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FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA

PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

COLOGNE UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

ENVIRONMENTAL PRODUCT EVALUATION GUIDELINE TOWARDS SUSTAINABLE CONSUMPTION

A CASE STUDY ON COMPRESSED ADOBE BLOCK

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES

DEGREE AWARDED BY

UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

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MASTER OF SCIENCE

"TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

FOCUS AREA "ENVIRONMENTAL AND RESOURCES MANAGEMENT"

DEGREE AWARDED BY COLOGNE UNIVERSITY OF APPLIED SCIENCES

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COLOGNE AUGUST, 2015

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And last but not least to my sister, my dearest friend.

Abstract

In recent years, there has been an increasing interest in environmental impact that products have through its life cycle. While industry has developed strategies and practices to perform less stress on the environment, there is still an information gap between industry and consumers when reporting the implications of a product. One of the greatest challenges is to make environmental information understandable and significant to consumers.

Lack of information and understanding of it is one of the most frequently stated problems with consumer practices which influence directly the way industry operates nowadays. To date, several studies regarding this problem have covered different topics and have highlighted the importance of a holistic approach. This research provides an overview of methodologies related to the field of design, consumer behavior and life cycle assessment with the purpose of assessing the development of a product or service.

A case study on a "compressed adobe block" was chosen to conduct this exploratory study and to determine the factors that affect the performance of a product throughout its life cycle. This research provides a framework of a standardized guideline for the exploration of a product stages trough life cycle to evaluate its performance and find points of improvement.

Keywords: *life cycle assessment, products, services, consumer behavior, environmental information, compressed adobe block.*

Resumen

En los últimos años, se ha experimentado un incremento de interés en el impacto ambiental que genera un producto de consumo durante su ciclo de vida.

Aun cuando la industria ha desarrollado prácticas y estrategias para tener un impacto menor en el medio ambiente, existe una brecha de información al respecto entre el consumidor y la industria. Hacer llegar al consumidor información sobre el impacto ambiental de un producto y que ésta sea comprensible y significativa implica un gran reto.

La falta de información o de entendimiento por parte de los consumidores frente aspectos ambientales relacionados con patrones de producción y consumo representa uno de los principales problemas para alcanzar prácticas de consumo más responsables. Hasta ahora, varios estudios han abordado esta problemática desde distintas disciplinas y resaltan la importancia de una aproximación holística de la misma.

La siguiente investigación provee una visión general de metodologías para asesorar el desarrollo y desempeño de un producto o servicio en relación al impacto ambiental. Con este propósito, como caso de estudio, se evaluó un “bloque de adobe compactado”, para poder determinar los principales factores de impacto en el ciclo de vida de un producto. La investigación provee una guía para la evaluación de impacto ambiental de un producto durante su ciclo de vida.

Palabras clave: *análisis de ciclo de vida, productos, impacto ambiental, bloque de adobe compactado.*

Zusammenfassung

In den letzten Jahren konnte ein zunehmendes Interesse zum Thema Umweltbelastung über Produkte und ihren Lebenszyklus aufgewiesen werden. Während die Industrie Strategien und Praktiken entwickelt um die Umwelt zu schonen, besteht weiterhin eine Informationslücke in der Kommunikation zwischen Industrie und den Verbrauchern bei der Berichterstattung über die Auswirkungen eines Produkts. Eine der größten Herausforderungen ist es, Informationen über die Umweltbelastung verständlich für die Verbraucher auszudrücken.

Mangel an Informationen und Verständnis des Problems ist eine der am häufigsten genannten Probleme mit denen in der Verbraucherpraktik die Art und Weise der Arbeitsweise der Industrie heute direkt beeinflusst werden. Bisher wurden mehrere Studien in Bezug auf diese Problematik in verschiedenen Themen behandelt, was die Bedeutung und Wichtigkeit eines ganzheitlichen Ansatzes noch hervorgehoben hat. Diese Forschung liefert einen Überblick über die Methoden in den Bereich des Designs, dem Verbraucherverhalten und dem ´Life Cycle Assessment´ mit dem Ziel einer Bewertung der Entwicklung eines Produktes oder einer Dienstleistung.

Eine Fallstudie über einen ´komprimierten Adobe-Block´ wurde gewählt, um diese explorative Studie durchzuführen und die Faktoren, die die Leistung eines Produkts während seines gesamten Lebenszyklus beeinflussen, zu bestimmen. Diese Forschung bietet den Rahmen eines standardisierten Leitfadens zur Erforschung der unterschiedlichen Etappen des Lebenszyklus eines Produktes, um seine Leistung zu bewerten und Punkte für eine Verbesserung zu finden.

Schlüsselbegriffe: *Life Cycle Assessment, Lebenszyklus, Produkts, Dienstleistung, Umweltbelastung, komprimierten Adobe-Block.*

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Glossary

Sustainable development: the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.

Consumption: use of material possessions that encloses complexity within economy, industry, environment and social implications.

Cradle to cradle: Model to visualize and conceptualize how things are developed; it gives a new perspective of the production system; it tries to have a parallel approach as the one of natural cycles and ecosystems.

Ecolabel: Label that provides consumers information relative to environmental aspects of a product.

Life Cycle Assessment (LCA): Is a technique for assessing the environmental aspects and potential impacts associated with a product.

Life Cycle Impact Assessment (LCIA): life cycle impact assessment phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system.

Introduction

In recent years, there has been an increasing interest in the environmental impact that products have through its life cycle. In light of crescent awareness on environment pressure due to consumption practices and its implications in part by the industry and in part by consumers (i.e., resource extraction, emissions and pollution as long as social implications trough manufacturing, waste generation through manufacturing and at the disposal stage), it is becoming extremely difficult to ignore the importance of regulation of industry practices.

Considerable literature has grown up around the theme of environmental performance on: the use of resources, industry practices, consumer behavior and design practices regarding sustainability.

Sustainability and its implication in different disciplines has been an object of study since 1987, when Brundtland Comission in the document “Our common future”, defined the term “sustainable development”. Since then sustainability has been addressed in different perspectives, disciplines and understandings. One of the greatest challenges is to reduce the gap of information regarding products between industry and consumers with the purpose of more conscious and “sustainable” practices.

There is a growing body of literature that recognizes the importance of a more integrated relationship on consumption. Existing research recognizes the critical role played by the consumer and its influence on the industry performance; several attempts have been made to reduce this gap whether on industry practices, the design process or on the consumer approach just to mention some. One of the greatest challenges is to aware the consumer about its influence in industry practices, this indicates a need to understand the various perceptions that exist among them.

This research provides an overview of the implications of a product, highlighting the importance of early stages of development and the consideration of all stages in its life cycle. A methodology for the evaluation impact of a product is proposed, by analyzing factors that determine its performance and implications in different stages.

The specific objective of this study is to identify environmental impact information regarding a product to be reported to consumers; furthermore, this work investigates the main stages of product development, where improvements on the system performance can be made. The thesis examines the way in which products are conceived; the relationship between stages of life and implications on the environment; part of the aim of this project is to develop a standardized guideline to assess the product development.

Qualitative and quantitative research designs were adopted to provide holistic framework that encompasses different disciplines perspective. The methodological approach taken in this study is a mixed methodology based on life cycle assessment and “cradle to cradle”. The investigation takes the form of a case-study of a “compressed adobe block”, where a combination of quantitative and qualitative approaches are used.

The study offers some important insights into product system analysis for environmental impact assessment; it aims to contribute to assess products by exploring different features of its interactions through its life performance.

However, it is unable to encompass the entire interactions that a product may have. It is beyond the scope of the study to examine comparable quantitative data. The main issues addressed in this thesis are: consumption and sustainability, “cradle to cradle” paradigm and life cycle assessment. Results include an: Environmental product evaluation guideline, as a basic framework to analyze and evaluate a product.

Objectives

General:

- To develop a product environmental evaluation guideline to generate a communication bridge between producers and consumers, by reporting consumers clear environmental information of a product.

Specific:

- To establish standardized environmental evaluation criteria for products (basic framework to further adaptations based on the selected product to be studied).

- To organize a product system by the identification and organization of processes performed within life cycle.

- To analyze data through life cycle assessment. (Definition of stages of LCA to be emphasized).

- To develop a framework to evaluate environmental impact on diverse nature of consumer products in order to be captured on an ecolabel or environmental claim.

Theoretical Framework

"The most interesting solutions lie at the boundaries of disciplines" (The Behavioural Design Lab, 2012, p.06).

Introduction

Since the "sustainable development" definition by Brundtland Commission in 1987, sustainability aspects are a growing concern in different topics, one of it is the environmental problem due to consume patterns; on this topic: industry, governments and consumers show an increasing concern .Even when changes in this area are becoming visible; still, they are not enough to achieve sustainable practices. More information and a deeper knowledge in the topic are needed.

The economic paradigm supports today´s practices, which in certain way gives a license to proceed with already know operational models of production. The "center" and "periphery" as referred by social sciences, show worlds wide apart when talking about repercussions from consumption patterns. These disparities roots lay on complex problem, one of them: the industry operation model. Nevertheless, it is important to question if fixing industry practices is enough to perform a positive change in the economic, environmental and social system, or if a change of paradigm is needed.

The way we consume reflects important issues of our culture such as its fears and weaknesses. Special attention should be put on the consumer because its desires are represented and full-filled by products that are supposed to cover basic needs; their desires regulate the industry and how it operates. For the industry, this implies a constant improvement on processes and technological implementations as well as market credibility in terms of consumer's perspective. The intention is to approach the consumer to reduce the gap between industry practices and the final product, by giving them simple information that represents the overall situation and give them a tool to understand the implications of a product they are purchasing.

Consumer decisions have a direct impact in the direction industries take; indeed industries and governments require regulation to achieve "sustainability”. To accomplish these "sustainable practices", it is important to understand the model’s functioning and its implications. If a consumer is informed or at least receives information of what a product involves, it can play as a decision making tool. Purchasing decisions have an implication at different scales: environment, social sphere, resources, etc. In this perspective, consumers have a direct impact on these scales when deciding to buy a specific product. The transition of models of production and purchasing the demand and offer of “green products“ as one way to call them, should not just be an advice, but an integrated approach from industry, government, academia, communities and consumers (The Behavioural Design Lab, 2012; Young, Kumju, Seonaidh, & Caroline, 2008).

Hence consumer, as an user of a "good" or "service”, plays a key role for this transition, environmental information need to be recognized by them. For this instance efforts towards the development of standardized criteria when evaluating environmental impact must be supported by all the parties involved (Global Ecolabelling Network, 2004).

In the pages that follow, several concepts such as: consumption and consumer behavior, design for sustainable consumption, “cradle to cradle” paradigm, ecolabelling and life cycle assessment; regarding the previously described problem, are addressed.

Consumption and Consumer Behavior

> *"The main objective of the individual in consumption is no less, in Mary Douglas' words than 'to help create the social world and to find in it a credible place'" in (Jackson, 2005).*

About Consumption

Meaning of consumption

> *"We consume, in part at least, in pursuit of meaning"(Jackson, 2005, p.17).*

For this study consumption is defined as the use of material possessions that encloses complexity within economy, industry, environment, and social implications. Consumption shows a cultural pattern representing a specific historical moment. These material possessions are the so called "goods" or "consumption goods"; these in terms of economy are known as commodities. In the purest essence of their creation they aim to satisfy a need (i.e., food, transport, housing), but culturally speaking they do not just cover the needs for subsistence but the symbolic representation of a culture constituting a system full of meanings representing the fundamental aspects of the social world (Douglas & Isherwood, 1996; Jackson, 2005).

Consumers are in a constant process of constructing and reconstructing an "identity" which is configured by the language of symbolisms. Human needs are covered by this "goods" helping to achieve personal or collective well-being; therefore, it can be said that consumption meets people´s wants and desires (Jackson, 2005). "Positive and sustained impact " as mentioned by The Behavioural Design Lab(2012), could be created by focusing on people´s real needs.

Consumer Behavior

Behavioral science

> *"Consumer behavior is key to the impact that society has on the environment" (Jackson, 2005, p.5).*

Consumer Behavior refers to the stages involved in consumption: from acquisition to use and disposal. As mentioned before consumption is a cultural practice full of symbolisms that communicate certain status, identity, preferences and aspirations; just to mention some of them. It is important to understand what consumption is when speaking about consumer behavior. Naturally these terms are strongly related; consumer behavior is influenced by several factors such as: culture, price, aesthetics, functionality, etc. In fact products are shaped by consumer behavior as consumer behavior by products (Jackson, 2005; Lockton, Harrison, & Stanton, 2010).

To study behavior themes is a complex duty, because of this, behavioral science could be defined as "a young field built on strong scientific heritage" that "seeks to understand human choices and wellbeing by drawing on insights and methods from psychology, economics and neuroscience" (The Behavioural Design Lab, 2012, p.04).

