Polish Packaging Research and Development Centre

COBRO

WP5

Position paper on the scope and system boundaries of Life Cycle Assessment to be used in the project.

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INTRODUCTION

Activities of environmental organisations, higher level of population environmental awareness, increasing legal requirements and last but not least the development of knowledge concerning impacts of many products on the environment have led to the creation of various methods of evaluating the impact of products and services on our natural environment. An example of such successfully industrially implemented method, that is directed at reducing the negative impacts on the environment, is the LCA (*Life Cycle Assessment*).

Although it has its roots in the beginning of 1970s Life Cycle Assessment methodology has been mostly established in late 1980s. This technique allows to track life cycle of the product since its production up to the stage of recovery or disposal of waste and seems to be a natural extension of both the strategy for waste management and environmental management systems.

Current waste management strategy assumes strictly defined waste management activities hierarchy, which in most simple terms is:

- waste prevention and
- minimization of its amount

Avoidance of waste production must be started at the stage of product design and production processes. Quantity of used mineral resources, materials, energy, amount of waste generated in the production process should be estimated and the way of recovery or disposal of the final product after its consumption has to be predicted. All those activities have led to the development of inputs-outputs analysis, also known as circulation of material analysis, ecological profile analysis, eco balance or cradle to grave analysis.

In the scope of life cycle assessment (LCA) one has to analyse the environmental hazards associated with the product throughout its life from cradle to grave. The LCA methodology can be used for the assessment of an actual product, the entire production process and

services. LCA allows the assessment of aspects and environmental impacts resulting from all stages of product life, including:

- mining and mineral processing,
- manufacturing,
- distribution,
- transportation,
- use,
- re-use,
- recycling and other recovery methods,
- final disposal of waste.

International Standard Organization defines LCA as a technique of environmental aspects and potential impacts associated with the product assessment, which includes four phases:

- identification of the purpose and the scope of research,
- inventory of inputs and outputs in the product system,
- potential environmental impacts associated with inputs and outputs of the system assessment,
- interpretation of results

LCA relates to complex interactions between a product and the environment. Main categories of environmental impacts require taking into consideration human health, usage of natural resources and the quality of the ecosystem.

LCA method, allows to define the methodology of effective resources management, according to both the environmental and economic aspects. It is therefore a powerful tool in developing ways to reduce consumption of natural resources and energy while maintaining a sufficient supply of goods and services. Additionally LCA analysis can be used to evaluate if used technology is really more environmental friendly than an alternative. Future LCA applications will be integrated with other decision making supporting tools in every situation when environmental issues are important. The availability and scope of information to be

analysed in LCA is still growing, which gives the possibility to extend the LCA on new products and application areas. Also together with the increasing of information level LCA analysis will be more and more precise. However only in few cases LCA analysis can be used as a single factor supporting process of making a decision. Analysis using the LCA method should only be used as one of many tools of extended producer responsibility. This concept can be used by state governments as a strategy which allows to make a transfer of management costs. Using LCA method can lead to implementation of optimal and elimination of unfavourable solutions.

Potential area of further development is an integration of LCA with other environment management methods. Most concepts of environment management miss many indirect environmental aspects, and this can be supplemented by LCA analysis. If we want to develop LCA method as a tool of quantifying of direct and indirect environmental aspects and potential influence exerted in the whole lifecycle of products, some classification of data collection process necessary. Another crucial question concerns the development of agreed methodology of data availability. Both methodologies and data are becoming better documented, which proves, that together with the development of ISO norms according LCA standards, future development of LCA method will be even more satisfying than previously[1],[2].

LCA is one of several techniques of environment management, used to study environmental aspects and potential environmental impacts over the lifetime of the product (i.e. from cradle to grave) – from resources obtained in production process, through using, up to the stage of waste and recovery or disposal.

Every single product has a specific impact on the environment, and the lifetime cycle of most of them is long and complicated. For that reason it is appropriate to try to minimize the environmental impact in all phases of product's life cycle, especially in phases, when this impact is greatest, and take action in the most efficient way[3].

[1] Rebitzer G. et al. ,*Life cycle assessment, Part 1: Framework, goal and scope definition, inventory analysis, and applications*', Environment International 30. **2004** pp. 701-720.

[2] Pennington D.W. et al.*, Life cycle assessment Part 2: Current impact assessment practice*', Environment International 30. **2004** pp. 721-739.

[3] PN-EN ISO 14040:2000, Environmental management -- Life cycle assessment -- Principles and framework

Such assumption should also lead to the product manufacturing, using and disposing costs reduction and an increase of companies competitiveness level. Those aspects are the subject of the implementation of integrated product policy strategy in Poland [4], which should lead to the in the systematic using of product life cycle evaluation methods in the future.

When looking specifically at packaging, its life cycle include the production of feedstock materials, production of packaging materials, production of packaging, packing, packaging usage and disposal scenarios. Figure 1 presents typical packaging life cycle in details:

