum are added during the process. In this process, emission to air will be the CO2 and dust. Thus, this process will lead to Resp. inorganic and climate change.

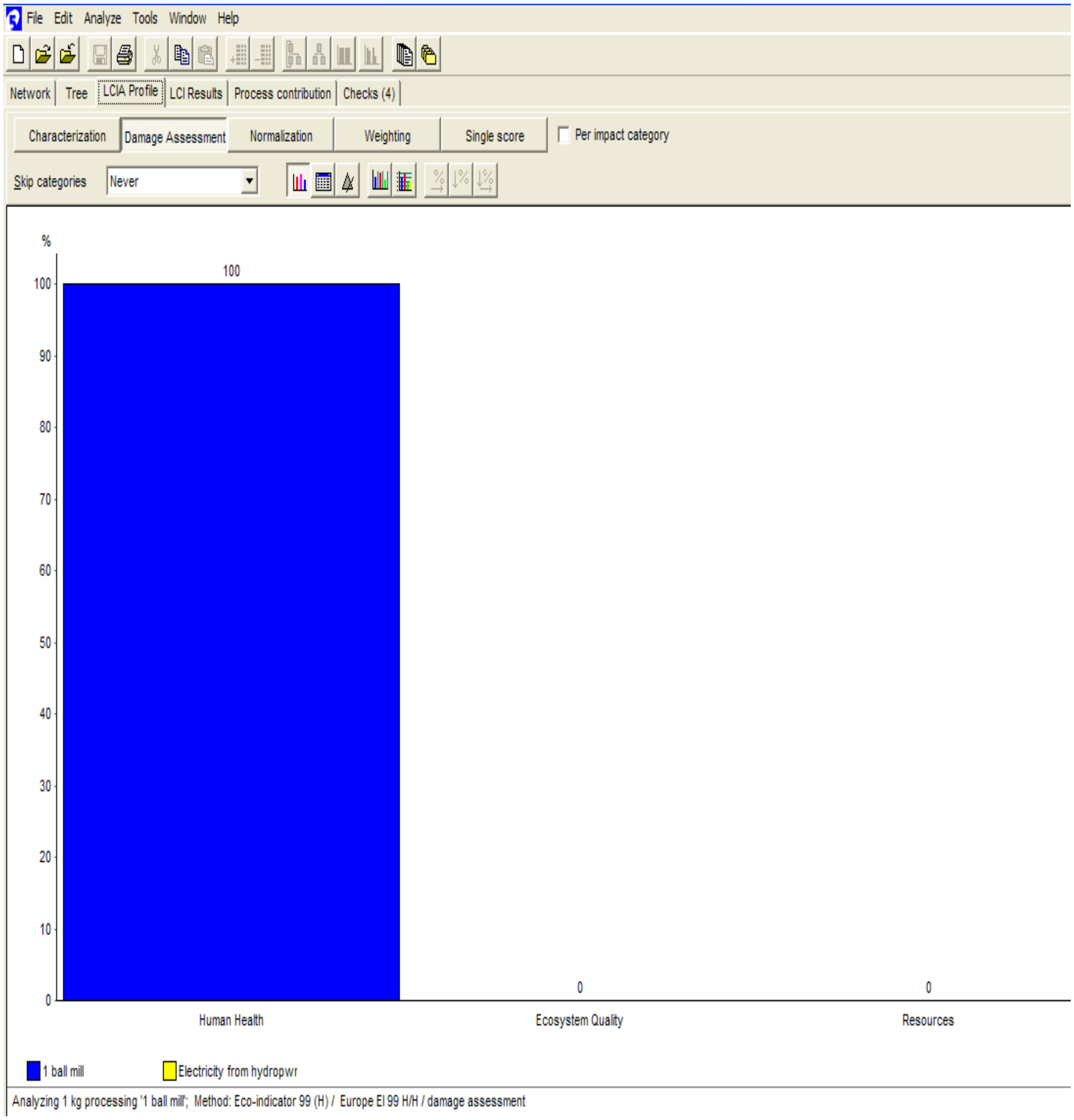


Figure 5.7: Damage Assessment output for Ball mill.

Damage assessment

The Damage Assessment clearly shows that Ball mill process did not contribute any impacts on ecosystem quality and resources. This is because no fossil fuel or transportations are needed during the process.

5.3.2 Process 2 – MIXING / BATCHING

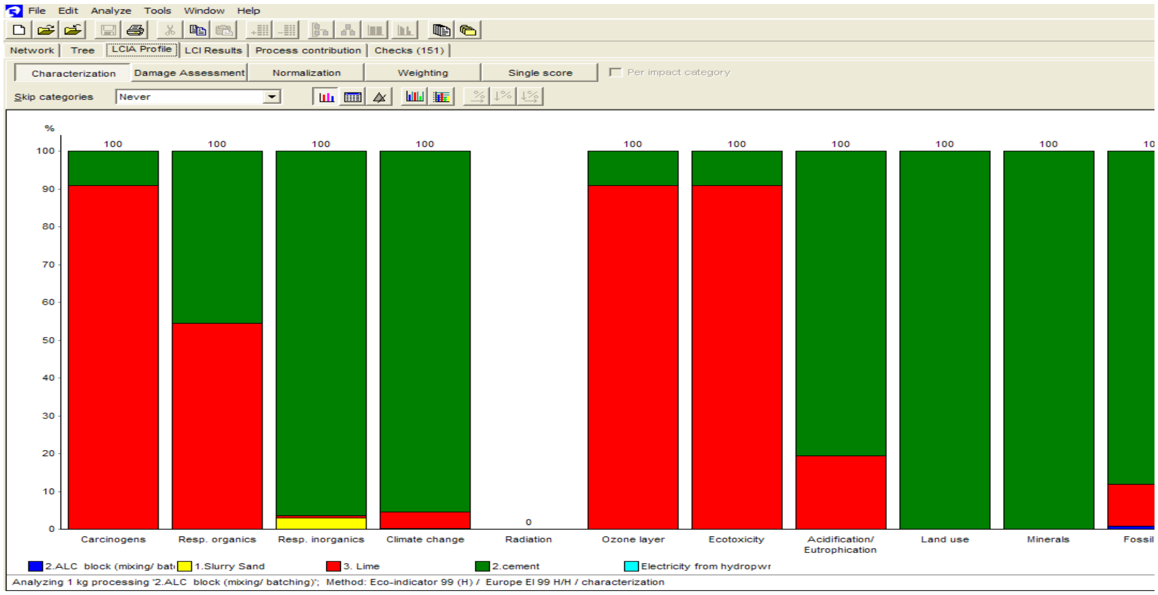


Figure 5.8: Characterization output for Mixing.

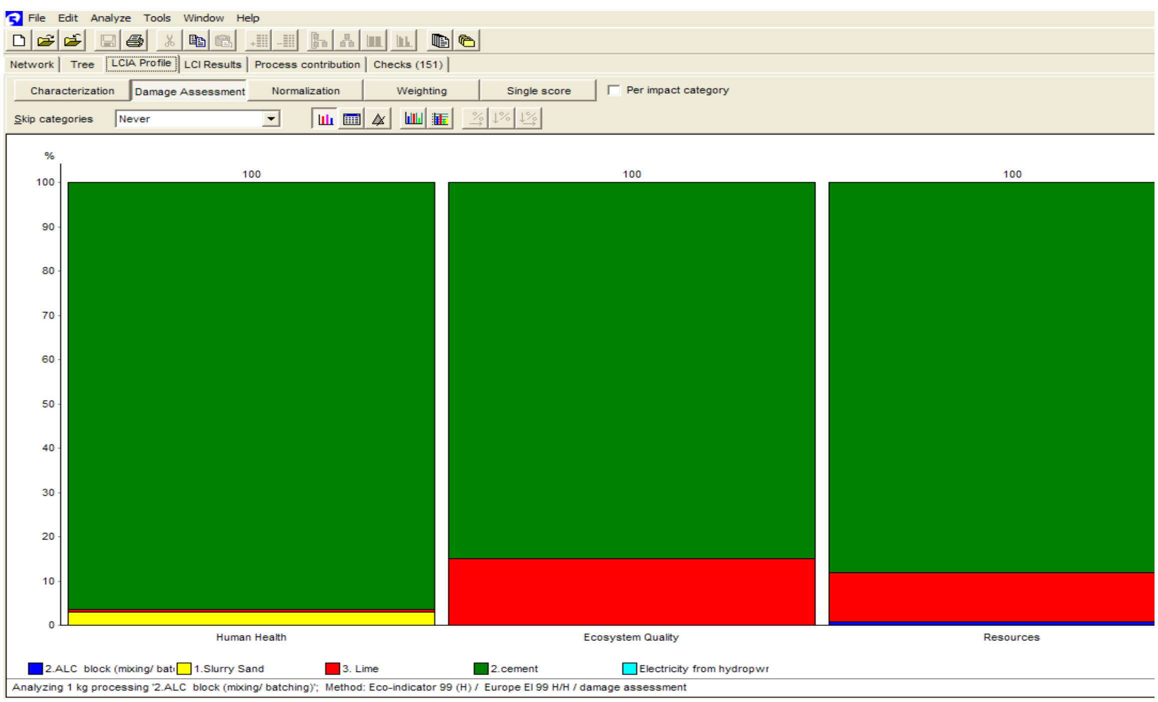


Figure 5.9: Damage Assessment output for Mixing.