Sustainable Consumption – Consumer Behavior and Sustainability

> *"Every time someone makes a decision about whether (or not) to purchase a product or service there is the potential for that decision to contribute to a more or less sustainable pattern of consumption. Each purchase has ethical, resource, waste and community impact implications" (Young et al., 2008, p.3).*

Once "consumption "and "consumer behavior "are stated, the term "sustainability" comes into the scene. To introduce sustainability into the context, I would want to introduce one of sustainability milestones: the concept of "Sustainable Development".

The term "Sustainable Development " was introduced by the Brundtland Commission in 1987 as "the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Nations, 1987). Consumption as a practice is influenced and carried by social structures and norms; it is representative of determined social practices, constantly evolving, helping to shape social structures. That's why the role of the consumer is crucial when speaking about sustainable consumption (Jackson, 2005).

Engaging consumers towards sustainable consumption is a challenge due to various subjects and because of the complexity that it carries. Consumer behavior shapes the production and consuming patterns; there is some evidence that suggest that consumer's decisions when purchasing have the power to lead the production-consumption model towards to more responsible and sustainable practices. However, the lack of information and the complexity of it discourage consumers in approaching to these practices (Young et al., 2008).

How To

In pursuance of sustainable consumption, and as one of the first approach begin with consumers, it is essential to understand the patterns of consumer behavior and how can it be influenced and directed towards sustainability. This change or conductive direction should be based in social contexts; touch points need to be identified to make environmental information or environmental concerns significant and meaningful for consumers

A key point for a transition model of production and consumption is the change of consumer behavior; hence, a question to be stated is how industries should proceed to approach consumer towards this change.

Design for Sustainable Consumption

> *"We believe the best way to solve social issues is to not only research how and why people make decisions, but use the design of products, services and places to help us all make better decisions" (The Behavioural Design Lab, 2012 , p.02).*

User and Sustainable Behavior

Consumers could have a strong role in conducting industry patterns each time they make a decision; whether they are conscious or not, consumers influence and contribute to the promotion of certain sustainable or not sustainable activities. The actual problem with sustainable claims in consumer goods, is the gap between consumer and the product (and everything it implies), the efforts made to approach the consumer are sufficient rationale but have a lack of impact.

Behavior is not influenced by suggesting consumers how to act, but about their motivation in order to succeed in certain desired behavior.

At this point further representative information should be given; instead of giving formal data that has no meaning for someone that has not background in the specific field where the data was generated, information should be given in a structure easy to relate. For this consumers need to be aware of the implication of the products and services they are selecting.

The Behavioural Design Lab (2012) gives the example of nutrition facts; they argue that instead of giving a specific number of calories, information for consumer would be easier to understand if they provide consumers with the relationship between the number of calories and its equivalent in time of excersising.

Up to now, previous studies found that in order “to make the user more efficient” diverse disciplines should work to affect user´s behavior when interacting with a product or service. Hence consumer approach is a key point for the success on industry environmental practices; because consumer desires have a direct and tangible impact in the market (Global Ecolabelling Network, 2004).

Design Principles towards Sustainability

Role of Design

Design is a creative approach to a problem that covers human needs and desires; therefore, it has a people-centered approach.

When considering the performance of a product in a system, design has a key role. It is one of the first steps on a product life. A “good design” should consider its implications trough all its life cycle; hence, design represents a good opportunity to look towards sustainability (The Behavioural Design Lab, 2012).

Design for sustainability has its main dialectic on the sustainable definition mentioned before; designing in a sustainable way must consider the full, short and long- term consequences and implications that could occur because of the realization of a product, and even think about the possible interaction in the unknown future.

In 1992 Mc Donough & Partners created the “Hannover Principles“, where they stated some of the principles for design towards sustainability, in this principles they highlight the importance of considering the principles with which things were designed. The authors suggest that designing for sustainability implies the radical change of principles which guide the process of design.

Design that takes into consideration its further implications related to: social impacts, use of resources, material flows, etc., can help enterprises to have rentable business; this can be achieved by minimizing the complexity of the product but enabling it to have more life cycles than just one.

Design as a primary step of a product system represents an opportunity of improvement and change; it can be regulated to minimize the damaging effects but should be rethought, regulation by itself uncovers the failure of the same (McDonough & Braungart, 2002).

Hannover Principles (insights)

Hannover Principles are constructed in a way that can address the sustainable development definition by "meeting needs and aspiration of the present , without compromising the ability of planet to sustain an equally supportive future"(William Mc Donough & Partners, 1992 , p.2).

To highlight some principles and just to mention some general key concepts, the following list summarize some of them:

- Expand design considerations to recognize effects and implications in every scale.
- The evaluation of the full life cycle products and processes, eliminating the concept of waste.
- Rely on energy flows.
- Nature as a model of inspiration; regarding natural cycles when designing could lead to more inclusive practices.
- Think of the future generations and the implications of the product.
- Look for continuous feedback and knowledge taking into account sustainable considerations.

Behavior Modeling

User behavior is determinant of the environmental impact of a product; one main implication for behavioral change is not to motivate but to make it simpler, simple information has the potential to make the consumer more efficient (Fogg, 2009; Lockton, Harrison, & Stanton, 2008).

Design and Sustainability Implications
Economics

To introduce this chapter I would like to define the term “circular economy”:

> “A circular economy is an industrial system that is restorative or regenerative by intention and design It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models”(Ellen Macarthur Foundation, 2013 , p.7).

Circular economy is a theoretical construct whose premise is a restorative system where economic growth is achieved by reuse of end of life materials rather than raw materials extraction at the beginning. Circular economy principles and design principles for sustainability have the same objective; therefore, it could be said that one is a tool of the other.

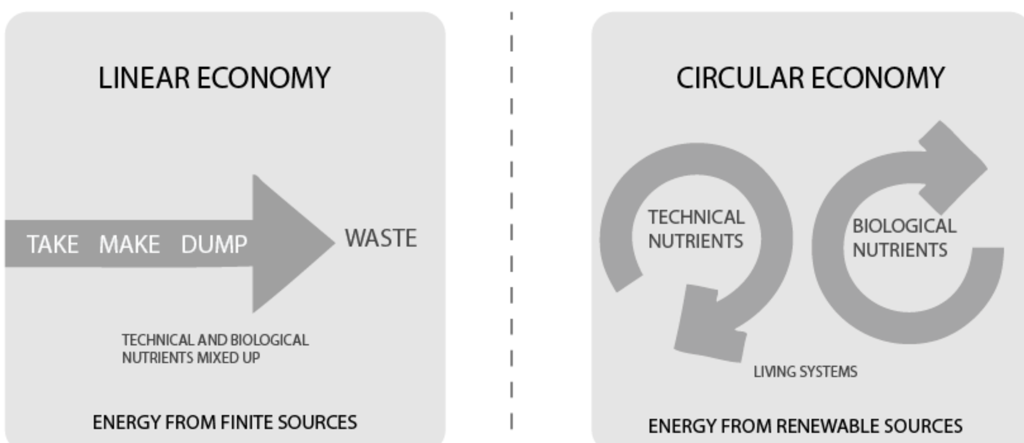


Figure 1 Linear Economy and Circular Economy. Note: Adapted from(Ellen Macarthur Foundation, 2013 after M.Donough and M. Braungart).

In the economic perspective, circular economy gives a different approach from the nowadays operating linear system, see ***Figure 1***, where the model could be defined as “take- make- dispose”. This pattern has its roots in the birth of industrialization; however, actual problems carried by industry and consumption patterns suggest that a new perspective should be given to give an answer to it. Circular economy is based in the following principles: avoiding of waste, circularity and energy should be renewable by nature.

On the reasons for addressing consumption models and to switch to circular economy

A new economic model is required for facing the resources depletion and the growing demand of products and services. The current economic model can be stated as defined by the Ellen Macarthur Foundation “take – make – disposal economy”, has its inner roots in the history of industrialization where the common pattern is linearity. In terms of resources and energy this model arouses losses.

From linearity to circularity (Systems)

System thinking allows to understand how every element is connected to other and how flows interact creating the whole; relationships can be traced and tracked.

Circularity also helps to have more manageable life cycles; by reducing complexity, these cycles interact and give feedback to each other. With this circular approach, a long –term resilience of economy is expected; some benefits to mention are: material saving, mitigation of volatility and supply risks, employment benefits, reduced externalities, and so on. Industry and consumers are both beneficiated trough circular economy.

Circular economy gives a chance to shift the system in an innovative and creative way, in addition to the increase of material productivity with positive impact on economy; hence the importance of the consumer centered vision. According to Ellen Macarthur Foundation (2013),“user centric economy will increase innovation, employment and capital productivity.”

Circular economy is about efficiency and innovation; it helps to reduce from the beginning the material and energy use and its implications, its essence is the circular design, which means improvement in: material selection, standardization, modularization, and design for disassembly.

For the transition towards circular economy, there is a need of government and business regulation. Circular economy implicates an industrial economy with restorative characteristics, this characteristics implies a design in products adaptive to it (Ellen Macarthur Foundation, 2013).

Circular economy principles

To summarize some of the circular economy principles, the following concepts are described (Ellen Macarthur Foundation, 2013):

Avoiding Waste: Waste as a concept that highlight the lack of effective/efficient operation of a system. Circular economy from a design perspective starts with the premise that waste doesn´t exist in the biological and technical system.

Resilience trough diversity: According to the authors systems since industrial revolution where developed in uniformity; this, in contrast with natural systems, is not continuously evolving and is not resilient to external dynamics.

Energy from renewable sources: Transition to the use of renewables. Think of the use of energy through the process.

Waste is food: In comparison with natural systems, material used as nutrients (input) should be useful for other steps, in a restorative way.

Innovation plays a main role in the transition from linear economy to circular economy, because it serves as an accelerator, leading to new opportunities. In this model companies get benefits because of the material and energy reduction; which, at the same time, creates competitive advantage.

Within this model, the main macroeconomic sectors (primary, secondary and tertiary) have new opportunities to be incorporated, however it is estimated that the sector of services will have a major impact. Services are meant to be a bridge towards the migration from linear economy to circular economy (Ellen Macarthur Foundation, 2013).

According to Ellen Macarthur Foundation (2013) consumers will become the users of services, instead of “one-time-transactions,” a “life-time service relationship” is going to be created. As an example, products and their obsolescence will change, increasing the life span and improving the experience of the consumer. This could help to trigger consumer behavior towards sustainability.

Cradle to Cradle

About Cradle to Cradle

“Cradle to cradle” is an approach of designing products and systems; it breaks with the paradigm of the traditional "cradle to grave" or "cradle to gate" approaches. The relevance of the “cradle to cradle” perspective is the opportunity to design solutions more in accordance to the natural system.

Classic models for product development suggest a linear perspective; when compared with natural cycles what is found is that they are not compatible. “Cradle to cradle” approach promotes a natural cycle thinking. It trackless every process in the conception of a product or service, putting special attention in the interactions occurring inside and outside the system where it is inserted.

“Cradle to cradle” is a model to visualize and conceptualize how things are developed; it gives a new perspective of the production system; it tries to have a parallel approach as the one of natural cycles and ecosystems, see ***Figure 2.***

Cradle to Grave

“Cradle to grave” life cycle weakness is that all the material energy and efforts used as an input are mostly lost in the process before the product gets to the hands of the consumer (McDonough & Braungart, 2002). The problem with “cradle to grave” approach is that it follows a linear process that most of the time only refers to production stage.

Industrial infrastructure that operates today is still linear, with the aim of producing as quickly and profitable as possible. This model dominates modern manufacturing; from this model terms as “built –in obsolescence” is commonly known, where products are from the beginning created to last for a certain time of period.