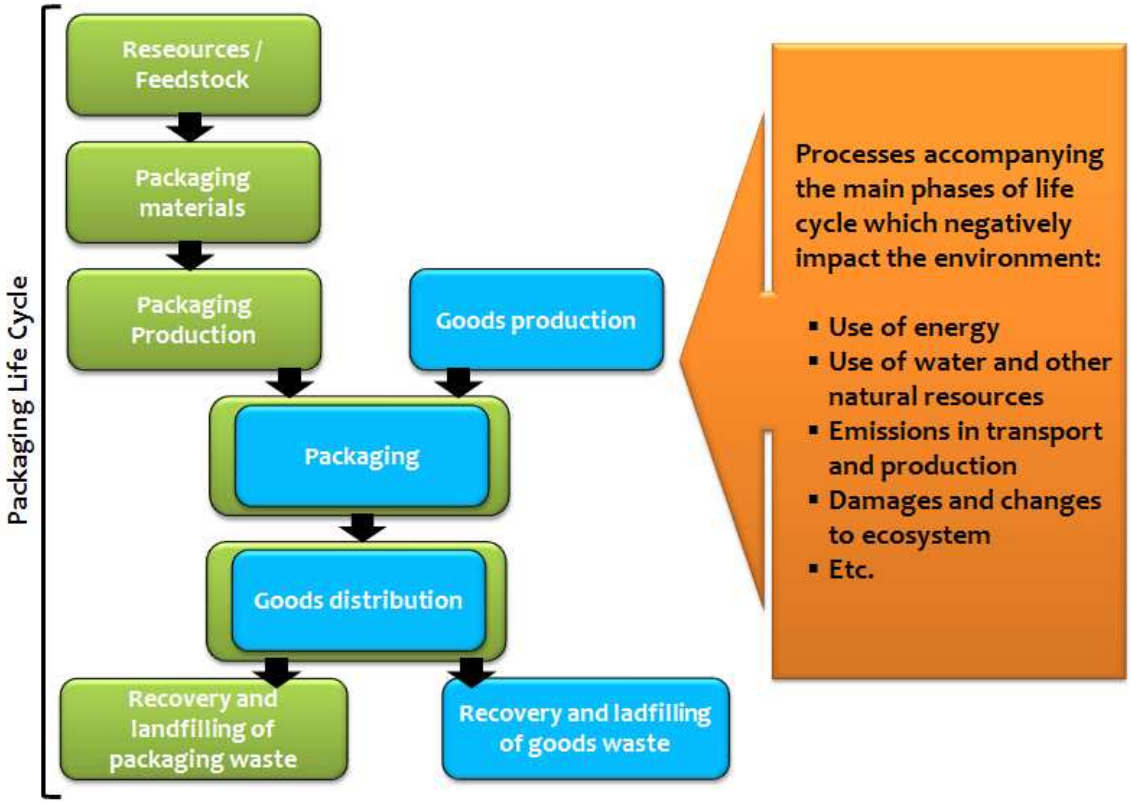

Figure 1. Main phases of packaging life cycle considering stages when the packaging should be seen together with the goods.

It should be emphasized that packaging life cycle includes filling phase (packing) and merchandise trade, which links the packaging with the logistics system of goods distribution

[4] [http://www.mos.gov.pl/sipw/zintegrowana_polityka_produktowa/strategia_ZPP.pdf] Polish Ministry of Environment, February 2005.

(most of the are goods are accompanied by the packaging on some stages of trade)[5]. For that reason LCA for packaging can cause additional difficulties. In LCA packaging should be evaluated as a whole, considering such elements as closures, labels, etc.

LCA can become a tool of comparisons of products and processes or the different products and processes components as a part of sustainable development, which gives new possibilities for industrial environment protection, i.e., understanding of environmental impacts associated with industrial areas activity. The questions of modern industrial development should be answered by green chemistry[6].

[5] CR 13910:2000 Packaging – Report on criteria and methodologies for life cycle analysis of packaging.

[6] Anastas P.T.; Lankey R.L. *‚Life cycle assessment and green chemistry: the in and yang of industrial ecology'*, Green Chemistry 2. **2000** pp. 289-295.

LCA METHOD IN ENVIRONMENTAL ASSESSMENT OF PACKAGING

LCA (Life Cycle Assessment) method, can be used for environmental assessment of a full cycle of a packaging existence[7]. Even though the LCA methodology has been around for over 30 years it is still a relatively novel technique of environmental management. One of its main aims is to include all factors potentially influencing the environment and associated with a specific product, which may be a product, the process of production or its use, as well as service. Currently LCA method has been standardized, and in European Union it is appreciated and recommended tool of environmental projects assessment in all areas of economic and social activities.

European legal system for packaging waste assumes the development and improvement of LCA methods in packaging evaluation and using it can lead to the reduction of negative impact on the environment. It can also be considered to be the basis for the selection of ecologically appropriate solutions.

LCA in packaging is based on an evaluation of packaging according to different environmental criteria considered in various stages of their life cycle, taking into account factors such as transport, reuse, waste disposal, etc. It is a tool which can show the total impact of packaging on the environment throughout its life cycle, from sourcing of raw materials needed to produce and ending with the stage of recovery or disposal of waste. LCA is used to calculate the impact of different types of packaging, used for packaging of the same product group to minimize or reduce the negative impact on the environment.

The importance of LCA methods that can be proved by the fact that its results are used in Germany where certain packaging is exempt from the obligatory deposit fee for beverages packaging.

In all German states from January 1st 2003, deposit fee for disposable container for beer, mineral water and carbonated beverages, such as: glass bottles, PET bottles and cans is obligatory. Exempt from the fee are laminate boxes and fruit juices, milk and soft drinks bags. Such exemptions have been justified by good LCA results, which showed that

[7] Górzyński J.: Principles of environmental analysis of products and services, WN-T, Warszawa 2007.

environmental burden resulting from using disposable laminate boxes and bags are the same as when using glass reusable bottles. Definitely greater environmental burden is caused by disposable (glass and plastic) bottles and cans[8].

Figure 2 schematically shows various stages of packaging life cycle and ecological criteria considered at those stages of LCA implementation.