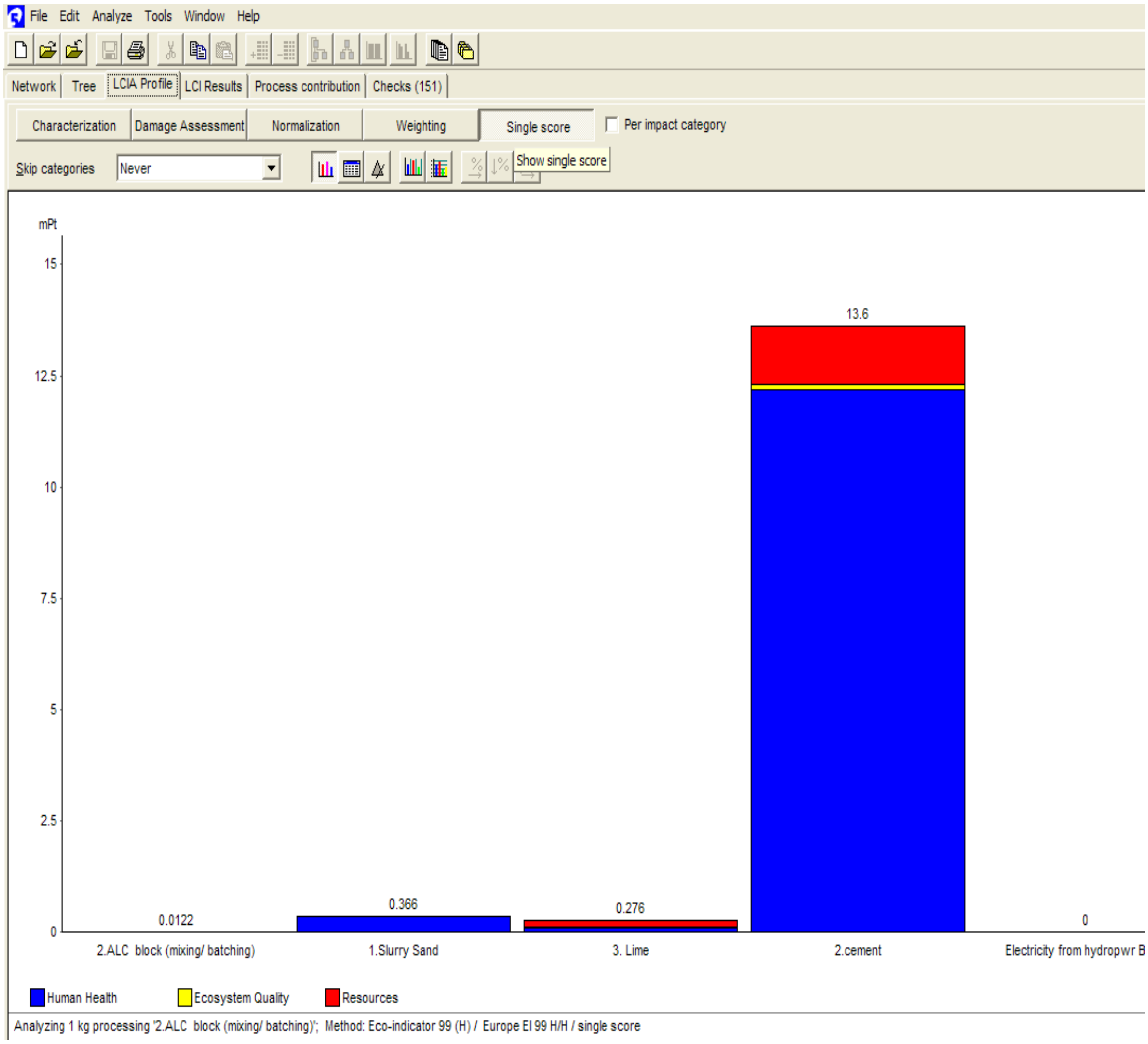


Figure 5.10: Single score output for Mixing.

Comments:

The results from figure 5.8 to figure 5.10 are very similar to the results of comparing the raw materials. This is because the raw materials are used during mixing process. Besides that, electricity is also used during the process but it did not affect the result of Life cycle impact assessment.

5.3.3 Process 3 – CUTTING

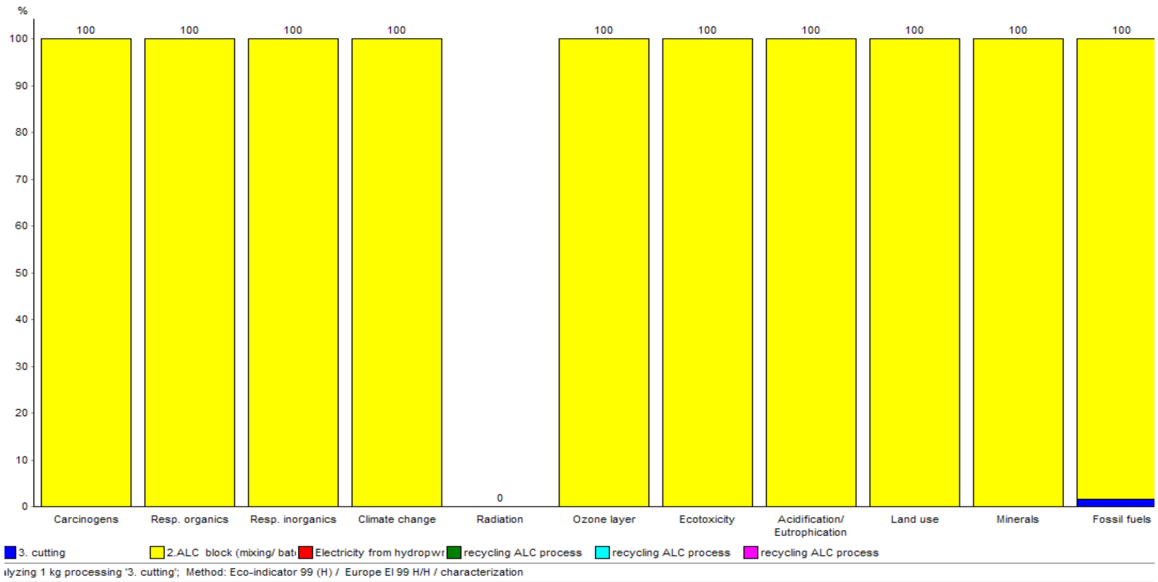


Figure 5.11: Characterization output for Cutting.

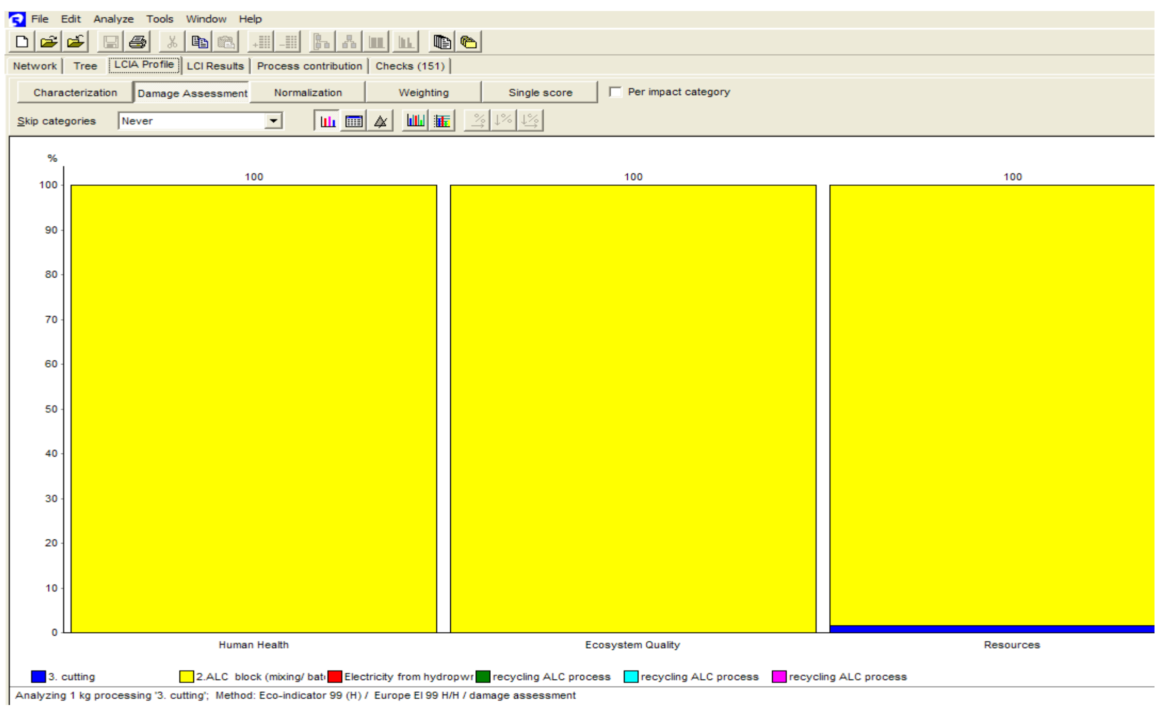


Figure 5.12: Damage Assessment output for Cutting.