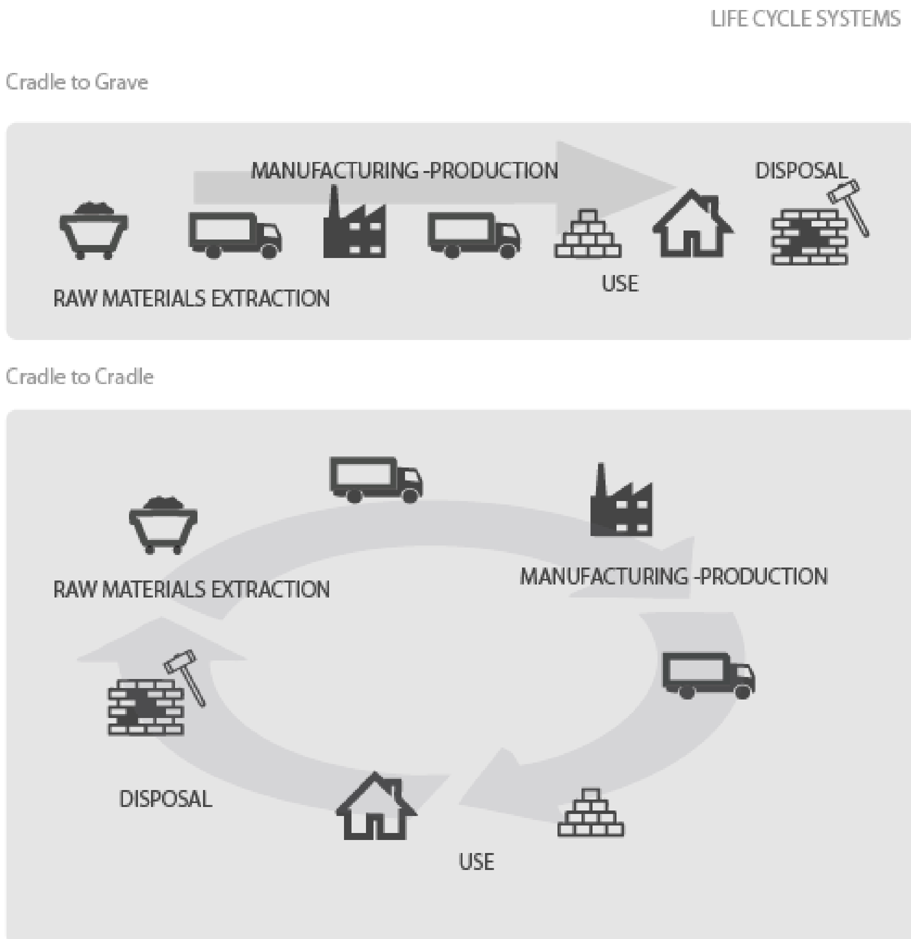


Figure 2 "Cradle to Grave" and "Cradle to Cradle" representations

Insights

It is relevant to mention the “cradle to cradle “perspective because of the positive implications that it could have in industry.

Linear practices in industry respond to a vision of the relationship between human and nature. This relationship has changed in recent time because of the awareness on environmental problems such as: pressure on ecosystems due to resource extractions, pollution trough manufacturing and disposal. The growing concern on this topics asks for a new perspective regarding natural cycles (McDonough & Braungart, 2002).

“Cradle to grave” is a paradigmatic approach to industrial systems, conceptualized on linearity. It tackles the resource extraction, the production and leaves the disposal part as a separate system where it is difficult to follow its possible implications once the product has been used. This model dominates today’s industry mode of operation.

“Cradle to cradle” authors make an analogy to explain products implications. They ask to think about a product as an iceberg; the visible part represents the 5% of resources needed for its production, while the remaining percentage represents all the resources implicated in the development of the product (i.e., raw materials extraction, production, transport)

Design solutions that had birth into the “cradle to grave”, are designed for the worst case scenario instead of being designed for the “suitable scenario” fitting with the living environment surrounding. It’s not about reducing the waste or avoiding it, nor either about being less bad to the environment, as the authors of “Cradle to cradle” explain, a good solution is not to repair the damage but to rethink the way things are being done (McDonough & Braungart, 2002).

Consumers must take the lead in reducing negative environmental impact, the authors argue: "The simple truth is that all of our major environmental concerns are either caused by, or contribute to, the ever-increasing consumption of goods and services" (Robert Lilienfeld cited on McDonough & Braungart, 2002).

Eco-efficiency and eco-effectiveness

On this basis approach two terms are defined: eco-efficiency and eco-effectiveness

Eco-efficiency: This term is subscribed in the linear system and consist on making the system efficient. The goal here is to be "less bad" by reducing adverse effects.

For the transition on the paradigm of the way of consuming and producing the next concept is emphasized:

Eco-effectiveness

For the authors of "cradle to cradle", being eco-effective is to work in the correct things instead of being less bad. In the design perspective, eco-effectiveness approach is not considered by its functionality or capacity to response to a need, but for taking into consideration the whole (McDonough & Braungart, 2002).

Biosphere and Tecnosphere.

"Cradle to cradle" authors address the tecnosphere and biosphere as two systems with similitudes having material flows. For the biosphere, biological nutrients enter to the system and give feedback; while in the tecnosphere, the technical nutrients are used to give input to the systems of industrial process.

Making this two systems comparable will help to improve considerably the use and performance of material and energy that serves as an input (nutrients). Design helps to accomplish this level of integration by eliminating the "waste" concept from the initial point of development of products and services (McDonough & Braungart, 2002).

When talking about waste it is often said that by reducing it, sustainable practices are partially achieved; however, to engage in sustainable practices, just as in natural systems the concept of waste should not exist.

"Cradle to cradle" is about mimicking or adapting the natural cycles and the industry cycles. Authors suggest that with a good design, products and its implications could feed both metabolisms.

Biological and Technical Metabolism

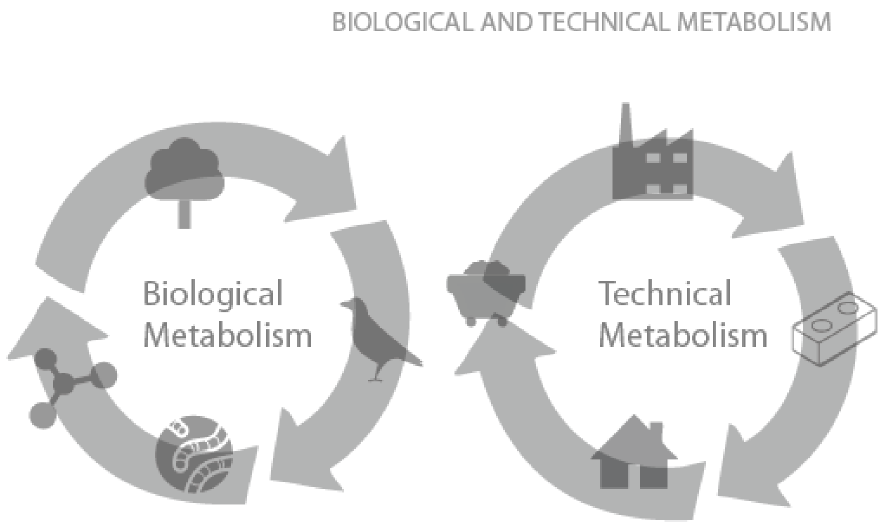


Figure 3 Biological and Technical metabolism

For the technical metabolism, just as in a biological one, nutrients should go back into the cycle, in this case nutrients are material or products (McDonough & Braungart, 2002). ***Figure 3*** illustrates de similarities between biological and technical metabolism.

For the industrial metabolism it is important to consider the concept touched before; which is the prevalence of services over products, regarding the functionality as a service leads to a changing perspective when highlighting the "nutrients" that are coming into the system (McDonough & Braungart, 2002).

Designing regarding the local

> *"Industries that respect diversity engage with local material and energy flows, and with local social, cultural, and economic forces, instead of viewing themselves as autonomous entities, unconnected to the culture or landscape around them" (McDonough & Braungart, 2002, p.132).*

Sustainability is local, in the sense that when designing it must expand considerations and recognize its effects. It is also important to consider that design solutions are not just of one kind that should stick to every problem; a good analysis of the current situation and scenarios help to achieve innovative solutions. Connecting technical flows to natural flows enhance products and services that have nutrients that return to the system (McDonough & Braungart, 2002).

Instead of the well-known "form follows functionality", "cradle to cradle" perspective suggests "form follows evolution"; this means that a product conception takes into account: materials, processes, use and its performance in time and space.

Again natural systems and performance take relevance when introducing the term "eco-effective", eco-effectiveness follows natural laws (McDonough & Braungart, 2002).

> *"What goes for aesthetic goes for needs, which vary with ecological , economic , and cultural circumstances- not to mention individual preferences" (McDonough & Braungart, 2002, p.152).*

Eco- effective design is also about respect that overcomes all the processes within the system in which a product is subscribed, it’s about: the extraction of materials, the use of it, the manufacture process, who is working, by which circumstances, its social impact in the stages, the user. The resemblance to the living world makes the human creation most effective.

As mentioned before, this switch of the system is not a day-night change; making better solutions within the paradigm in the *status quo*, just makes solutions inside the *how to* of an operating model; instead, switching the way of thinking leads to a complete different paradigm where new opportunities of change are possible (McDonough & Braungart, 2002).

Life Cycle Assessment

About Life Cycle Assessment

Products contribute to environmental stress because of raw material extraction and energy consumption; to carry on environmental impact studies, LCA (Life Cycle Assessment) is a tool that helps to quantify them by analyzing product materials and interactions through all the life cycle stages (Wolf, Pant, Chomkhamsri, Sala, & Pennington, 2012).

LCA is a suitable tool because it has a scientific and quantitative framework for analysis; it also can be applied to a diverse range of products of different nature and on diverse scales (i.e., company, technology, country, etc.). It integrates all the stages throughout a product life cycle, helping to identify different problems (Wolf et al., 2012).

As suggested by William Mc Donough & Partners (1992) LCA is a tool that covers just one part of the evaluation where the complexity of the system and its interaction can be addressed; it can be seen as an "open concept" that still needs development to be a realistic tool.

Life Cycle is a key tool when evaluating a product performance because of the opportunity that it brings to identify the opportunity areas of change. Also, it gives an overall view of the system where a product is subscribed; when complemented by other assessment tools analysis of a product could be more assertive.

Life Cycle Assessment Types

There are different types of life cycle assessment that help to approach the social- economic and environmental aspect of a product. ***Figure 4*** shows the different topics that this assessments cover: Environmental Life Cycle Assessment is the technical environmental assessment, while LCCA (Life Cycle Cost Assessment) covers the cost-effective relation of product and S-LCA (Social Life Cycle Assessment) cover social issues.

Integrating the three topics leads to a wider view and more comprehension of the problem, leading to better solutions.

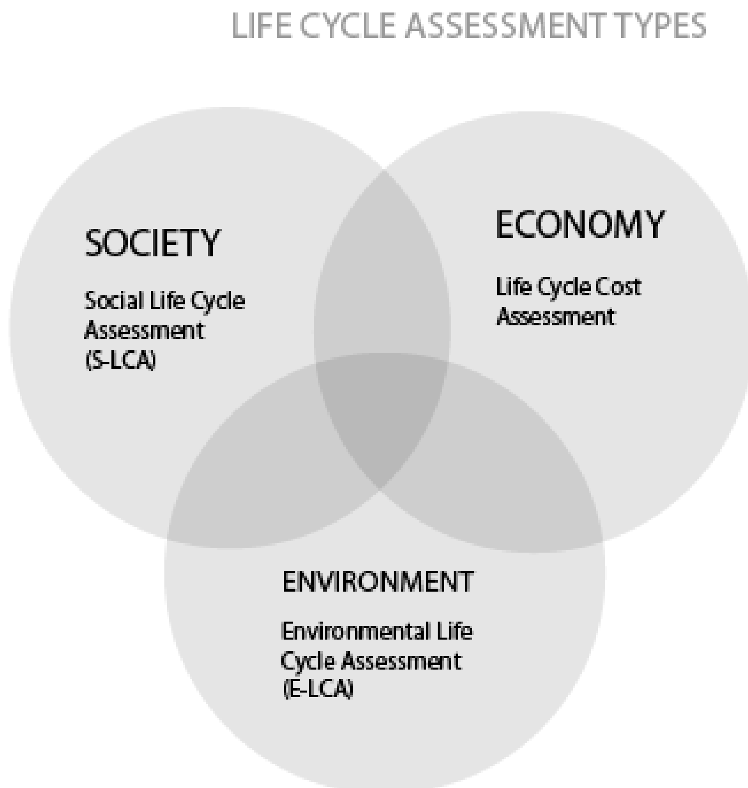


Figure 4 Life Cycle Assessment Types.
Note: Adapted from the IES blog.

Life Cycle Assessment Phases

LCA consist in three main phases: inventory, impact analysis and optimization.

Inventory phase involves: energy and raw materials acquisition, manufacturing, transport, use and maintenance, recycle and waste management. See ***Figure 5.***

Impact Analysis assess: the environmental stress identified in the inventory phase. See ***Figure 6.***

Optimization: this is the feedback part of the LCA, where by the evaluation of the system performance, and by using qualitative and quantitative methods, opportunities and weakness can be identified. See ***Figure 7.***

Inventory phase:

Involves energy and raw materials acquisition, manufacturing, transport, use, maintenance, recycle and waste management.