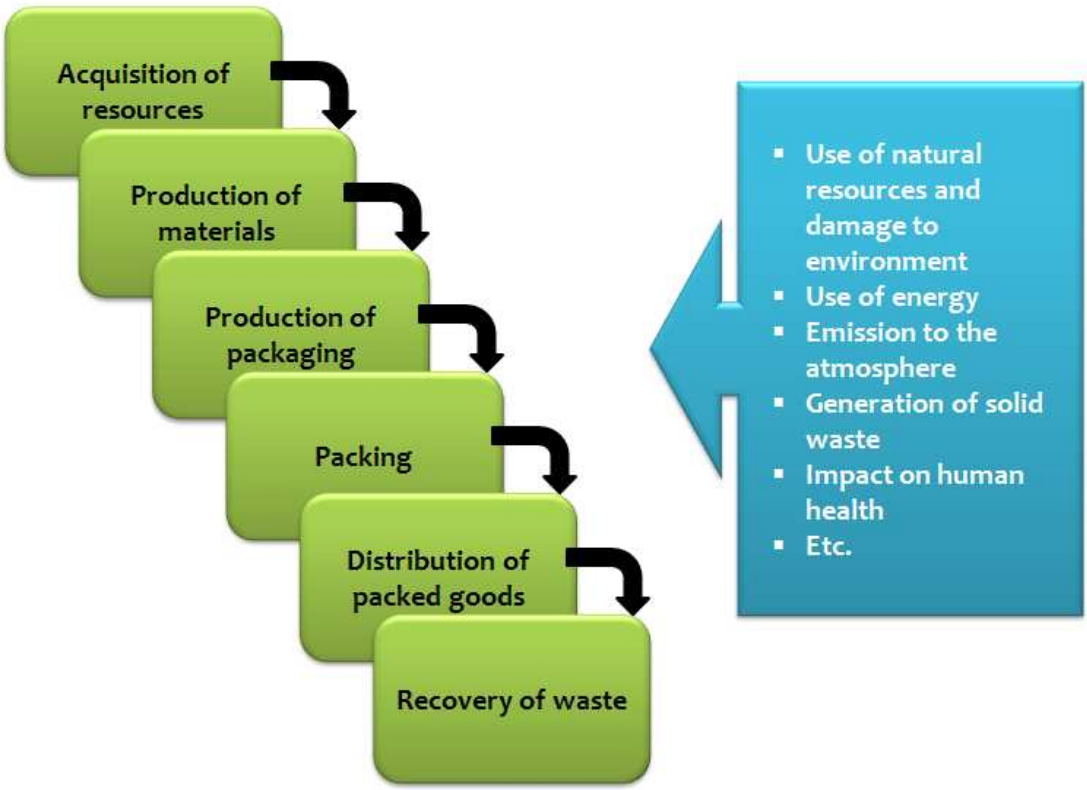

Figure 2. Stages of packaging life cycle and ecological criteria considered at those stages during LCA implementation [9]

Guidelines and criteria for performing LCA for packaging have been introduced by CEN Report No. CR 13910. This report is compatible with ISO 14040, which provides general LCA rules for all products. Packaging life cycle assessment includes following phases: definition of the purpose and scope, collection analysis, impact assessment and interpretation of results. Phases are illustrated by Figure 3

[8] Żakowska H.: *Deposit system as an instrument of packaging waste management – German example* Ekopartner nr 12/2003.

[9] Żakowska H.: *Guidelines for packaging LCA and limitations*, Opakowanie nr 11/2004, s. 20-23.

The purpose and the scope of the LCA for packaging should be clearly defined, documented and consistent with the intended way of use. As Figure 3 shows, mentioned purpose and scope are reference points for the whole description and for all results.