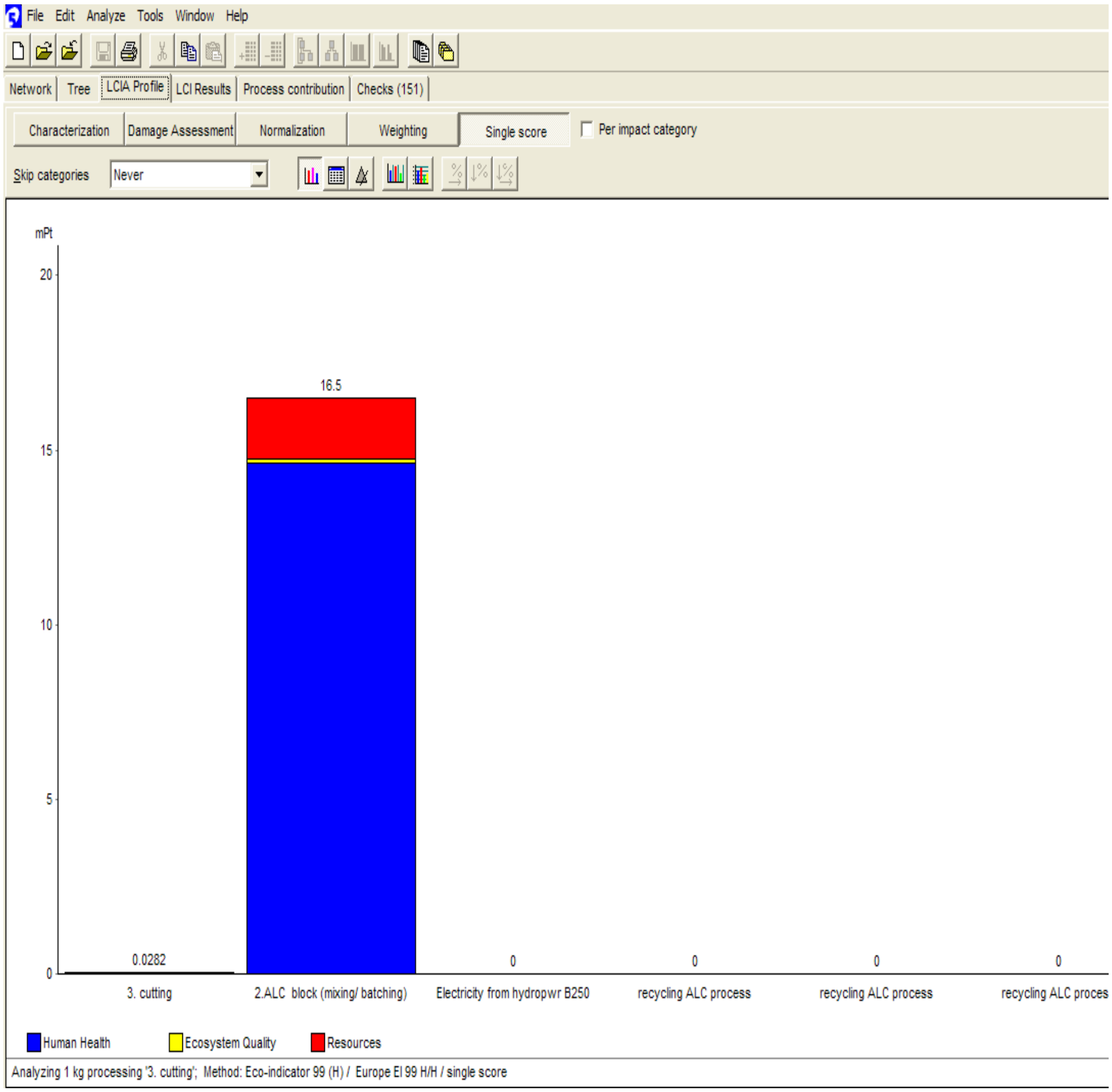


Figure 5.13: Single score output for Cutting.

Comments:

The mould is transferred to the cutting machine. The Machine will automatically cut the mould into the required size. In this process, electricity and some of the natural gas will be used. Hence, the impacts are not much on LCIA results. Cutting only contributes small part in fossil fuels due to transportation. Damage to resources is due the gas consumption during the process and this is shown in damage assessment and single score.

5.3.3 Process 4 – AUTOCLAVING

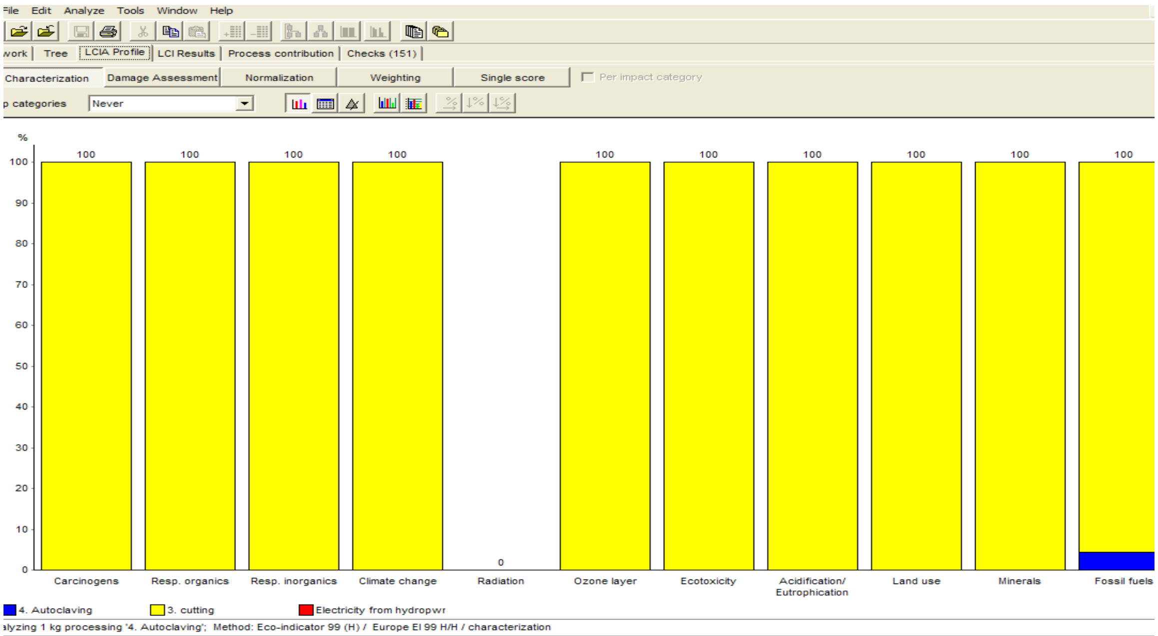


Figure 5.14: Characterization output for Autoclaving.

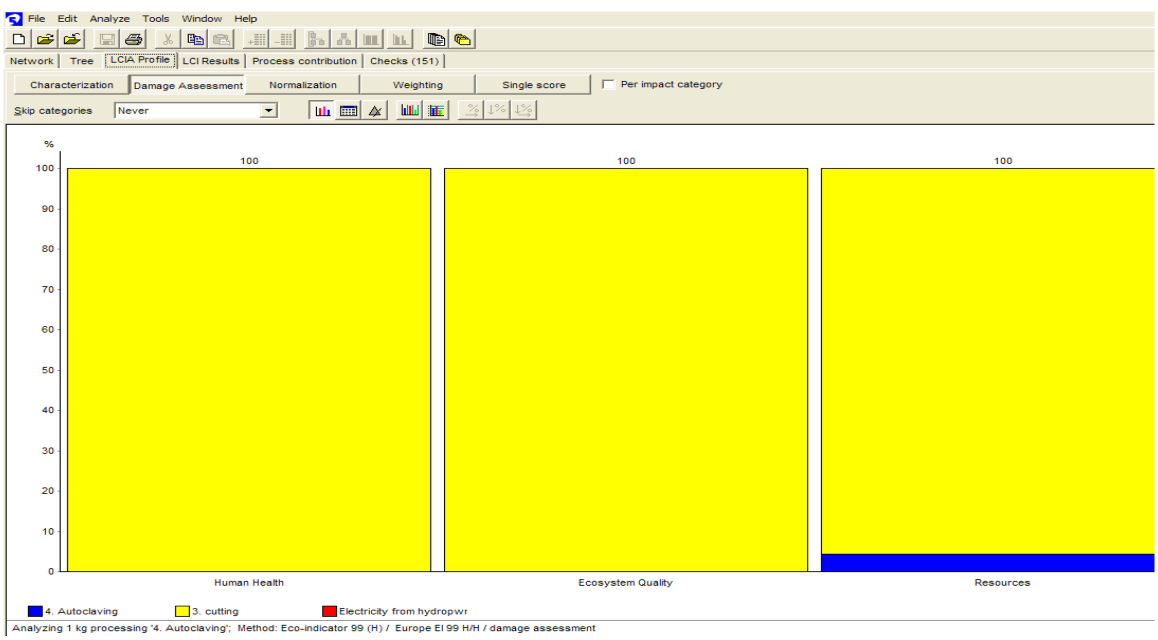


Figure 5.15: Damage Assessment output for Autoclaving.