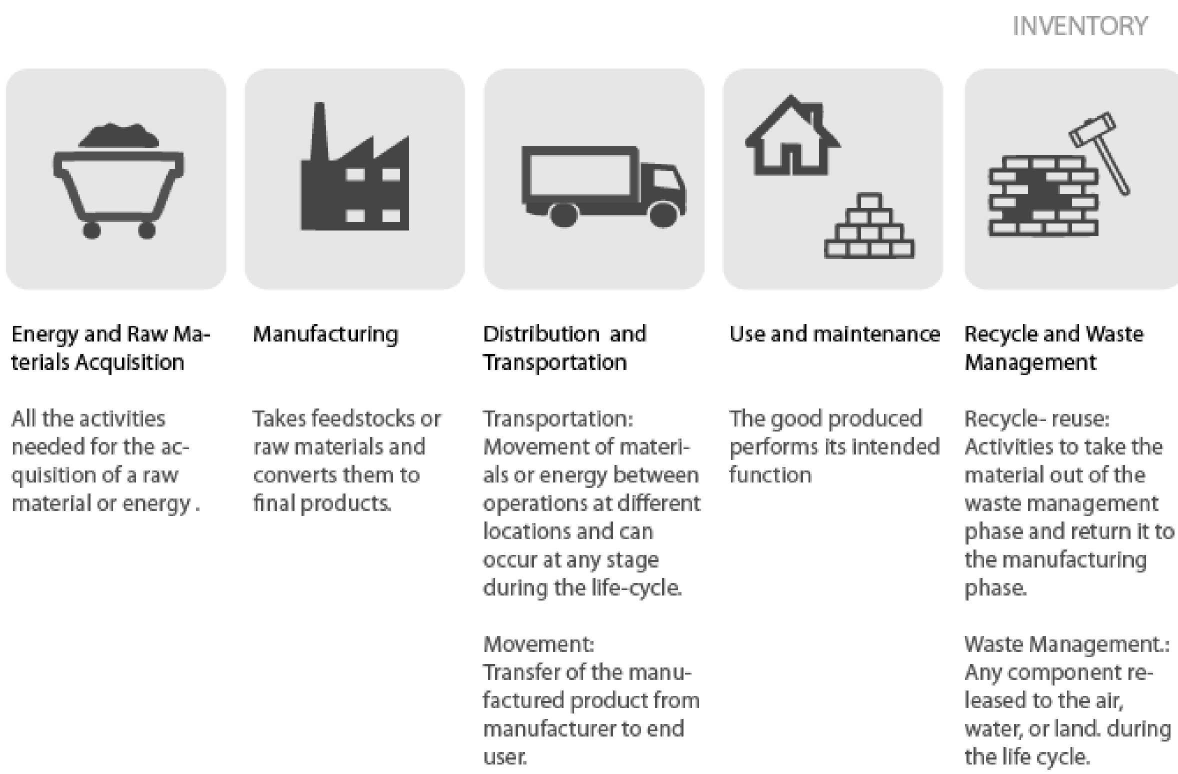


Figure 5 Inventory Phase .
Note: Information adapted from (William Mc Donough & Partners, 1992).

Impact Analysis: Address the effects caused by the life cycle in: ecosystems, human health, resources, etc.

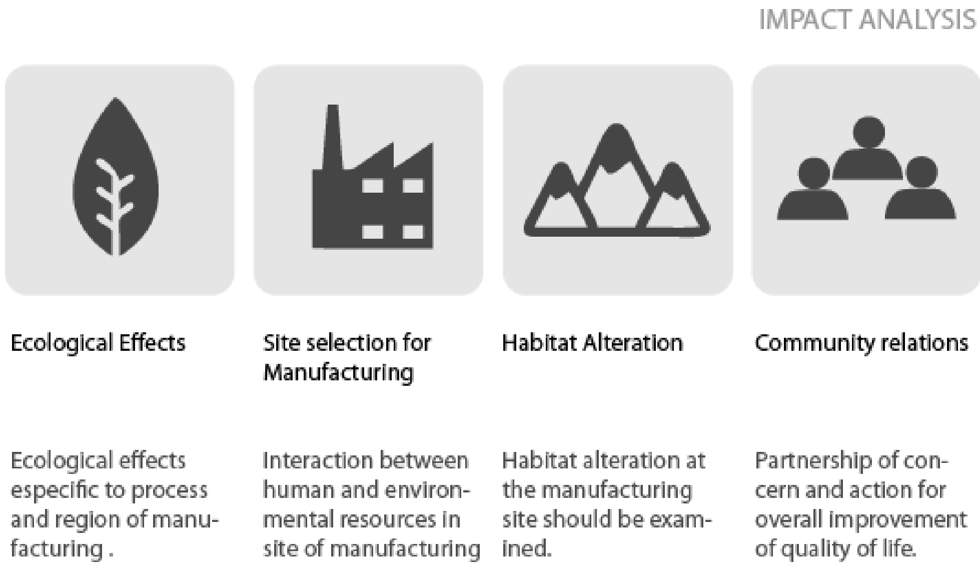


Figure 6 Impact Analysis.
Note: Information adapted from (William Mc Donough & Partners, 1992).

Optimization:

Figure 7 Optimization .
Note: information adapted from (William Mc Donough & Partners, 1992).

The Design Process

Industrial design is a creative activity that constitutes the material environment by satisfying the material and spiritual needs. The purpose of industrial design is reached by establishing the formal properties of industrial products. Industrial design activity can be considered as a “neuralgic area” when talking about objects interaction in the environment; as the decisions for the design process determine a relationship between man and nature (Bonsiepe, 1978).

When designers start giving direction to design activities towards environmental problems, “survival through design” will become validate instead of “disaster trough design” (Bonsiepe, 1978).

Rethinking the way things are done is a first step into the design change. This transition to change can start by rebalancing the way a problem is framed, the analysis of the system and its repercussions and its influences trough time and space. Ecological design should not focus on the object itself but in its complex interactions (Ellen Macarthur Foundation, 2013).

Problem and Requirements

Because this study highlights not just the importance of carrying on a study for the life cycle of a product, but also the importance of the first stages of its development. This chapter is about the design perspective for the creation of products.

As a general description of design, it can be said that :the design activity can be understood as a creative activity that constitutes a material environment to support spiritual and material needs (Bonsiepe, 1978) .

The design process implicates a general vision of the system to be addressed. To introduce this subject I would like to point that there are several design methodologies, but even when the process can vary, almost all start with a problem as response to human needs.

One current thought when addressing a problem is that the solution is inherent to it. When taking this approach the definition of the problem outlines a solution. The design practice inquires a delimitation of a problem to understand the needs in order to come with a solution. Once the problem is stated, so are the needs.

With this framework of problem and needs, is coherent to proceed with the requirements; which help to give a product or service specific characteristics through its performance. As this study intends to cover the life cycle perspective from “cradle to cradle” as much as possible, a cycle perspective should be used.

Design process archetype

The design process archetype structure holds and input and an output, see ***Figure 8,*** in between there is a process. This process can be held in different ways, from the linear to the circular or cyclic perspective.

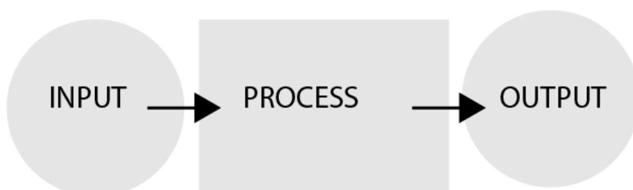


Figure 8 INPUT - OUTPUT Note: Adapted from (Hugh, 2005).

The process is the step where information is analyzed and synthesized. According to Koberg and Bagnall in Hugh (2005*)* the analysis consist on the examination of the problem by breaking it in parts in order to reconstruct them in accordance to our understanding; this second part is the called “synthesis” , see ***Figure 9.***

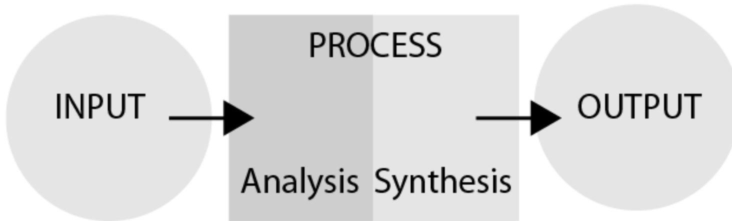


Figure 9 Analysis, Synthesis
Note: after Koerg and Bagnall , 1972 in (Hugh, 2005).

Problem and Solution

From different perspectives when approaching a problem, what can be said is that once you have a problem a solution is somehow there, as an inherent consequence of it. There are different systematic approaches to get to them, as a sequence, as a parallel process or as a loop, see ***Figure 10.***

The understanding of the problem and the way it is conceived is strongly linked to the solution that is going to be given.

As mentioned by Rittel and Webber,1973 in (Hugh, 2005)*:*

> *"The information needed to understand the problem depends upon one's idea for solving it." "Problem understanding and problem resolution are concomitant to each other."*

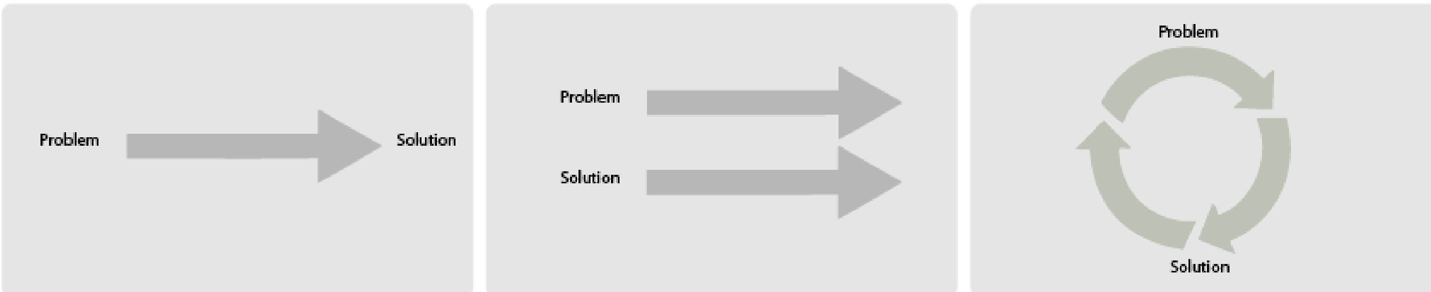


Figure 10 Problem- Solution.
Note: Adapted from : (Hugh, 2005).

Ecolabelling

"Individuals, companies, and customers can now fast- track adoption by exercising their right of choice to demand, take up, and—jointly with the provider—continually improve products and services" (Ellen Macarthur Foundation, 2013, p. 82).

About Ecolabelling

An Ecolabel is a label that provides consumers information relative to environmental aspects of a product. This information is based on life cycle considerations; its goal is to communicate environmental aspects of a product by giving accurate and verifiable information in order to increase the demand on products and services that cause less stress on the environment. They surge as a response to the growing concern for environmental protection, and also serve to aware consumers of environmental implications produced by their choices (Global Ecolabelling Network, 2004).

They can be used as a market-based instrument to seek environmental improvement (protection and conservation) and represent a market advantage.

Ecolabelling has its origins in the growing concern of environmental problems, serving also as a tool for governments and non-governmental authorities to encourage production and consumption of environmentally preferable goods and services (Global Ecolabelling Network, 2004).

Consumer awareness of environmental issues related to products can be raised with ecolabelling programs. A trusted ecolabel can promote environmentally beneficial actions. An ecolabel has to be trusted by the consumers; this is achieved by providing reliable information of the environmental impact of a product (Global Ecolabelling Network, 2004).

Product environmental criteria should be based on indicators from life cycle considerations to provide information related to all aspects of product performance (i.e., development, provision, use and end of life). Labels need to have guiding standards in order to give accurate information to consumers.

To reach credibility, ecolabelling programs should be able to be observed and analyzed at any time; this depends on: the quality and performance of the product, as well as the credibility of the information provided by the producer. (i.e., credible, relevant, measurable criteria). Ecolabelling criteria helps to identify the opportunities phases of a product, aiming to encourage the demand and supply of products which cause less stress on the environment (Global Ecolabelling Network, 2004; ISO, 2012).

According to the GEN (2004), positive responses of industries and consumers suggest that ecolabels are being successful in providing environmental information to consumers.

Ecolabelling definition

According to the Global Ecolabelling Network (2004), an “Ecolabel is a label which identifies overall environmental preference of a product or service, within a product category based on life cycle considerations.”

The objective of ecolabelling, according to the International Organization for Standardization (ISO), is to encourage the demand and supply of products that cause less environmental stress, trough communication of accurate and verifiable information on environmental aspects of products and services (Global Ecolabelling Network, 2004).

Ecolabelling programs are voluntary, and are used as a tool in the marketplace to enhance environmental goals. For producers they serve as a marketing tool to improve their image in the market place (Global Ecolabelling Network, 2004).

Participants

To achieve a successful level of environmental performance communication, multiple stakeholder's participation is important, see ***Figure 11***. The support and involvement of interested parties gives credibility to ecolabelling programs.