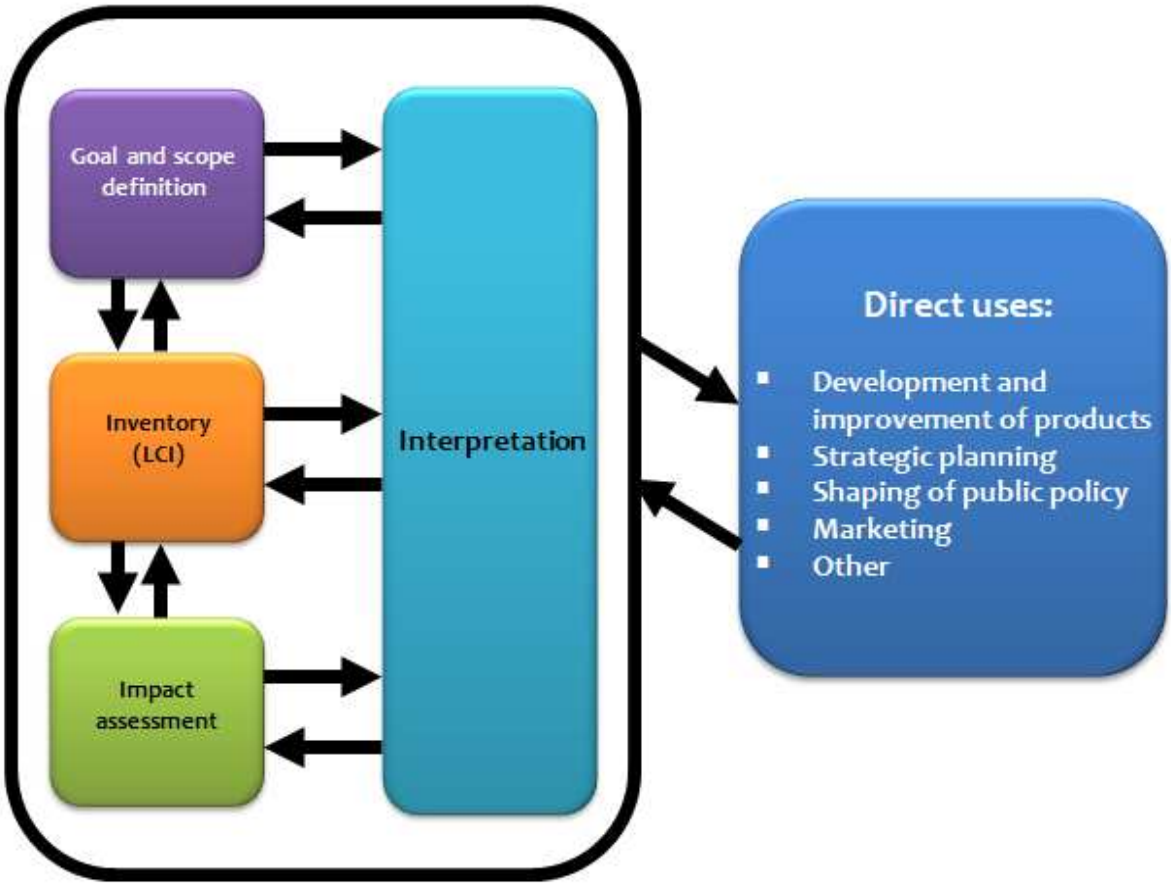

Figure 3. Life cycle assessment phases according to ISO 14040.

When defining the purpose and scope following observations regarding the actual use of packing must be considered:

- The fact packaging is always used for goods leads to the close integration of packaging and distribution logistics system. Packaging is used to transport, protect and provide information to its users. It means that in LCA all closures, labels and packaging components like printing inks, etc. should be considered. On the other hand packaging is a part of goods distribution system. Any change in packaging itself results in packaging system changes, followed by, significantly environmental effects. For that reason packaging life cycle assessment studies should include system of goods

distribution, collecting system and waste recovery and / or disposal processes.

- LCA should include all packaging (individual, collective, transport) used for packaging a particular product and all stages of life cycle (most packages accompany the goods only for a certain period of their life, ie. until the sale or consumption). Packaging life cycle in connection with a product is shown on figure 4.

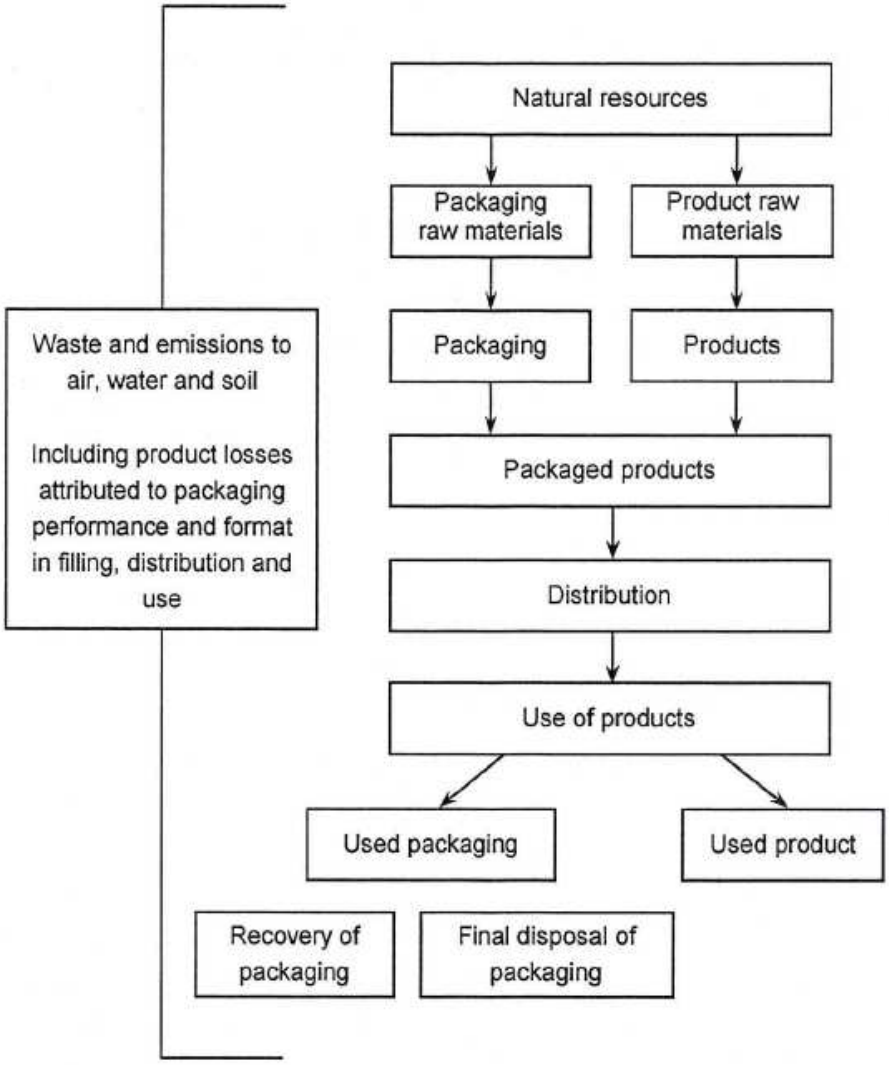

Figure 4. Packaging life cycle in connection with goods according to CR 13910

Analysis of all levels of goods packaging and distribution (including transport) and the loss of goods resulting from the use of certain packaging should be accounted for and considered in the assessment of life cycle. This is portrayed in the following examples:

- Yogurt cups placed in a rigid transport boxes can be stacked on top of each other, and fill the whole space in the transporting vehicle. If one uses less resistant boxes (eg, with no additional reinforcing elements) , due to the lower layers of cups damage, one cannot pile boxes on the full amount of the car. Then to carry the same amount of yogurt a transport company needs to make a greater number of rotations and consumes more fuel per tonne of transported goods. In this case in LCA increased emissions of harmful substances during transit and the profits achieved by using less packaging material should be compared.
- If the primary packaging of yogurt is exchanged to minimize its mass, it could cause a reduction in its physical characteristics and lead to significant loss of goods during transport and its shelf life. Such product waste affects the environment negatively and in this case also the structure of the transport packaging should be changed to accommodate the reduction of mass, which can also increase the overall environmental burden.