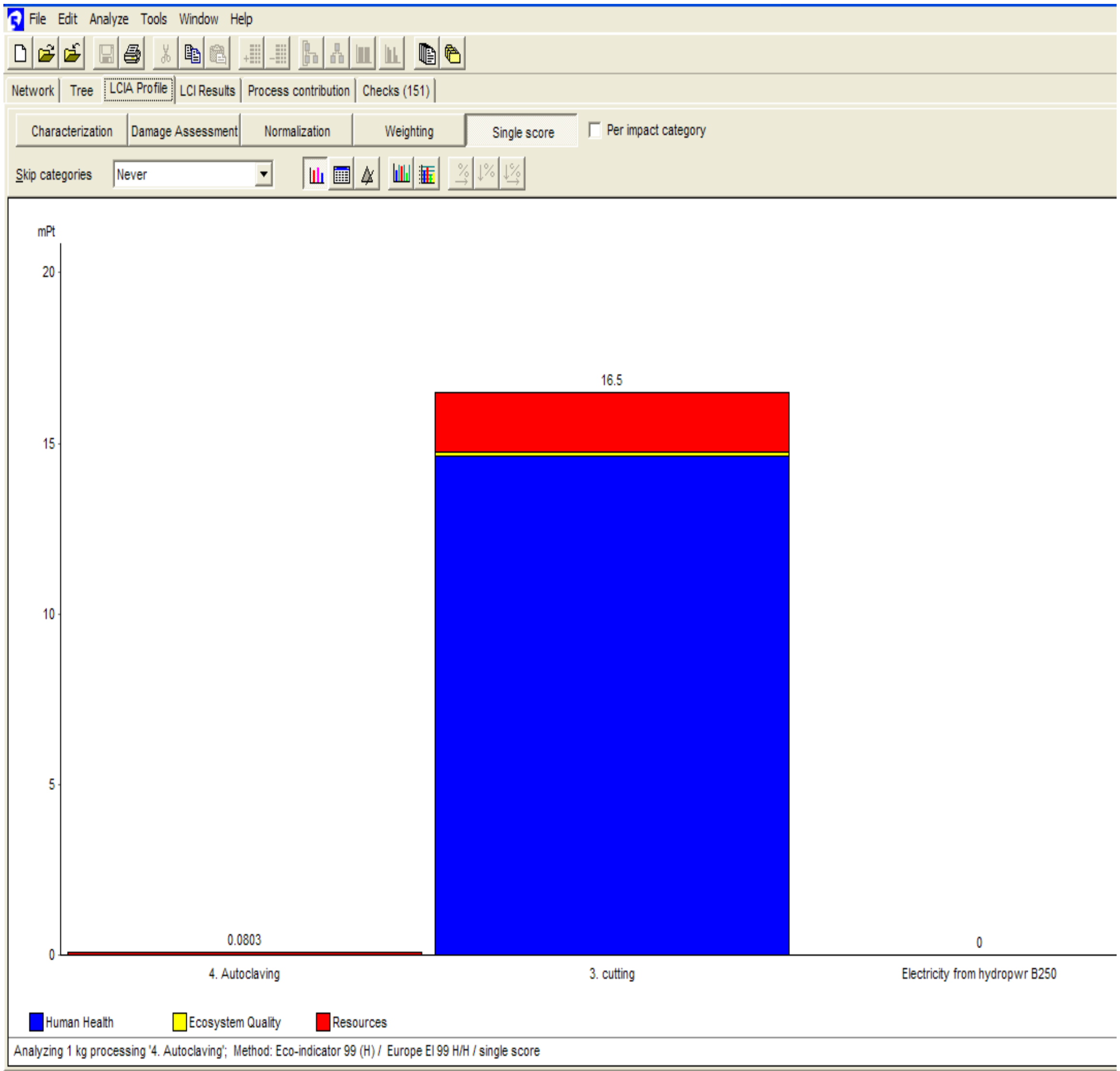


Figure 5.16: Damage Assessment output for Autoclaving.

Comments:

The results for cutting process and the autoclaving are very similar. These are shown in figure 5.14, 5.15 and 5.16. This is due to the same inputs from natural and technosphere are used in the process of cutting and autoclaving. As a conclusion, the LCAI results will be increased due to electricity consumption.

CHAPTER 6

Interpretation

6.1 Introduction

As mentioned in chapter two, interpretation is the last phase of life cycle assessment methodology. In this phase, the following steps are needed to be conducted:

iv. *Identification* of the most important results of the Inventory Analysis and of the Impact Assessment.

v. *Evaluation* of the study's outcomes, consisting of a number of the following routines: completeness check, sensitivity analysis, uncertainty analysis and consistency check.

vi. *Conclusions, recommendations and reporting,* including a definition of the final outcome such as:

- A comparison with the original goal of the study
- The drawing up of recommendations
- Final reporting of the results

The results of the Interpretation may lead to a new iteration round of the study, including a possible adjustment of the original goal. (Jacqueline Aloisi de Larderel, 2003)

6.1 Inventory analysis

6.1.1 Electricity Distribution

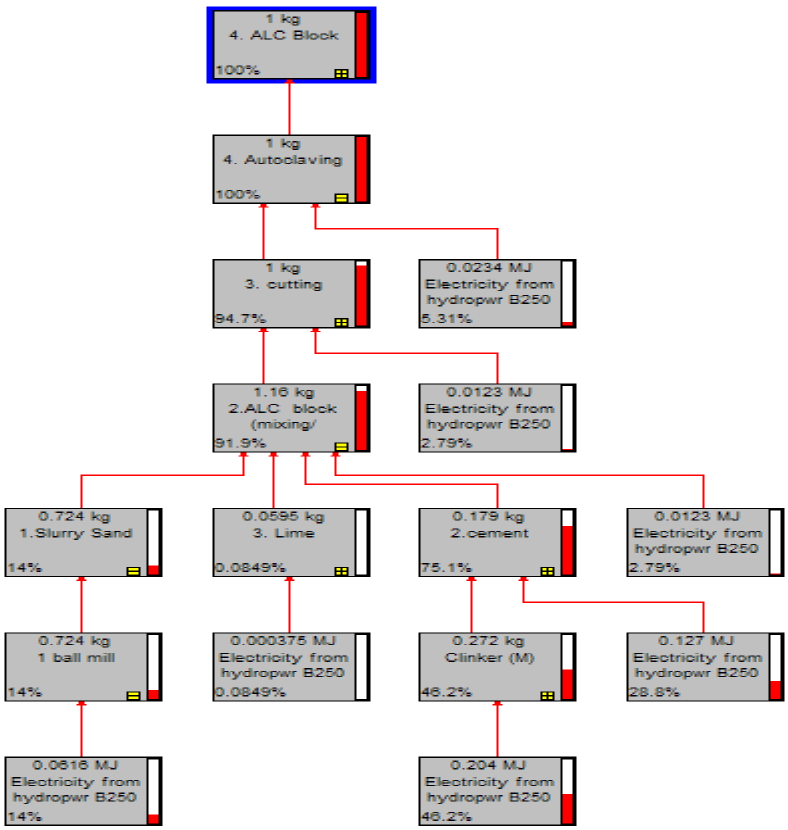


Figure 6.1: Tree's analysis output for electricity distribution of the overall manufacturing process

Name	Electricity Distribution (%)
Ballmill	14
Lime	0.0849
Clinker	46.2
Cement	28.8
Mixing	2.79
Cutting	2.79
Autoclaving	5.31