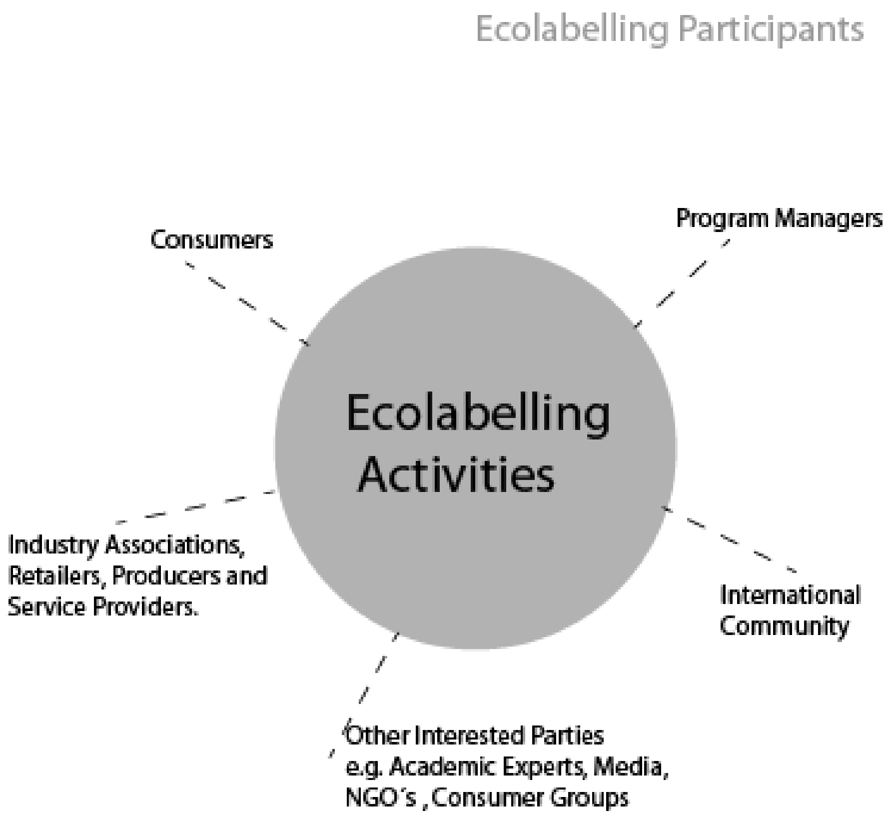


Figure 11 Ecolabelling Participants.
Note: adapted from (Global Ecolabelling Network, 2004).

Government: Government can influence the demand of ecolabelled products by initiatives and activities.

Industry and commercial associations (retailers and companies): Product producers and service providers in representation of industry have a key role, formulated criteria for certification and licensing should be credible, verifiable and practical for the market place.

Consumers: For ecolabelling, consumers should be considered as the generators of market impact in relation with their demand.

Ecolabelling types

(ISO, 2012) classifies types of labelling by number, see ***Figure 12.***

Type I: Ecolabells based on the fulfillment of a set criteria, expressed with a mark or logo.

Type II: Self-declared environmental claims

Type III: formalized set of environmental data describing environmental aspects of a product.

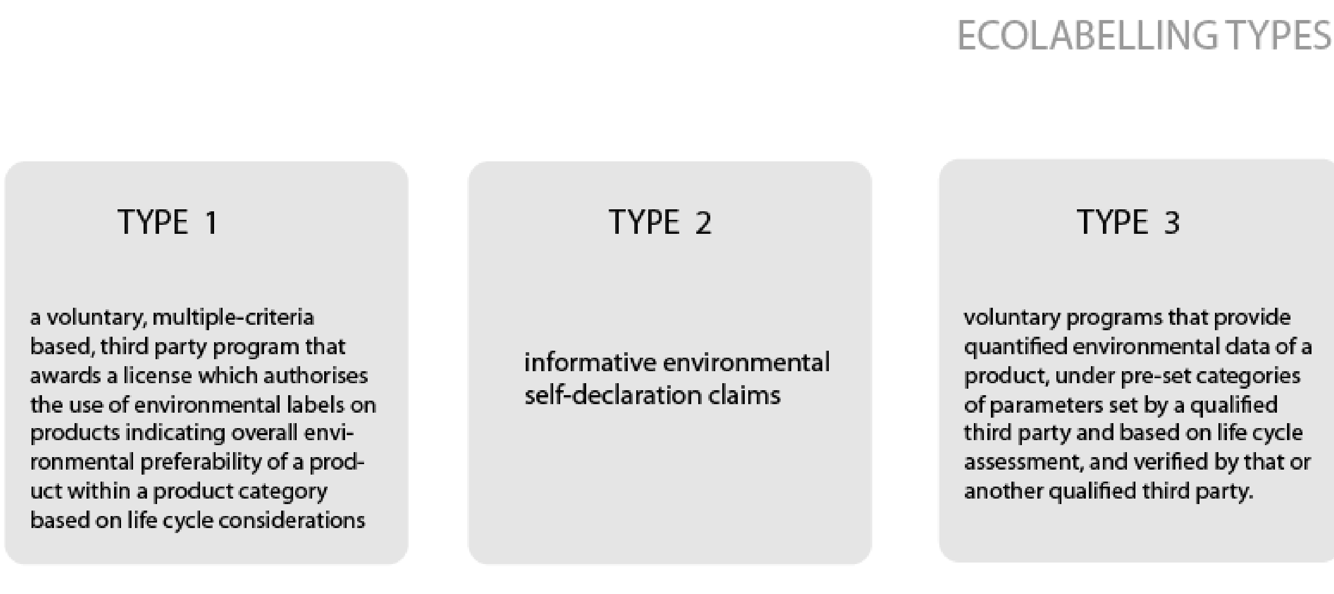


Figure 12 Ecolabelling Types according to the International Organization for Standarisation (ISO).

Green washing

One major drawback of this approach is that there is a need of consistence in ecolabelling schemes and transparency to avoid “green washing”.

The term “green washing” is used to refer to environmental claims, with a marketing purpose, that undercover industry practices, portraying them as “sustainable” or “green” practices.

Because of that, ecolabeling could appear to be a tricky alternative. International Standards as ISO help to synthetize scientific information, into environmental claims. This ensures that the consumer is receiving valid information from manufacturers, avoiding the “green washing” (ISO, 2012).

A key indicator of positive performance is the consumer demand, these points to a consumer “Eco label recognition”. To avoid “green washing” there should be a balanced representation from all the parties involved in order to give preference to a specific sector or stakeholder interest (Global Ecolabelling Network, 2004).

Difficulties arise; however, when information is not accurate or results confusing to the consumer; this misleads the objective of an Ecolabel, discarding the importance of the real environmental impact that a product has.

ISO Standard for self- declared claims

ISO 14021:1999

As mentioned on ISO (2012), in order to have an accurate claim, the provider must have the information available for further revision; including the test or method used, documentary evidence for product testing, test results, and the information of the independent parties when use, to evaluate a claim. Product environmental criteria encloses: the local, regional and global environmental issues, technology and economic aspects.

According to ISO data requirements should be accurate and not misleading, substantiated, verified and not misinterpreted.

For self-environmental claim the information must be open to the public and has to be verifiable and transparent. Life Cycle must be taken to establish environmental criteria (i.e., resource extraction, manufacture, distribution, use and disposal).

Methodology

The methodology structure represented in ***Figure 13,*** represents the tools and phases used to develop the Product Evaluation Guideline.

Phase 1 consisted on review of literature regarding: Life cycle assessment, eco-labelling, consumer behavior and design processes. For a wider view of the topics, theoretical framework provides more information.

By carrying a life cycle assessment on the compressed adobe block, taking into account the theoretical framework, the first phase of the guideline was developed. This phase took some design methodology frameworks for the problem and requirements statement; after that a system analysis is performed parallel to the life cycle assessment for a further qualitative analysis of the environmental impact throughout life cycle.

Phase 2 is a qualitative recommendation to present the information obtained from the product evaluation guideline (Phase 1). It is represented in form of a self-claim.

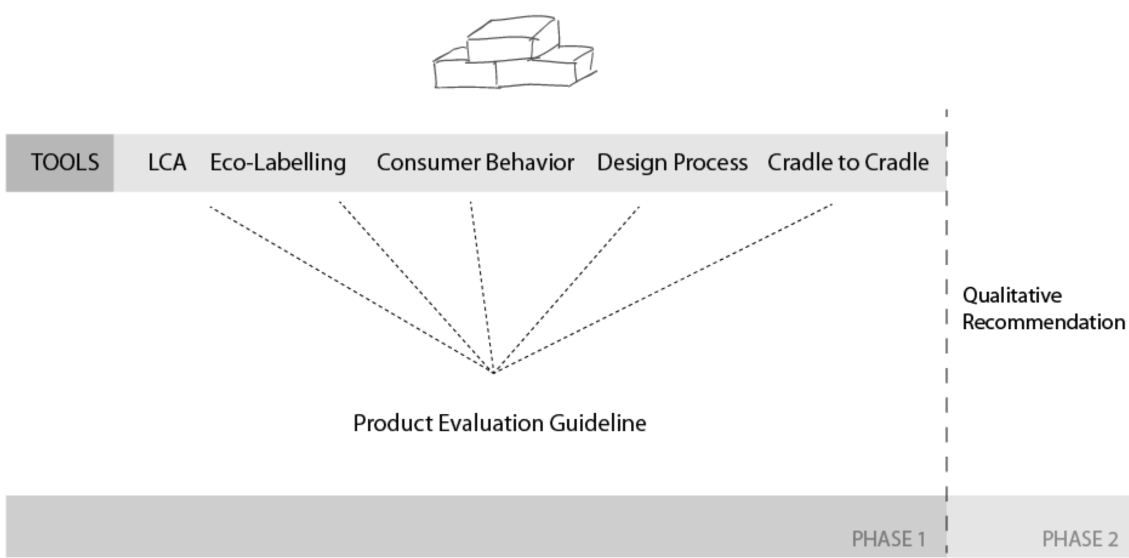


Figure 13 Thesis methodology scheme.

Note: The following study follows the LCA standards dictated in the ISO 14040:2006

Life Cycle Assessment

Introduction

LCA[1] is an assessment tool on environmental aspects and potential impacts throughout a product´s life. In the perspective of “cradle to grave”, it analyses the data related to acquisition of raw materials through production, use and disposal.

LCA framework involves the next phases: goal and scope definition, inventory analysis, impact assessment and interpretation. These phases are detailed described in the following pages, see ***Figure 14***.

It helps to improve the environmental performance of products through different stages of life cycle; infers in the decision making process for: industry, government and non-government planning, design process, strategic planning, selection of environmental performance indicators, marketing of products including environmental claims, labeling and declarations (International Standard, 1997).

[1] LCA : Life Cycle Assessment

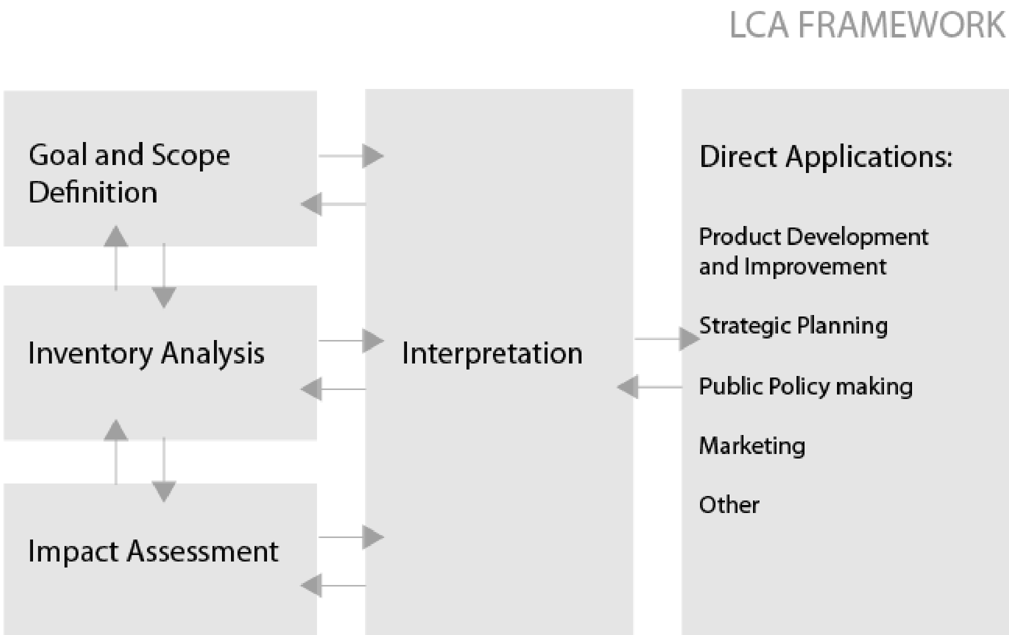


Figure 14 LCA Framework, Data from ISO 14040:2006

Goal and Scope definition

As the first step of the intended study, goal and scope have to be described in detail and in accordance to the application of the study.

Goal: The goal of an LCA study states the application and reasons for carrying it; it also should specify the audience to whom the results are going to be reported.

Scope: The scope needs to be covered in depth, detailed and consistent in order to address the goal. The following points need to be covered to establish the scope of the study:

Function and Functional Unit

Functions of the product or system: Specify the functions of the system.

Functional unit: It must be defined and measurable; it measures the functionality of the product.

System Boundaries

In system boundaries the processes to be included are determined; inputs and outputs should be selected in order to be consistent with the goal of the study previously determined. Elementary flows are inputs and outputs in the modeled system.