When discussing LCA performed for packaging, the results usually refer to a quantity of goods, and the functional unit – packaging – is expressed in units of mass of packaging material. For example, the results can be given in kilograms of packaging material needed to deliver one litre/kg of a particular product. LCA can relate to a total production of one product by one company or the whole market of a product in a certain region - when the analysis is used to optimize the distribution system. It is also important to take into consideration the requirements of the product itself. This could include: required packaging durability, required protection during transport, quality of food preservation, protection from light, legal requirements connected with packaged goods (for example: groceries), etc. Therefore the analysis performed for packaged goods and their quality preserving, including losses on the way from producer to final user, should be taken into account. In the example of yogurt packaging in LCA one should consider the following issues:

- Kind of yogurt, i.e.:
  - What is the quality of yogurt in different packaging?
  - What requirements should be met by a packaging to be filled with yogurt, including those related to the transport?

- Providing of specific weight/volume of the good may be associated with the production of its larger quantity. Delivery of 1000 litres of yogurt to the final customer normally does not mean manufacturing of 1000 litres of yogurt, this results from losses generated during processing, packaging and distribution, including prolonged retention in the warehouse/shop. For example delivery of 1000 litres of yogurt may in fact equal to 1100 litres of manufactured yogurt.
- Providing of specific weight/volume of the goods may result in consumption of smaller quantities. Delivery of 1 000 litres of yogurt usually does not mean consumption of 1000 litres of yogurt, which is a result of losses during consumption. Some yogurt is lost due to damage of the packaging, some might spill, some is disposed due to the expiry date, etc. For example providing 1 000 litres of yogurt may in fact equal to 800 litres of consumed yogurt.

In LCA analysis done for packaging it is also important to determine the boundary within which the analysis will be performed. This can lead to elimination of some processes related to the analysed commodity. However, some specific aspects of the packaged product should be taken into account when they are directly related to the packaging. Typical illustration of the limits within there is LCA performed is shown by Figure 5.

Collection analysis for LCA for packaging should take into consideration principles set in ISO 14041. It includes procedures for collecting data and calculations leading to the determination of the quantity of materials and energy introduced to the unit processes (input) and leaving the processes (output). These inputs and outputs may include resources use and related emissions to air, water and soil. From these data one can derive an interpretation, depending on the purpose and scope of life cycle assessment. It should be emphasized that LCA methodology is still under improvement, and in the future described guideline may be changed. This in fact is one of the most difficult stages in life cycle assessment. It require data from many different sources that may be confidential and difficult to reach. The data collection itself is a time consuming process. Packaging and distribution systems are separate for certain companies, so it is difficult to draw general conclusions. For example the distance in the distribution and consumption models for individual countries are quite different, and LCA needs essential comparability. Data from databases often are often too general and difficult to apply in specific cases.