Table 6.1: Electricity consumption for the total process

6.1.2 Damage to human health

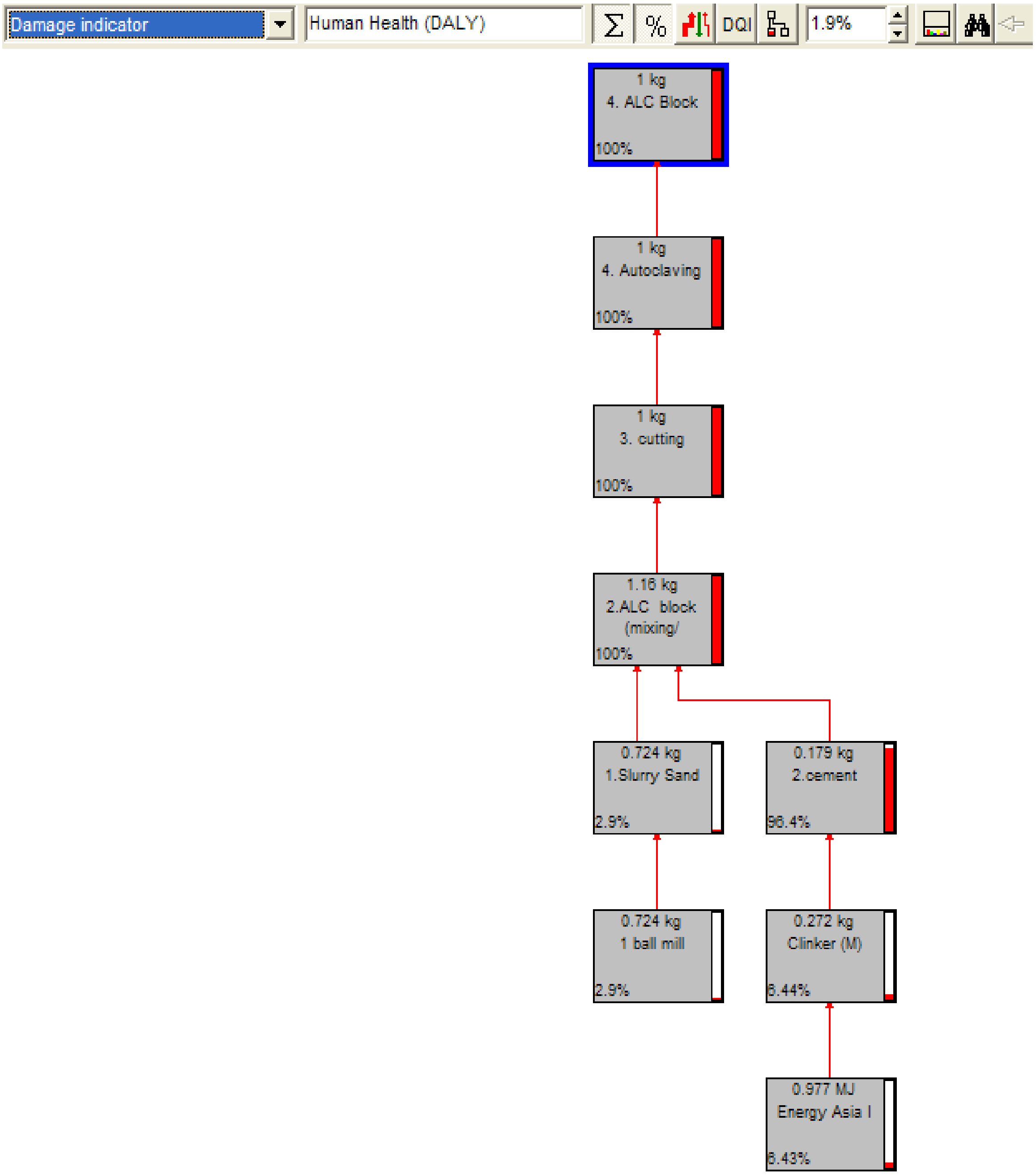


Figure 6.2: Tree's analysis output for human health

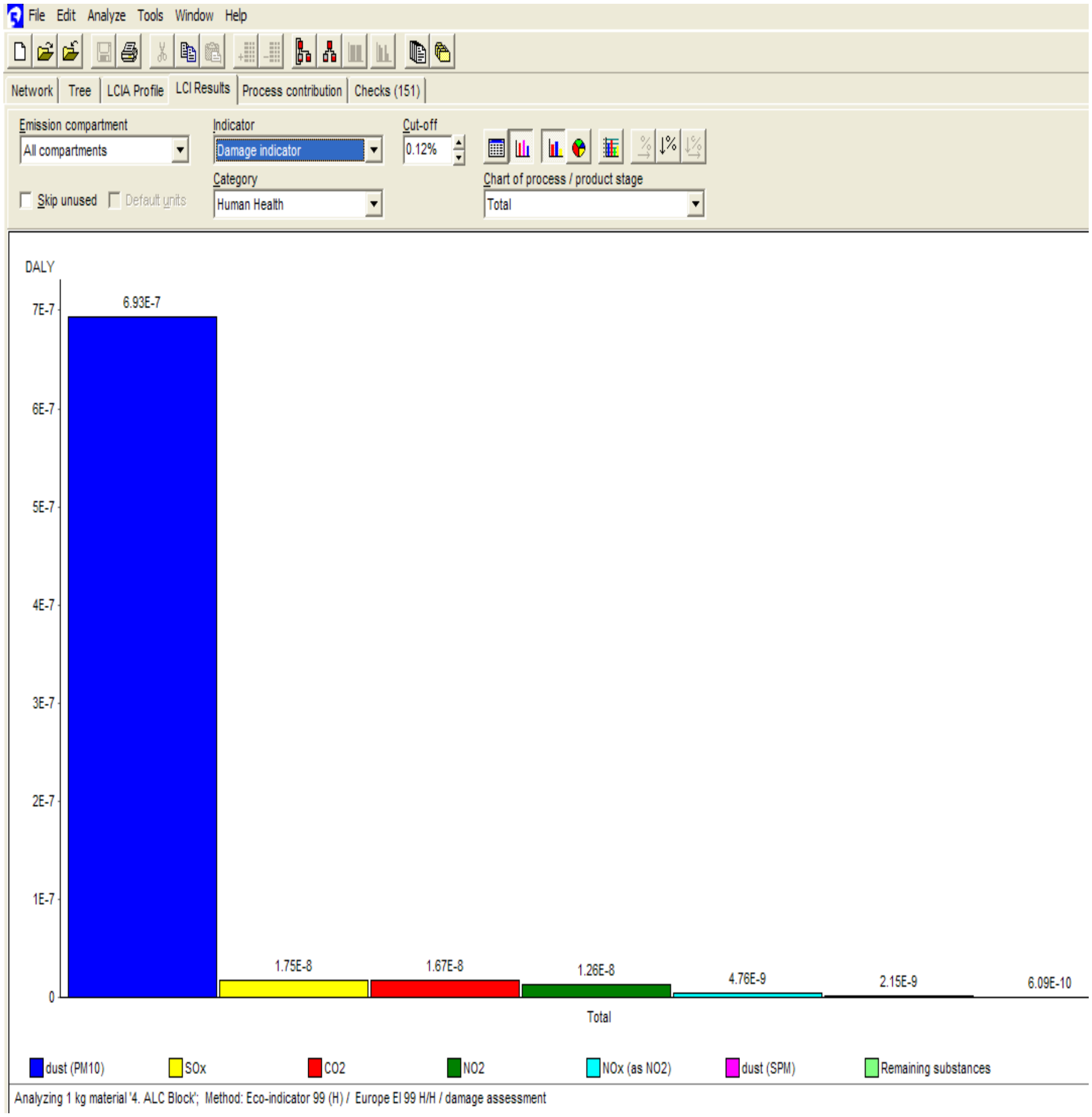


Figure 6.3: Damage indicator to Human health

Comments:

The major contributor for the human health in the CSR ALC manufacturing process is the cement with 96.4% as shown in figure 6.2. Figure 6.3 shows that the dust caused the most damage to the human health.