Data requirements

Specify the requirements of data to be used for the LCA, the quality of data should facilitate to address the intended goal and scope. The following information is needed to be provided:

Assumptions
Limitations
Initial data quality requirements
Type of critical review
Type and format of the required study

System Boundaries: Gives a framework to organize the information within the system. This includes processes and their interactions; the wider the processes, the more complexity that exists and its interactions. This includes processes from the different stages (i.e., raw materials, transport, manufacturing, use and disposal).

To show the interactions between the processes a flowchart is helpful because it can represents its interactions, see ***Figure 15***.

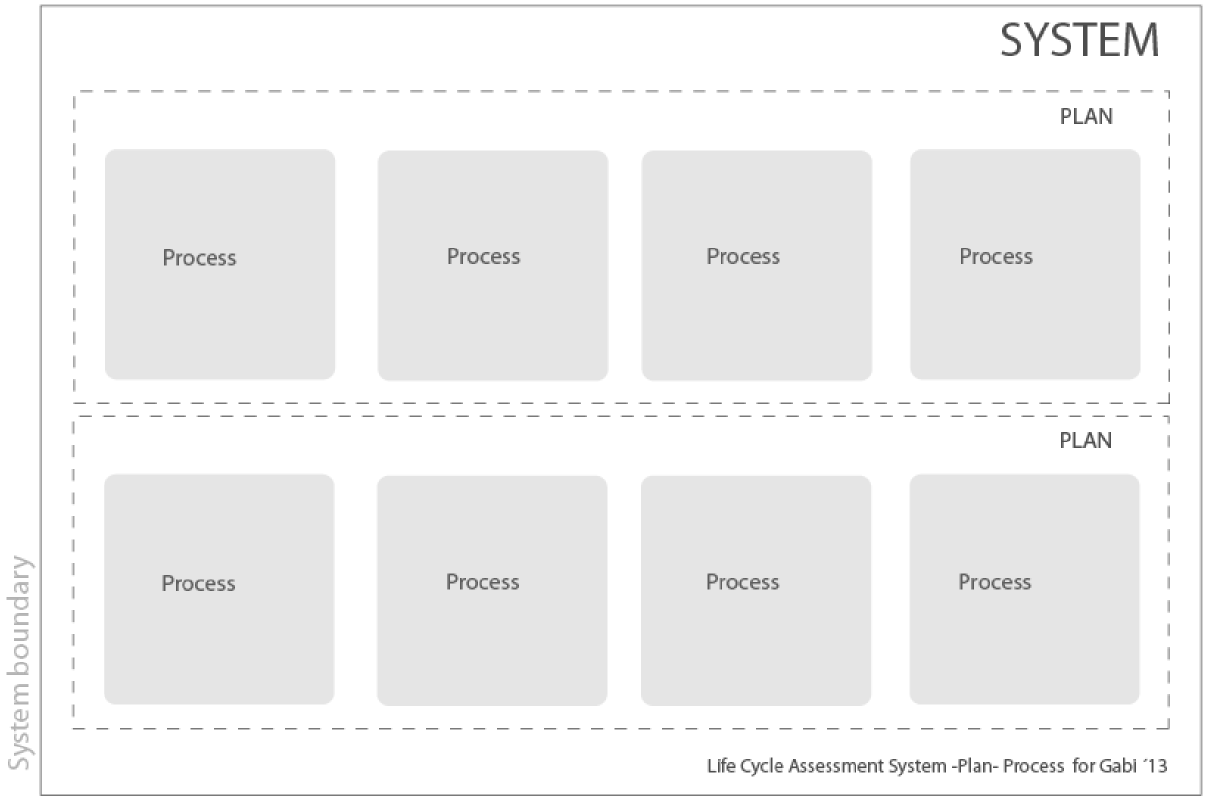


Figure 15 Life Cycle Assessment Framework . System-Plan-Process.

Unit process: A unit process represents a specific process, where an input and output can be determined. They can represent an operation, a series of steps or composite systems, see ***Figure 16***.

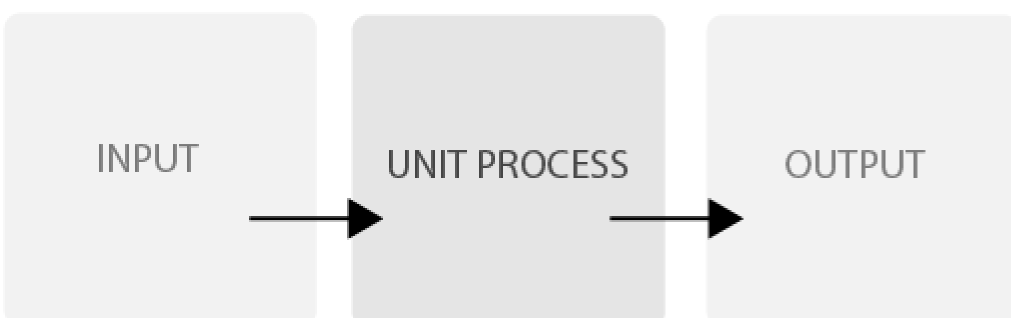


Figure 16 Input- Unit Process- Output

GaBi processes

As the study was carried with the help of GaBi software, the description of types of processes are explained in ***Figure 17***.

PROCESS : life cycle inventory / eco-profile

PLAN: a collection of processes / process chains (also known as a system)

Gabi SYSTEM-PROCESS

agg	In contrast to unit processes, an aggregated process contains the entire life cycle data for part of or for the complete life cycle of a product system. This kind of dataset is often referred to as a cradle to gate or system process
aps	An 'avoided product system process' containing the life cycle information for a product system or part of the system that can be "saved" when a secondary material is substituted for a virgin one ("credit"). Avoided product system data sets are especially used in the context of allocating environmental burden in the presence of recycling or reuse.
p-agg	A partly terminated system contains all LCI data for the process except for one or more product flows that require additional modelling. For example, the steel wire process is a partly terminated system because all of the inputs and emissions for the process are accounted for except for the type of steel being used to make the steel wire. This process type is sometimes referred to as a partly linked process.
u-bb	A unit process black box, represented by u-bb, refers to a multifunctional process or process chain at a plant level. This type of process may represent a group of processes rather than a single process step. For example, the entire production chain of a computer keyboard key (excluding acquisition of raw materials) rather than the individual manufacturing and transport processes for the keyboard key. u-so
u-so	A unit process single operation is often referred to as a unit process or gate to gate process. This process type contains only the data for one specific process step and no LCI (or Life cycle inventory) data

Figure 17 GaBi System - Process definition. Note: Information adapted from (GaBi, 2013)*.*

Life Cycle Inventory Analysis

This phase involves data collection and calculation procedures to measure inputs and outputs of the product system to be studied as material for the impact assessment phase.

- Data for the calculation procedures could be qualitative or quantitative.
- This data should be recovered for each unit process within the system boundaries.
- Procedures of data collection may vary depending on the goal and scope of the study.

Life Cycle Impact Assessment

In this phase results from the life cycle inventory analysis are used to evaluate the potential environmental impact. These results are associated to specific environmental impacts.

- Model of impact categories should be assigned.
- In this phase the objectives of the study should have been met.

Life Cycle Interpretation

Inventory analysis and impact assessment are combined in this phase.

- Interpretation phase output covers the conclusions and recommendations for decision-makers.

Case of study- Compressed Adobe Block

Life Cycle Assessment

Introduction

The following case study is one of the tools to accomplish the objective of identifying the stages and areas of opportunities on environmental improvement along life cycle .The methodology is followed as stated at the ISO 14040:2006.

The object of study is a compressed adobe block, developed by the UASLP[2] for urban use. Being considered as a traditional construction material, the adobe appears to be a suitable regional alternative. The possibility of production and use of this traditional material in the region of San Luis Potosí, could give an alternative solution to social and environmental problems related to construction materials.

According to the authors one of the main problem was the lack of documentation of traditional techniques on urban construction; because of that the adobe block was submitted to several tests to prove its comparable performance characteristics with other materials used in urban construction, such as the traditional brick (Rodríguez Hernández, Algara Siller, Cárdenas Martínez, & Arista González, 2014).

The product was submitted to previous studies; including granulometric testing, and compressive strength. The proposed material covers the applicable regulations and technical requirements for construction in San Luis Potosí, México.

Hereafter more detailed information about the product is given.

[2] Universidad Autónoma de San Luis Potosí (UASLP), Facultad de Ingeniería – Ciencias de la Tierra .

About the Compressed Adobe Block

Note: Before carrying the LCA study, I consider of relevance to present the most possible information about the product and its implications in order to have a complete picture of the system where the product is subscribed. This will help to understand further studies and relation with other topics among this thesis.

Adobe Definition

Following Cambridge definition[3] an adobe is a mixture of earth and straw made into bricks and dried in the sun, used to build houses in some parts of the world.

Compressed Adobe Block (Hallowed)

A compressed earth block (CEB) is an earth block or adobe block, it is compacted to improve its quality and performance. For this study the name given to the product is: Compressed Adobe Block, but theoretical it is a CEB. This kind of blocks represent an improvement over traditional earth building (Guillaud, Joffroy, Odul, & Eag, 1995).

Because of the machine characteristics the product can be hallowed, the voids could account from 5 to 30% of the block, improving adherence of mortar, and reducing the weight and use of material (Guillaud et al., 1995).

[3] Definition taken from Cambridge University Press 2015. Dictionaries Onlinehttp://dictionary.cambridge.org/dictionary/british/adobe

Product Brief

Product: Compressed Adobe Block

Place of Origin: San Luis Potosí – México/ Arid and semi-arid region

Location: México

Materials and Components

Materials in ***Table 1*** correspond to the sample "L" from the article "Urban adobe design for housing construction in Mexico"(Rodríguez Hernández, Algara Siller, & Cárdenas Martínez, 2014). Each sample corresponds to the productions of approximately 3 blocks. This information was used for previous analysis at the LCA stage.

Material	Amount	Percentage
Soil 1 (Kg)	22	
Ixtle (Kg)	0.025	2
Lime (Kg)	1.5	6
Gypsum (Kg)	1.5	6
Water (L)	3	
Mucilage (L)	2	

Table 1- Sample "L"

Machinery

Adopress 1000 [4] is the machine used for the elaboration of the blocks. The machine characteristics are the following: ***Table 2 and Figure 18.***

Adopress model	HP	Personnel	Pieces by unmold. 10 * 15 * 30 cm	Production in 8 hrs. 10*15*30 cm
1000	2	3	1	700

Table 2 Adopress 1000 caracteristics.
Note: Data from ITAL MEXICANA S. A.

Energy Consumption: 2.873KWh per block.

Figure 18 Adopress 1000
Source: ITAL MEXICANA

[4] http://www.ital.com.mx/adoberas.html

Technical Specification

Size: According to the Adopress manufacturer the final size of the brick using this machine is: 30*15*10 cm

Load Capacity: 90 kg/cm2 (up to 3 loadbearing walls)

Product´s Service Life: 50 years[5]

[5] According to Federal Official Gazette (SEGOB ,Mexico) DOF: 15/08/2012, housing service life corresponds to approximately 50 years.
http://www.dof.gob.mx/nota_detalle.php?codigo=5264340&fecha=15/08/2012

Source of materials considered in the LCA assessment

San Luis Potosí – About the region and its materials

Here it is important to highlight: the considerations of use of resources and the resources bank, as long as the usability and functionality of the product in relation to its interaction with the environment and repercussions in the social context.

As described before, the use of local materials was a main consideration when carrying the Adobe Block studies by the UASLP, due to this a following explanation of 3 main components for the sample are described . The three of them have bank sources among the state of San Luis Potosí in Mexico, which is also the intended place of use.

Ixtle (*Agave Lechuguilla*):

Ixtle is a fiber obtained from the maguey (*Agave lechuguilla*); it serves as a substitute of the straw for the elaboration of adobes. The material is abundant in the semi-desert center zone of San Luis Potosí State, see ***Figure 19***.

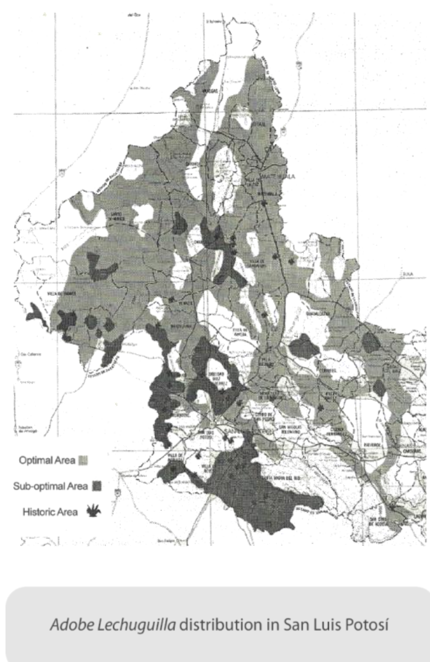


Figure 19 - Ixtle Distribution - San Luis Potosí , México, Adapted from : (Aguirre Rivera, Charcas Salazaar, & Flores Flores, 2011).