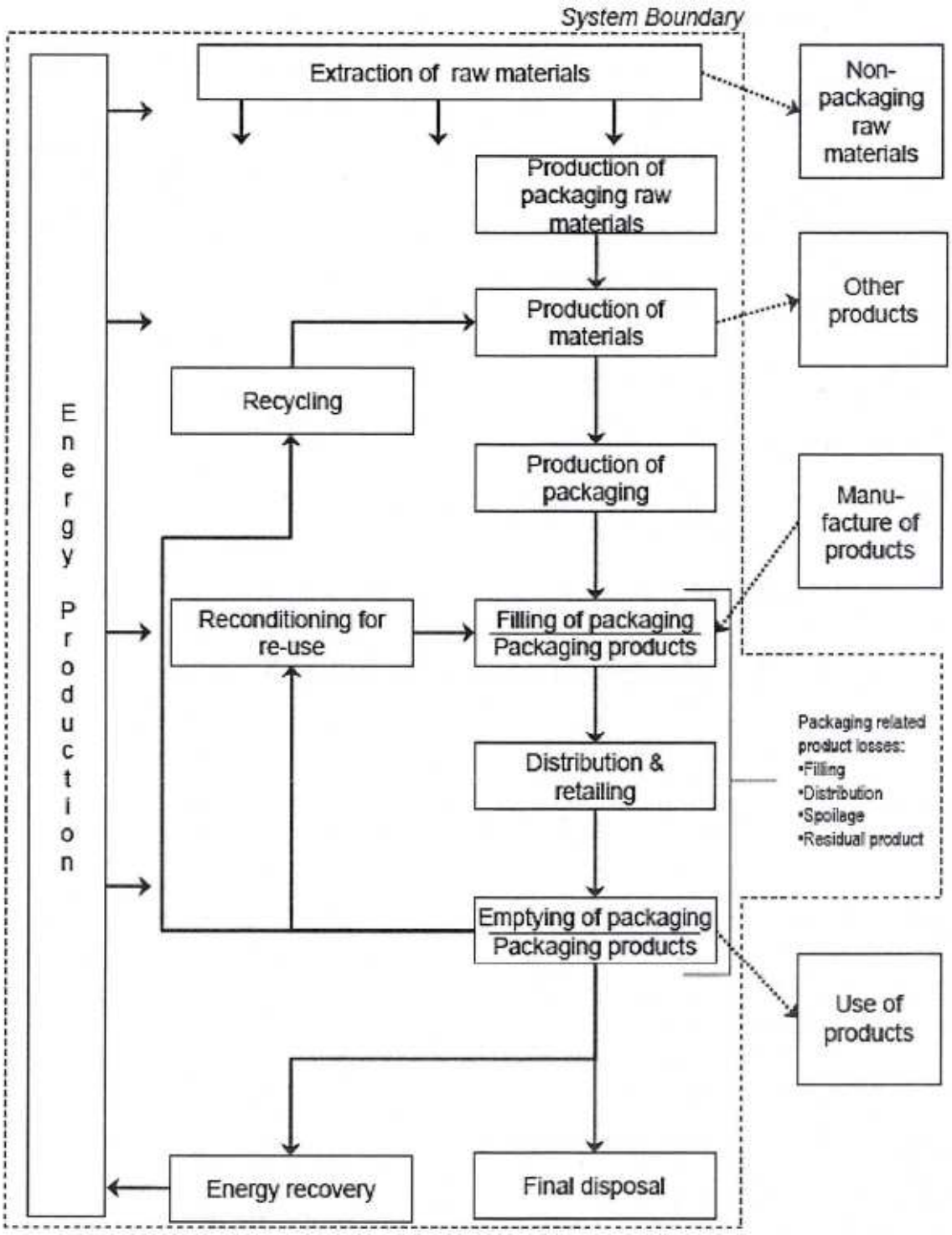

Figure 5. Example of border in packaging life cycle assessment according to CR13910

Life cycle assessment is one of many available tools of management for continuous modifying of packaging considering its environmental impact. These ratings concern entire lifetime of the packaging, i.e. acquisition of materials, production of packaging, packaging process and functional characteristics, post-consumer packaging collection, recovery or

disposal of waste. It should be emphasized the results may give rise both to improve the industrial processes associated with the production of packaging, as well as the same packaging. Another application of life cycle assessment is providing of appropriate support during in the new packaging designing. Comparative results for the various packages can be used as decision-making processes supporting elements. However, there is caution and prudence in results interpretation needed.

It is important to compare packaging by similar features, i.e. using a functional unit that enables to compare different packaging as objectively as possible. This means similar use, volume, performance, similar way of goods protection, requirements of safety, etc.

According to the ISO standards for life cycle assessment, in the case of comparison applications available to the public (comparison of different packaging used for a particular product), it should be critically reviewed (ISO 14040). Comparisons of results for different packaging, and different packaging systems, should be made only in case of the same application. But this is not enough to ensure proper comparison, because there are differences in the limits of the system inevitably (for example rules for obtaining and producing raw materials) , the functions of the system, assumptions, data quality, etc. Even small differences can have decisive consequences and inappropriate using of results can lead to wrong conclusions. Such improper use of a set of life cycle analysis can be a problem for the packaging sector, as well as for users of packaging and should be avoided. Assessment of the durability of various materials used for the same packaging goal should be interpreted cautiously. There is no certainty one packaging material can perform the same functions as another.

Another limitation of LCA is time and geography. Main packaging features is its short life cycle and constant changes adapting the form, shape and performance to the changing tastes of customers. The main role of packaging should be the rationalization of goods distribution, leading to efficient use of resources in logistics and loss prevention by proper protection of the quality of goods. Therefore, packaging design should be an expression of balance between resources needed for adequate goods protection and customers preferences.

Distribution system that is optimized for efficient use of resources (including energy) is very often dependent on local conditions, which may be very different in different parts of the world. Linked with this issue is the aspect of specific energy models used in different regions

of the world. Energy model choice reflects defined geographical boundaries in the distribution system.

Despite many restrictions, Polish scientific institutions have taken many attempt to use LCA methods in packaging evaluating [10], [11]. For instance, comparative ecological balances for glass and PET packaging made by Department of Products Ecology, Faculty of Commodity at Poznan University of Economics showed polyester packaging have a comparable, and in some cases even better[12], impact on the environment than glass containers. Interesting are also results of LCA for packaging cosmetic creams[13].

LCA method is also used for the evaluation of biodegradable packaging, which shows using of such packages helps to save energy and reduce emissions of carbon dioxide [14], [15].

[10] Podsiadłowska A., Foltynowicz Z.: *Life Cycle Assessment – LCA* 'Odpady i opakowania – nowe regulacje i obowiązki', redacted by Urbaniak W., 'Wydawnictwo' FORUM, Poznań 2002.

[11] Lewandowska A., Foltynowicz Z., Podleśny A.: *LCA – Applications, '*Problemy Ekologii' nr 3/2004.

[12] Podsiadłowska A., Foltynowicz Z.: *LCA of beverages packaging, LCA in Practice*, 'Odpady i opakowania – nowe regulacje i obowiązki', by redaction of Urbaniak W., FORUM, Poznań 2002.

[13] Foltynowicz Z., Lewandowska A., Borowska W.: *Environmental assessment of selected hand crème packaging*, 'Ważenie Dozowanie Pakowani'e nr 2/2006.

[14] Davies G., Binney G., Song J., Murphy R.: *End of Life Management for Bioplastic Packaging*, Conference for the Engineering Doctorate in Environmental Technology, End of Life Management for Bioplastic Packaging, 2005.

[15] Detzel A., Krueger M.: Life cycle assessment of Polylactide (PLA). A comparison of food packaging made from NatureWorks PLA and alternative materials, IFEU, Heidelberg, July 2006.

LCA design in EcoPaperLoop

During EcoPaperLoop kick off meeting in Milano, it was agreed that COBRO will describe the theoretical framework regarding the scope and boundaries of LCA according to the main European Standard on LCA – EN14040, and provide a suggestion of how those should be set up for the specifics of the project.

The ISO standard – ISO 14040 – 'Environmental Management – Life Cycle Assessment – Principles and Framework' specifies the following steps that need to be taken when performing Life Cycle Assessment.

1. The Goal and Scope Definition
2. The Life Cycle Inventory Analysis (LCI)
3. The Life Cycle Impact Assessment (LCIA)The Life Cycle Interpretation phase
4. Reporting and critical review of the LCA
5. Limitation of the LCA
6. Relationship between the LCA phases, and
7. Conditions for use of value choices and other optional elements.

The choices for this, first step of the ECOPAPERLOOP project all reside within the Scope Definition phase.