6.1.3 Damage indicator to Ecosystem Quality

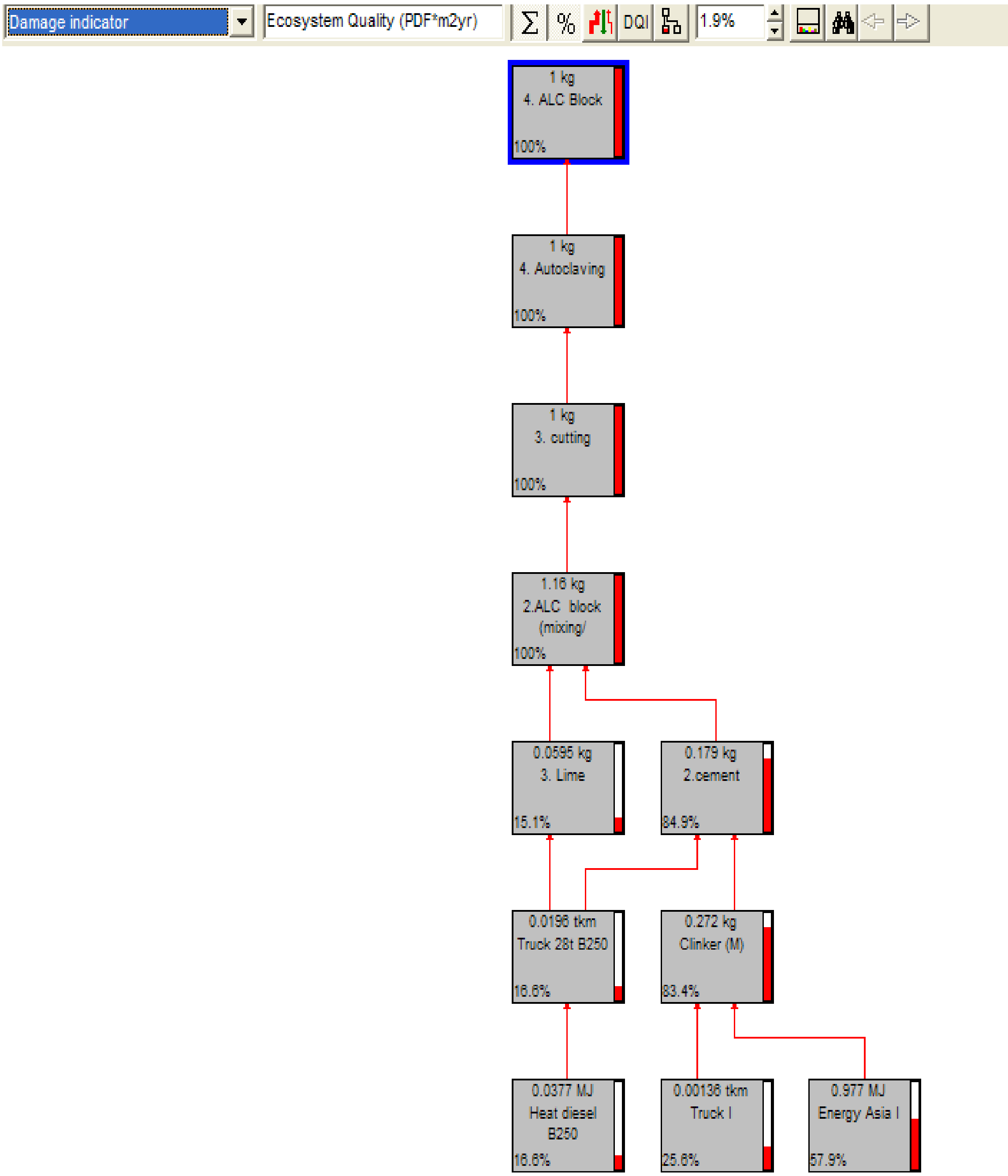


Figure 6.4: Tree's analysis output for ecosystem quality

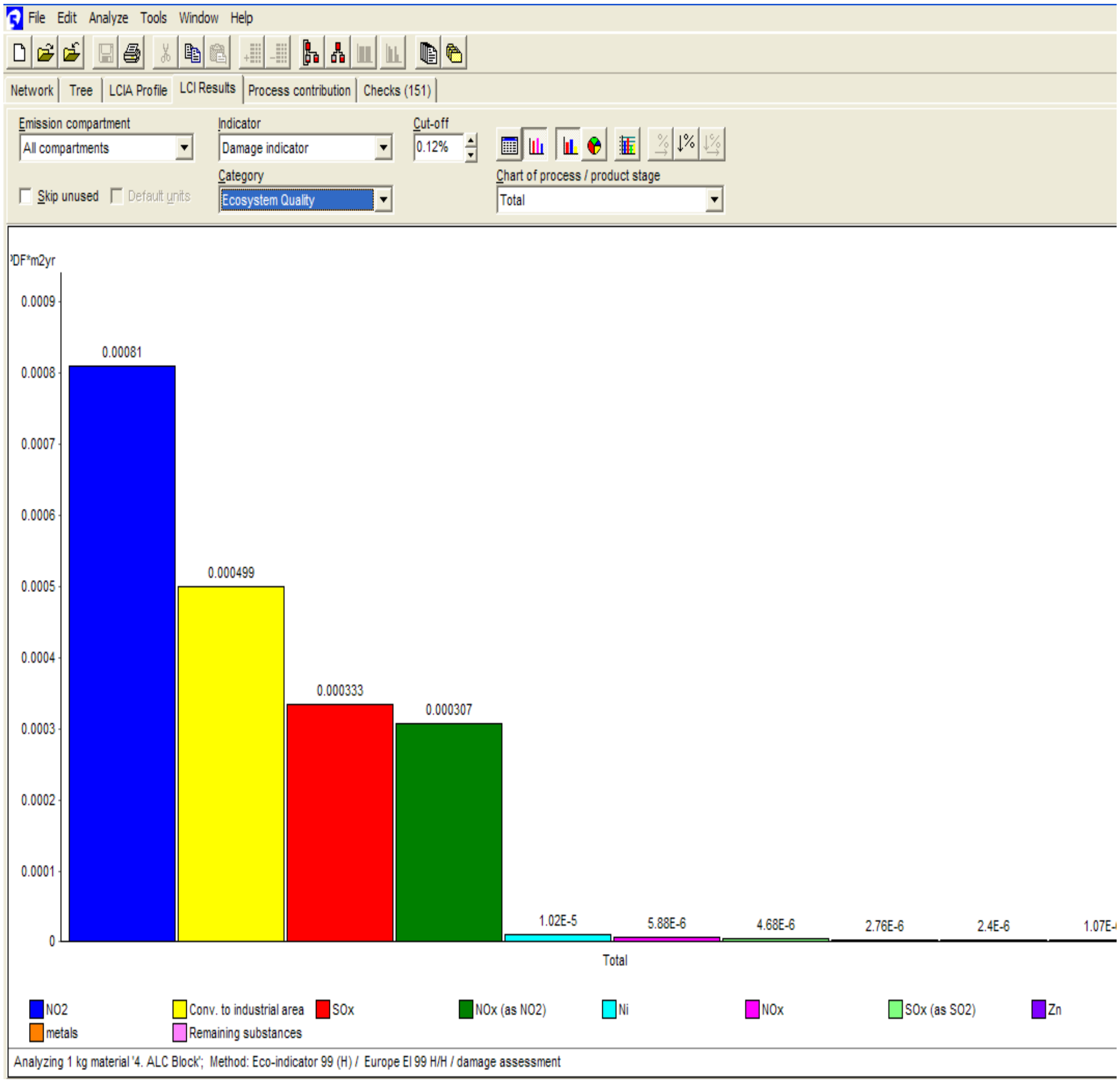


Figure 6.5: Damage indicator to Ecosystem quality

Comments:

The used of energy (57.9%), truck (25.6%) and diesel (16.6%) are the major contributors for the damage to ecosystem quality. Damage to ecosystem is caused by the NO2, Conv. to industrial area, SOx and NOx.