Mucilage:

Mucilage is subtracted from the nopal cactus *(Opuntia robusta)*, it's a viscous liquid that because of its properties helps as waterproofing element when applied at the exterior. It has been broadly used as an additive for waterproof paint (Aguirre , 2011 as reported in Rodríguez Hernández, Algara Siller, & Cárdenas Martínez, 2014).

The process for obtaining of the mucilage has been a well-known practice for years; this material is also common in the region of the study. In the case of the adobe block also serves as a binding agent.

Soil- Clay:

The soil used for the adobe block comes from the municipality of Villa de Arriaga in San Luis Potosi (Siller, Cárdenas Martínez, Arista González, & Rodríguez Hernández, 2012).

The soil used for the elaboration of the blocks has its bank material at 100 km from the city where the product is being intended to be applied, see ***Figure 20***, in order to be in an acceptable range, the bank of material should be situated at half of the actual distance (Rodríguez Hernández, Algara Siller, & Cárdenas Martínez, 2014).

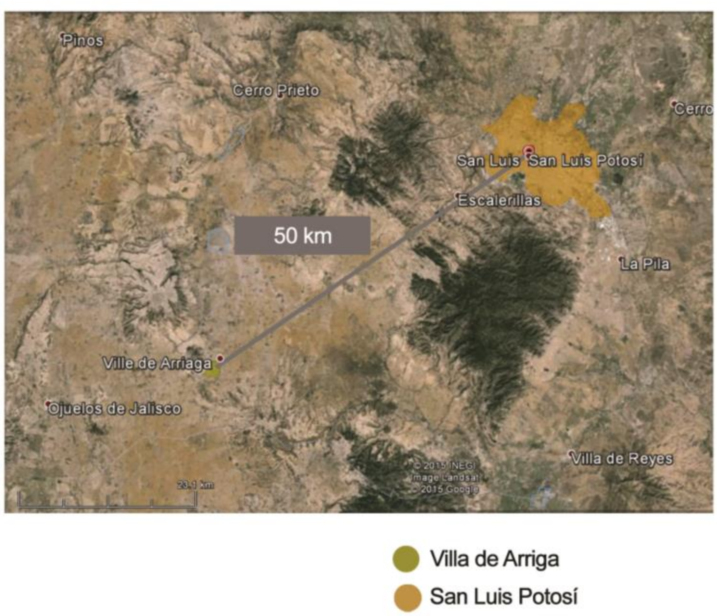


Figure 20 Distance between "Villa de Arriaga" and San Luis Potosí.
Source: Google Earth 20015.

Process

For the process, three materials are considered to be reported: ixtle, mucilage and soil. They were specially considered for this study because of its relevance and meaning on the site of intended application and because of their characteristics to reduce environmental impacts, see***Figure 21***.

The process of the adobe block starts with the extraction of raw materials. Starting with the soil, the material is extracted from "Villa de Arriaga", transported to the site for production; there the soil should pass through several grids until the desired size of the grain is obtained. Parallel to this process the mucilage and ixtle are obtained.

In the case of the mucilage, it is exuded by the nopal cactus and collected; the mucilage should be used in the first three days from collection, with more than 3 days the material starts to lose its properties. The ixtle, which is a fiber extracted from the maguey, has diverse techniques for extraction.

Once all the elements are obtained, they are mixed with the help of an industrial mixer; gypsum, calcium and lime are mixed with the soil, using water and mucilage as additives. After that the obtained mix is poured into the mold of the Adopress machine and it is compressed; once the process is done, the block needs to dry at ambient temperature, and it does not need any kind of oven. When the block is dry, the block is ready to be used.

Figure 21 Compressed Adobe Block process.

Note:

It is of high importance the use of local materials. In the case of the adobe, due to its properties, it is suitable for construction on the Medium Zone and the Huasteca in San Luis Potosí where precipitations are abundant (Rodríguez Hernández, Algara Siller, & Cárdenas Martínez, 2014).

One of the main advantages of the compressed adobe block, regarding the process, is that it does not need the use of furnaces. This avoid the high temperatures used in traditional brick, that contribute with pollution and greenhouse gases (Rodríguez Hernández, Algara Siller, Cárdenas Martínez, et al., 2014).

As mentioned before the material characteristics give a better thermal performance in accordance to the temperatures and type of climate. Also, at the disposal stage, this material can be reintegrated into the natural environment once the function stage is finished (Rodríguez Hernández, Algara Siller, Cárdenas Martínez, et al., 2014).

The adoption of the adobe block as construction material in urban areas, in this case: San Luis Potosí, could also have positive social implications.

Nowadays the traditional brick as construction material used in San Luis Potosí has been related to illegal practices in the suburbs of the city, where waste such as: tires, plastics, etc. are used as fuel for the furnaces. This kind of practices lead to negative environmental impact but also, in the social context, represent non-optimal conditions for working.

LCA report

For the first part of the LCA study, the following structure was used to settle down: the goal and scope, the function and functional unit. ***Figure 22*** represents the path followed to determinate the previous mentioned concepts, and their direct interaction.

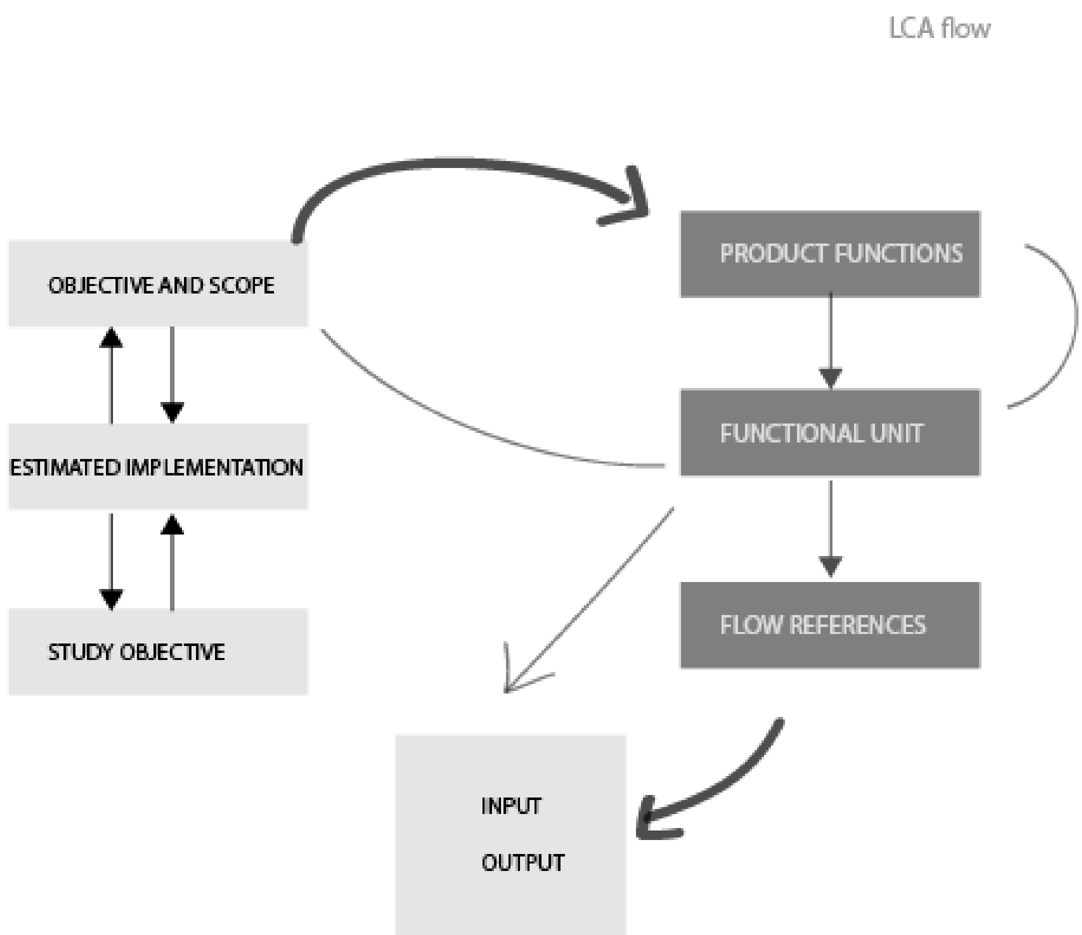


Figure 22 LCA steps for intended study

Definition of goal and scope

Goal of the study

The current LCA study intend to find the significant phases of a consumer good, in this case by the study of a compressed adobe block developed by the UASLP[6] .

The main objective is to understand the implications of each state of production and use, following a "cradle to gate" framework in order to identify main topics towards environmental evaluation. The reasons for carrying this study are to highlight the importance of a review of stages among a life cycle of a product and the possibility to identify at an early stage the opportunities of improvement.

The results will be used as a basement, using the opportunities of improvement found through all the stages, to perform a better relationship with the environment; where the use of material, social and economic implications would be taken into account. Also, these results are going to be used to establish the main information to be reported at an environmental claim.

It is important to mention that the main interest of this study is not a quantitative result, even though it's important to mention that quantitative data is useful to corroborate the qualitative interpretation, but the interpretation trough the analysis.

Scope of the study

Functions of the product system

The function of the compacted adobe block is to constitute a wall system for construction by giving support and structure in order to delimitate a space. This product is suitable to construct up to 3 loadbearing walls (Siller et al., 2012).

[6] Universidad Autónoma de San Luis Potosí

Functional Unit

The selected functional unit for the study is one adobe brick, see ***Figure 23***, it was selected for the purpose of the study due to the information and the process; however, as other studies carried with construction materials suggest, the functional unit could be consider as 1m² of a construction wall, see ***Figure 24***. The period of time suggested for life service on construction materials is around 50 years.

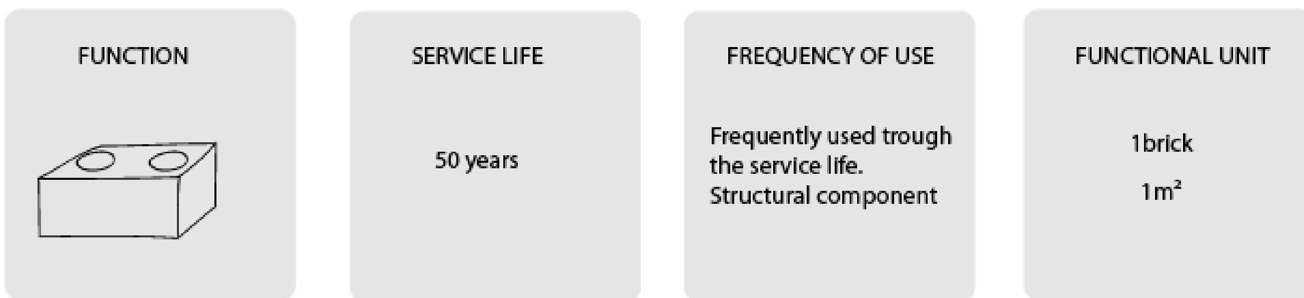


Figure 23 Functional Unit Components.
Note: Adapted from González Maza, 2012.

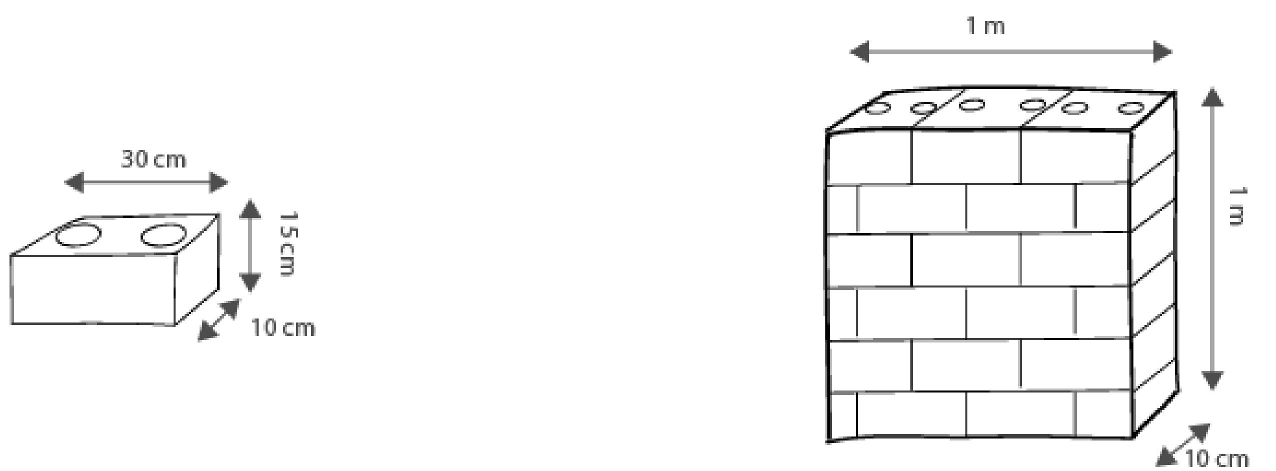


Figure 24 Functional Unit measures.
**** aprox. 20 compressed adobe blocks per wall.***

Product system to be studied

The adobe product system cover the stages involved in the production and use of the compressed adobe block. The earlier stage comprise raw materials collection, followed by manufacturing process, transport, use, disposal and possible reuse of materials, see ***Figure 25.***

The framework where the system is inscribed is in the "cradle to cradle" model, because of the compressed adobe block nature.