In order to define the Scope of our assessment we need to answer the following questions:

1. **What product system we want to study**
2. **The functions of the product system/s**
3. **The functional unit**
4. **The system boundary**
5. Allocation procedures
6. Impact categories selected and methodology of impact assessment and subsequent interpretation to be used
7. Data requirements
8. Assumptions
9. Limitations
10. Initial data quality requirements
11. Type of critical review, if any
12. Type and format of the report required for the study.

In this planning phase of the LCA in ECOPAPERLOOP we do not yet need the answers to all of those questions. What is essentially needed is the answer to the first four questions. This document will focus on those.

Product System and System Boundaries

A product system is a collection of processes, input output and product flows, performing one of more defined functions and which models the life cycle of a product.

A system may have a number of possible functions and the one selected for a study depends on the goal and scope of the LCA. LCA is conducted by defining product systems as models that describe the key elements of physical systems. The system boundary defines the unit processes to be included in the system. The choice of elements of the physical system to be modelled depends on the goal and scope definition of the study, its intended application and audience and the assumptions made. The models used should be described and the assumptions underlying those choices should be identified.

In the instance of ECOPAPERLOOP our main product is packaging and graphic paper with main focus on the processes of recycling.

Figure 6 below represents an example of typical packaging product system along with clearly identified system boundary.

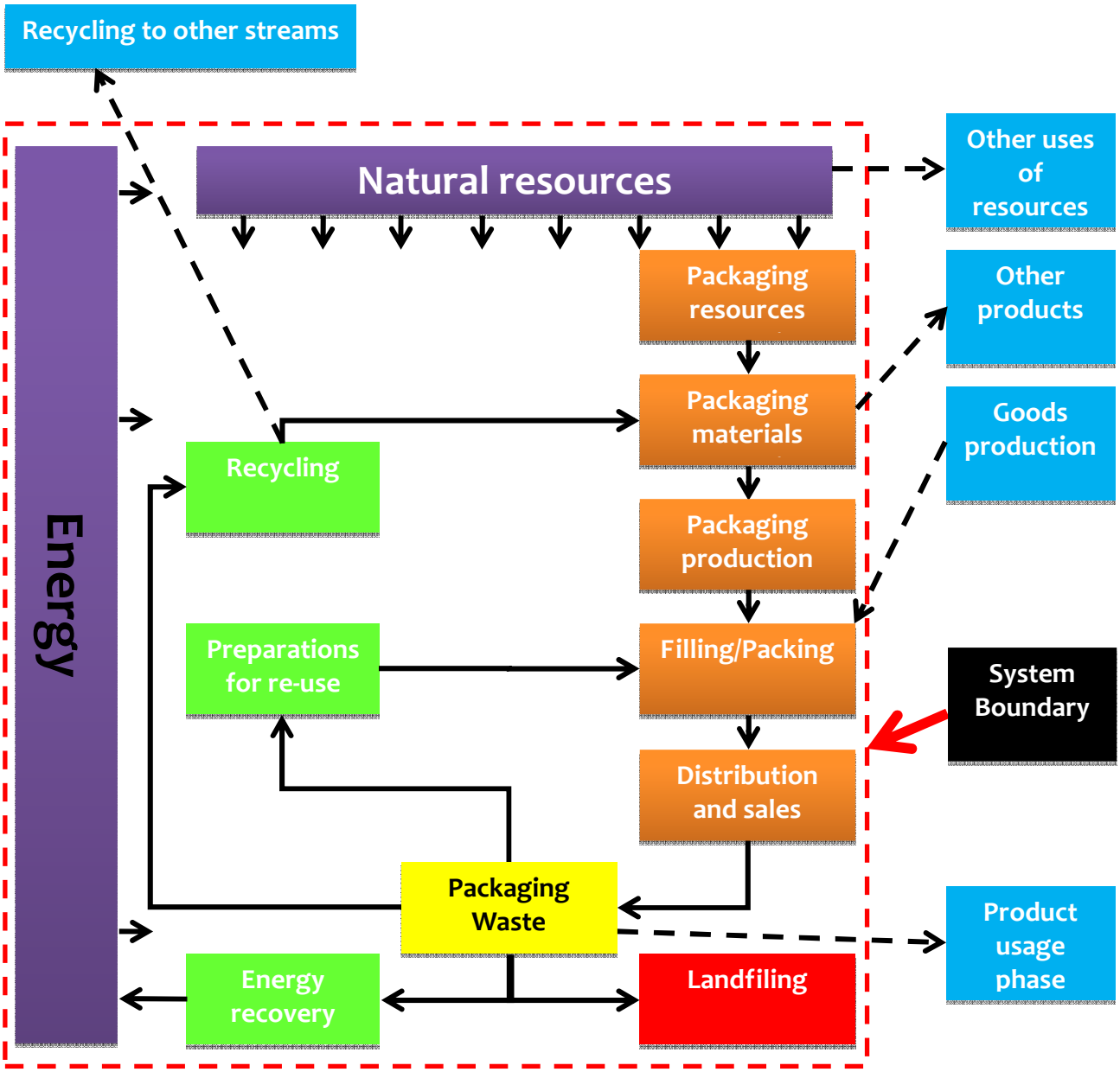

Figure 6. A typical packaging product system

In ECOPAPERLOOP we will be looking at recycling improvement in multitude of packaging and graphic paper applications. This provide two essential facts:

1. Improvements direct to the assumption that LCA should demonstrate differences between systems with and without improvements/changes
2. It can also be assumed that the main differences will happen in the end of life stage (unless processes before those stages are affected as well)

Therefore the system boundary of LCA's in ECOPAPERLOOP can be adjusted to what has been proposed in figure 7.