6.1.4 Damage indicator to Resources

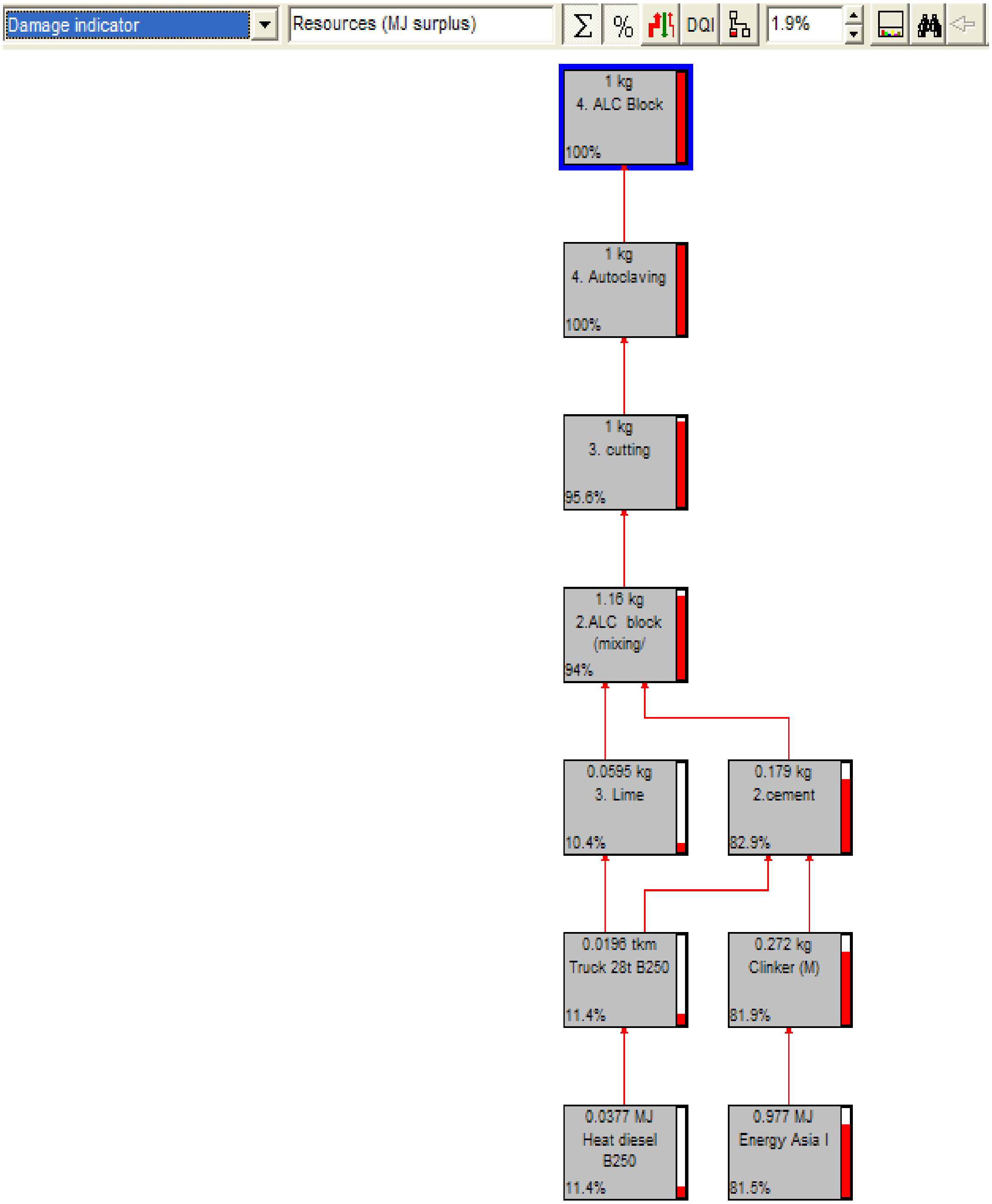


Figure 6.6: Tree's analysis output for Resources

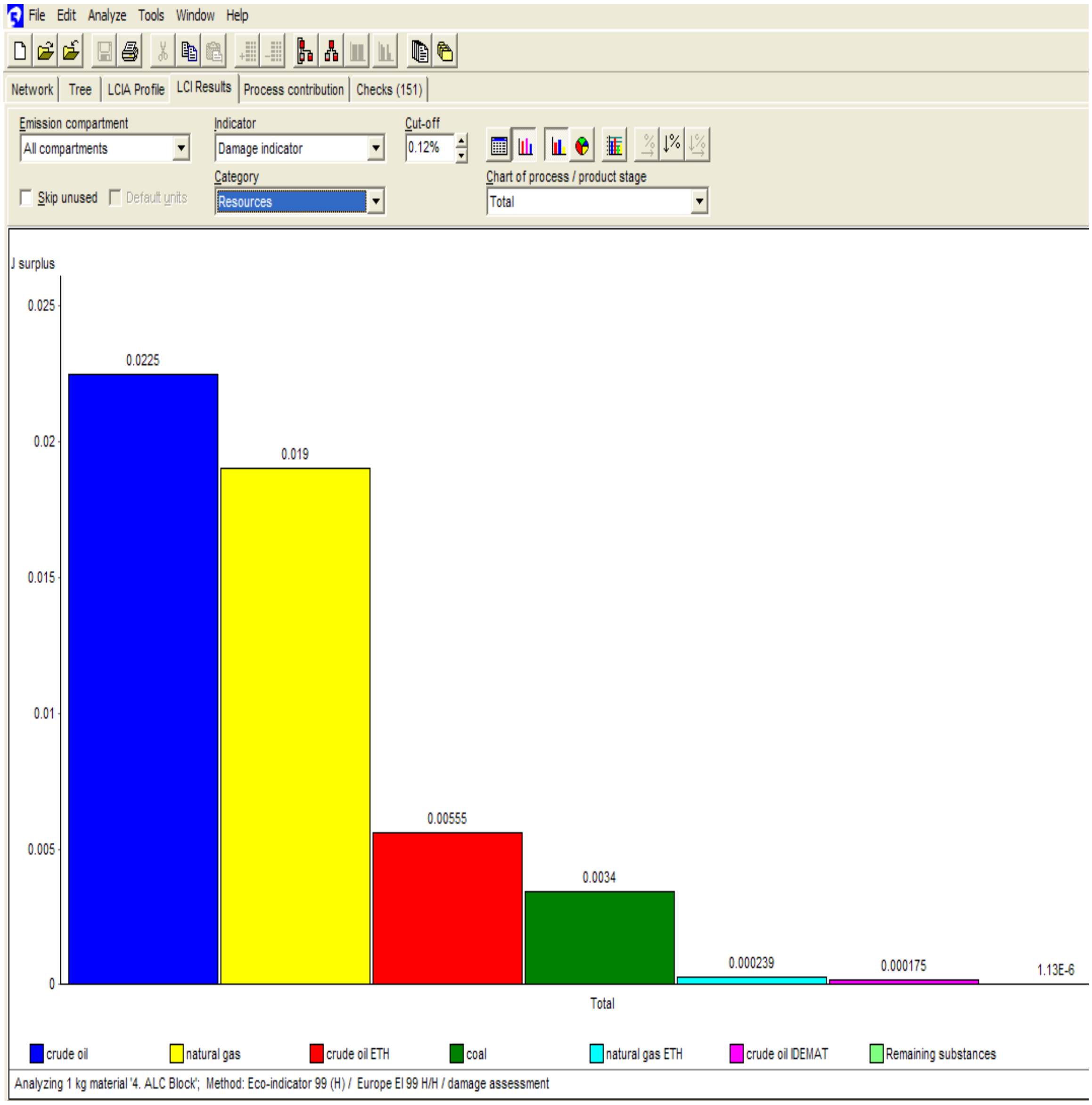


Figure 6.7: Damage indicator to Resources

Comments:

In figure 6.6, the energy with 81.5% is used during the manufacturing process, which is the major contributor damage to resources. Figure 6.7 shows that crude oil and natural gas are largely used during the process and it is the main problem to cause damage to resources.

6.3 Sensitivity analysis

CSR ALC block is still a new technology product today. So, no previous research of life cycle assessment on this product is carried out before. Now, CSR block is comparing with concrete block as shown in figure 6.8. The life cycle assessment of concrete block is obtained from the SimaPro database.