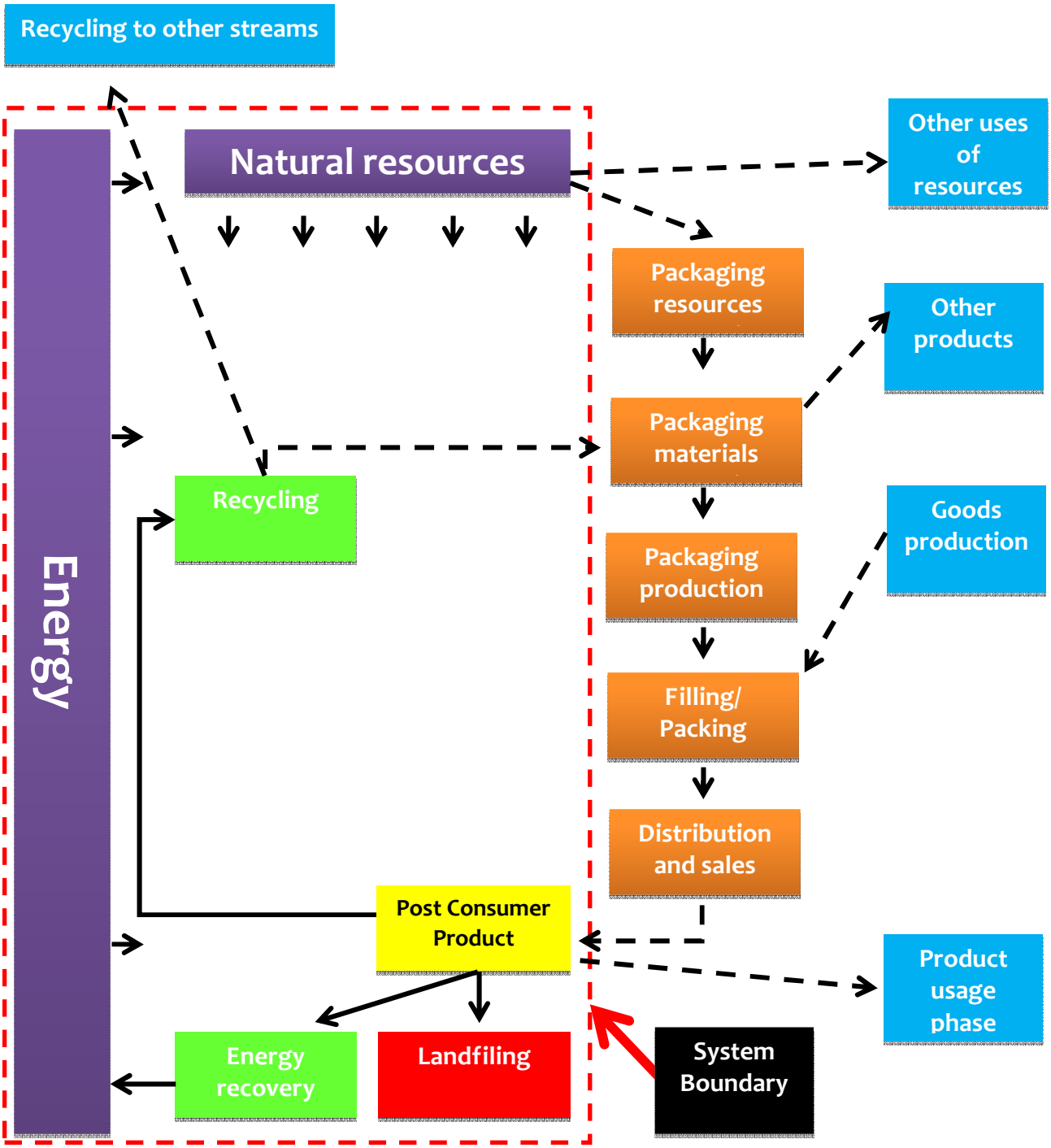

Figure 7. Proposed system boundary for ECOPAPERLOOP on an example of packaging material

This system focuses only on the end of life scenarios of packaging paper / graphic paper, as it is not part of the scope to analyse the impacts related to other supporting processes of production, transport etc. Therefore the input of LCA's will be the post-consumer product – with all material and base production processes accounted for, excluding all auxiliary processes during filling/packaging, distribution and sales etc. This is based on the assumption that all previous auxiliary processes will

not change when considering normal and improved product. Whereas the landfilling and energy recovery processes will not change as well, it can be expected that the percentages of materials going into those waste scenarios may change, that is why they are included in the boundary.

The focus of the study would be to assess the environmental impacts related to some specific recycling parameters, which are affected by the nature of the packaging waste. The relationship between packaging waste innovative properties and technical parameters of the recycling process are one of the main outputs of Work Package 3. These parameters should be listed as well in the Scorecard evaluation for the recyclability of packaging products and they are mainly related to waste paper repulpability, recycling process waste and adhesive content in the pulp.

The main issue of the LCA study will be to associate proper environmental impacts and categories to the technical recycling parameters, in order to evaluate the impacts of different waste packaging during the stock preparation stage of the recycling process. The following paper production with the prepared stock pulp will be not assessed and included in the study.

Functional Unit

A system may have a number of possible functions and the one(s) selected for a study depend(s) on the goal and scope of the LCA.

The functional unit defines the quantification of the identified functions (performance characteristics) of the product. The primary purpose of a functional unit is to prove a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results. Comparability of LCA results is particularly critical when different systems are being assessed to ensure that such comparisons are made on a common basis.

In the instance of ECOPAPERLOOP we are dealing with paper recycling. Usually in the LCA concerning recycling functional units are:

1. Mass of waste material
2. Transformation of mass/cubic area of waste material into recycled material – i.e. kg / square meters of recycled material

The final choice of functional unit will be determined by the types of products that will be chosen for the project.