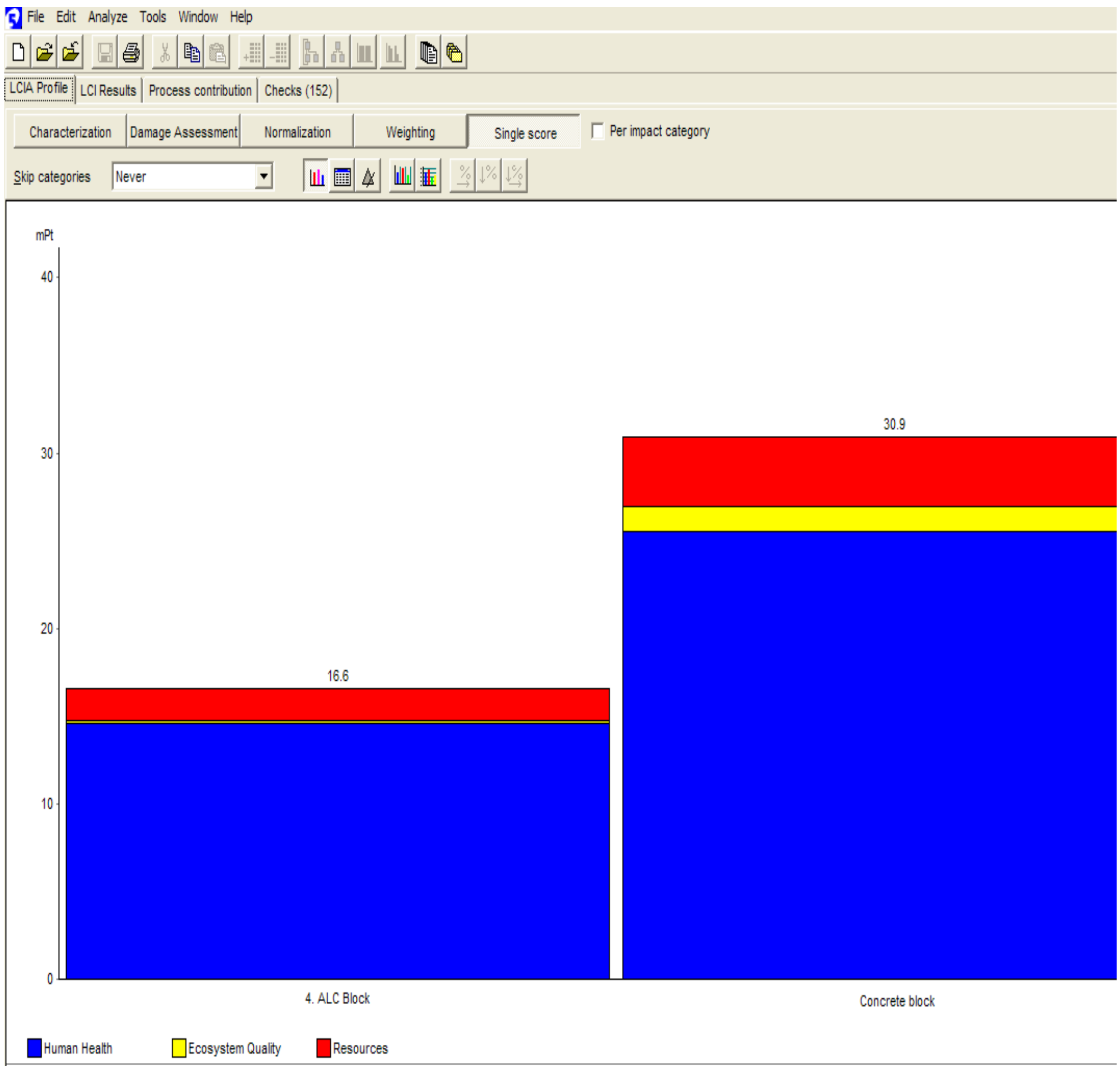


Figure 6.8: Single score output for CSR block Vs concrete block

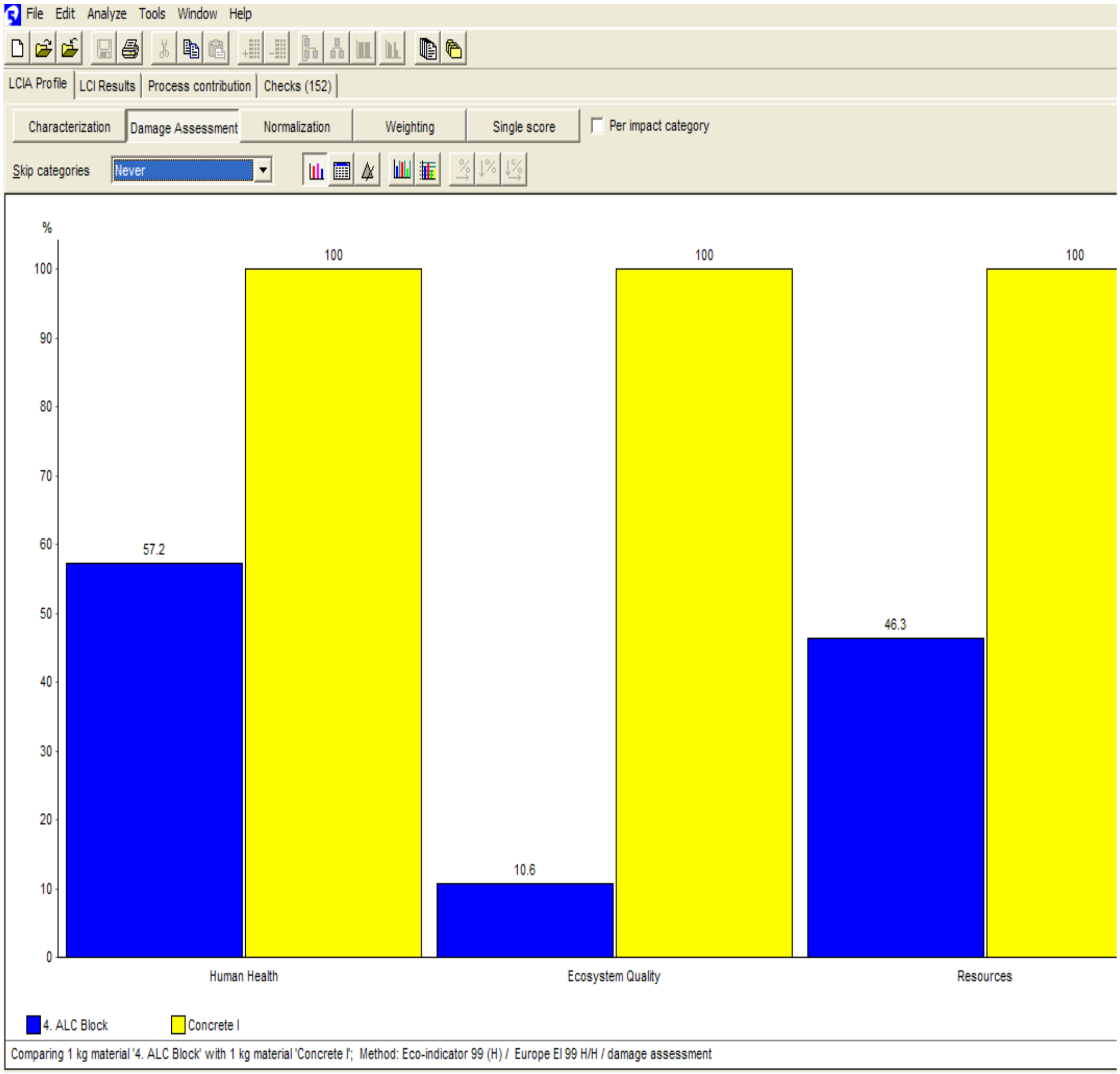


Figure 6.9: Damage Assessment output for CSR block Vs concrete block

Comments

The result from figure 6.9 clearly shows that CSR ALC block is an environmental friendly product compare to concrete block. CSR block is half of the total damage to human health and resources compare to concrete block. For ecosystem quality, CSR block only contribute 10.6% over the concrete block.

6.4 Conclusions

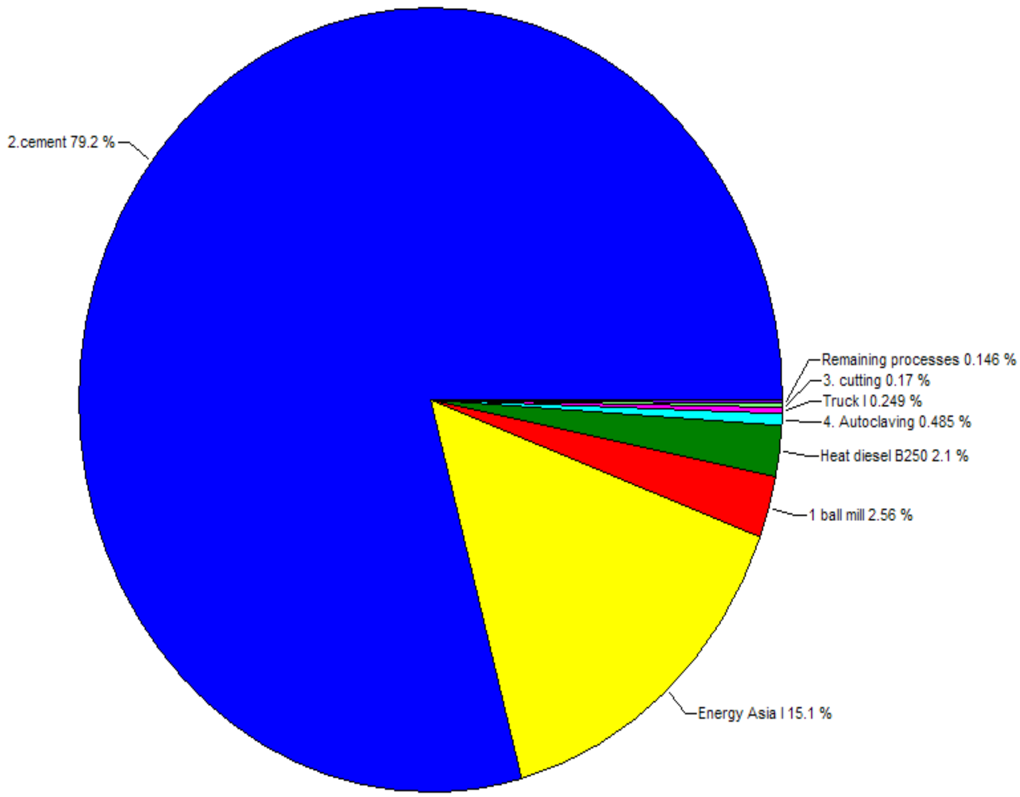


Figure 6.10: Single score output for total process contribution

The project aim to minimise the environmental impacts caused by CSR block even though the inventory result has proved that CSR block is an environmental friendly product. The figure above can be used as conclusion of CSR block analysis. The most serious impacts on environment are caused by cement, which is up to 79.2 % of the total impacts. The energy of electricity consumption (15.1%) is second contribution of the total process. Ballmill and heat diesel are contributed to the total process with 2.56% and 2.1 % respectively. The least environmental impact caused by the product or process in each stage its life cycle is the Autoclaving process (0.485%), truck (0.249%), Cutting process (0.17%) and the remaining process is 0.146%.

The objectives of this project have been met as follows:

- Literature review of previous Life Cycle Assessment related to building and construction industries have been conducted.
- Background information of CSR building material is included in this research project.
- A comprehensive study of the Life Cycle Assessment methodology and the software has also been carried out.
- Able to obtain the data information from the CSR building material company.
- Managed to set up a LCA model for compiling and accessing environmental for the CSR ALC block.
- Carried out inventory analysis.
- The results are compared with other studies to make sure it is functioning.
- Carried out sensitivity analysis
- Comparing the CSR block with concrete block.
- Recommendation for future improvement.

6.4 Recommendations

79.2 % of the total impacts on environment are caused by cement. Besides that, the clinker process also caused 83.4 % of the total damage to ecosystem quality. Therefore, action must be taken to reduce the usage of cement. This can be achieved by using environment friendly material to replace cement. Besides that, to adjust the volume of cement in the process is the first step to reduce the environmental impacts of CSR ALC block.

Electricity consumption (15.1%) is second contribution of the total process. Solar system may be used to save the electricity consumption. The limitation of solar system is the system only can provide electricity for small voltage only. Hopefully solar electricity can lower the environmental impacts.

CSR building material company may choose to import the raw materials such as sand, lime and cement form the nearest dealer. This can lower the fuel consumption and therefore lower the impact due to the reduced of travel distance.

At the current stage, the waste product will be used for land fill. Further research is required to set up a machine which can recycle the waste product. Thus, this can reduce the environmental impacts due to the landfill.

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APPENDIX A

Project specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project
Project Specification

FOR:	**WEI KIAN, LAY**
TOPIC:	**LIFE Cycle Assessment of CSR Autoclaves lightweight concrete (ALC) Production in Malaysia.**
SUPERVISOR:	**Dr. Guangnan Chen**
ENROLMENT:	**ENG4111-S1, D, 2007;** **ENG4112-S2, D, 2007**
PROJECT AIM:	The project seeks to investigate the products of CSR ALC as well as to produce an outline of Life cycle assessment Methodology and set up a LCA model.
SPONSORSHIP:	CSR BUILDING MATERIALS (M) SDN BHD
Programme:	**Issue A, 2007**

1. Research previous Life Cycle Assessment studies undertaken on building and construction materials production Activities.

2. To study the potential of adopting the LCA methods to Malaysia's building and construction industry.

3. Research information on the Life Cycle Assessment methodology and the software package used in its undertaking.

4. Research the background information relating to the Autoclaved lightweight concrete.

5. Define the goal and scope of the Life Cycle Assessment of CSR ALC manufacturing plant.

6. Collect data needed for the Life Cycle Assessment from the CSR company plant.

7. Use LCA software to determine and compare the environmental impacts of the CSR ALC product.

8. Set up a basic LCA model to confirm the feasibility of the method, and to characterize the environmental impact of CSR ALC manufacturing process.

As time permits:

9. Implement a feedback for the CSR ALC product in order to provide a scientific basis for the optimum use of natural resources. Finally design the optimum selection of manufacturing methods for CSR ALC Company

10. Compare the CSR ALC product with cement sand brick in construction industry.

AGREED:

_______________(student)   _______________(Supervisor)

wei kian, Lay, Date: ___/___/___   Dr.Guangnan,Chen,Date:___/___/__