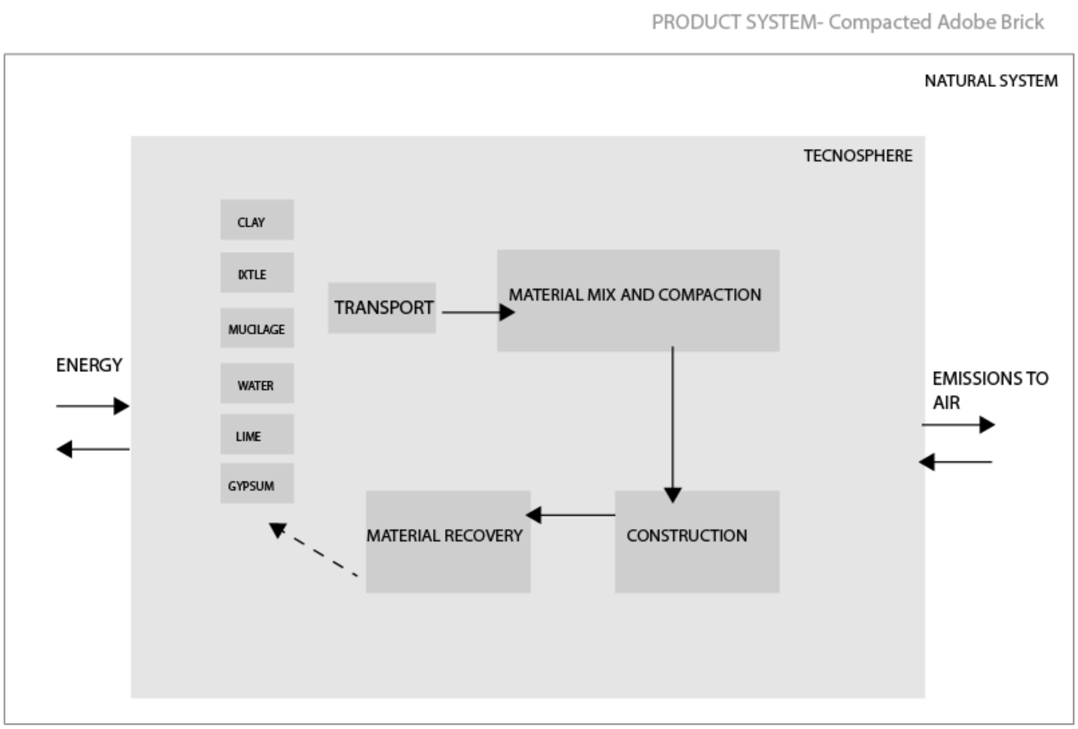


Figure 25 Product System Representation

Product system boundaries

For the purpose of the study, some data was not taken into account because of the time and the availability of it; however, for the unit processes the study can be approached upstream and downstream until the desired level.

In this case the LCA covers the environmental part, and considers in general some implications in social and economic aspects.

The system contains several process types: most of them are single operation process, which refer to a specific process step, without LCA inventory data. The system addresses raw material extraction, transport, manufacture, use and end of life.

Allocation procedures

Because of the data availability and the time for the study, the allocation procedures taken into account where the ones that represent a higher impact on the environment and that for the purpose of the study appear to be more significant.

In accordance to the goal and scope; it is important to take into account that the compressed adobe block, which is the object of the study, was developed in San Luis Potosí with materials from the region. Because of that, processes related to extraction of soil and its transport as well as the transportation from bank of resources to place of manufacture are highlighted ,see ***Figure 26***.

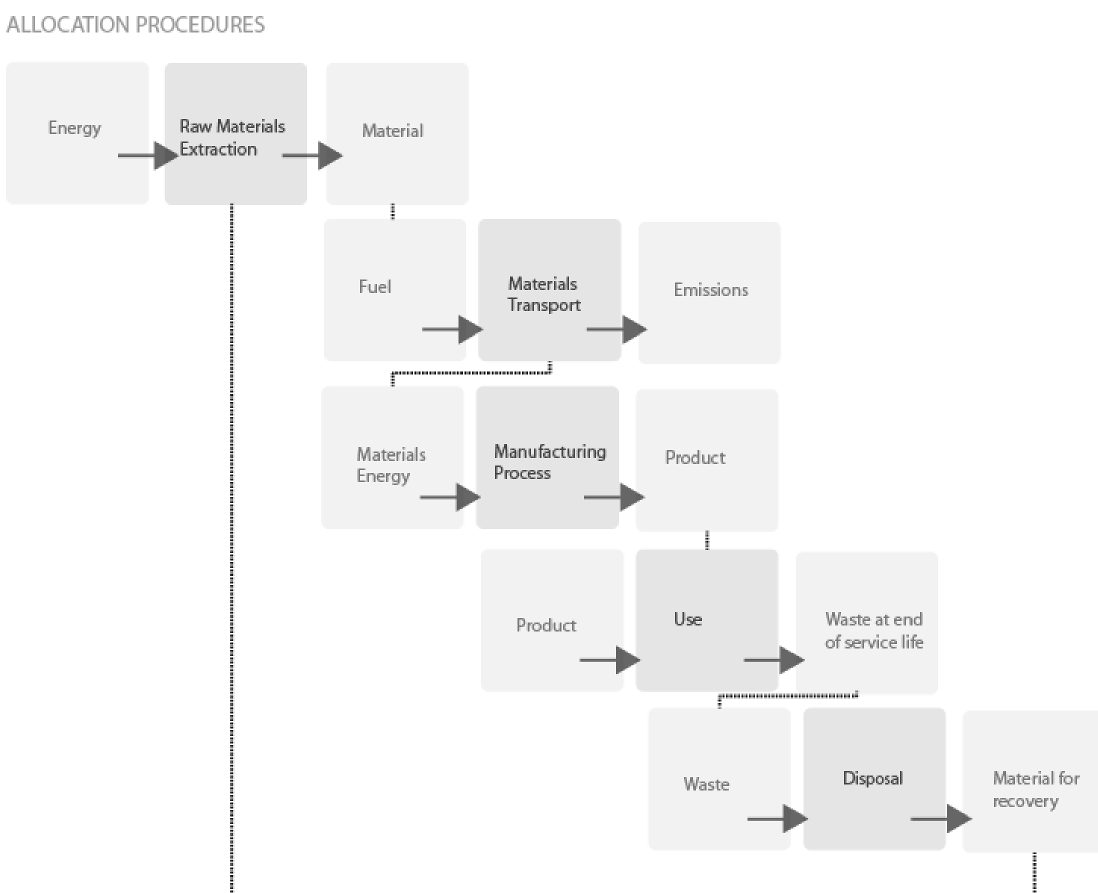


Figure 26 Compressed Adobe Block - Allocation Proceddures

Data requirements

About data requirements some of the data was taken from the process documentation related to the manufacture of the compacted adobe brick. Data not available in the documentation, was taken from similar studies and the rest was estimated, see ***Figure 27***.

	PROCESS	TYPE OF PROCESS	DATA SOURCE
RAW MATERIALS	Clay	u-so	Bibliographic
	Mucilage	u-so	Bibliographic
	Ixtle	u-so	Bibliographic
	Water	p-agg	GaBi Database
	Lime	p-agg	GaBi Database
	Gypsum	p-agg	GaBi Database
TRANSPORT	Transport of Clay. (Significant Distance)	u-so	Bibliographic
	Diesel Mix Refinnery	p-agg	GaBi Database
MANUFACTURING	Material Mix process and compression	u-so	Bibliographic
	Electricity grid mix	p-agg	GaBi Database
USE		u-so	Estimated Bibliographic
END OF LIFE		p-agg	Estimated

Figure 27 Life Cycle Assessment Data Sources for the Compressed Adobe Block – used in GaBi study.

Assumptions and Limitations

Due to the time for data collection, economic data is not included.

Data analyzed was selected because of the representativeness in the study.

Data sources vary because of the access to information; ***Figure 27*** shows: the process, type and source of data.

Type of critical review

The results obtained from the study would be interpreted in order to fulfill the criteria of the evaluation guideline.

This LCA assessment is used as a base frame for the development of the environmental impact guideline; because of that, it was not carried in all its possible complexity, but in a basic approach through all the stages of the life cycle.

LCA data analysis

REPORT- Data analysis (quantitative)

Note: The study was carried using GaBi 6, education license.

About GaBi 6

GaBi is a software to assess life cycle analysis, it helps to model the system and includes sets of environmental data related to materials depending of their country of origin. It calculates the environmental impact with the provided data. The software is also useful for economic analysis. For this study some data was used from GaBi database and other was given. When analyzing the system some processes were omitted. ***Figure 28*** illustrates the system layout studied with the software.

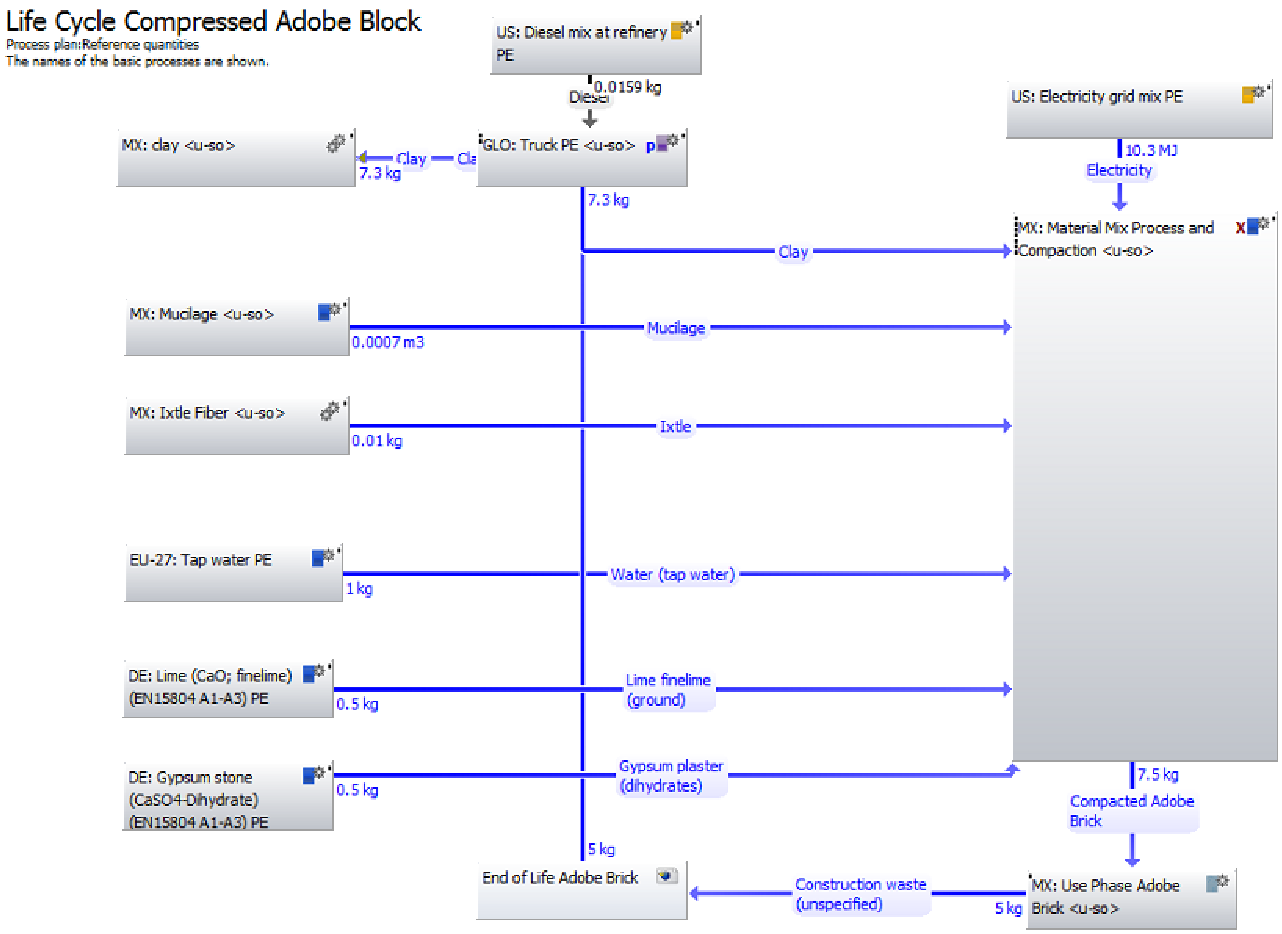


Figure 28 Life Cycle Compressed Adobe Block - System view in GaBi software

Impact Categories

The impact categories selected to report the environmental performance of the product were selected according to EPA (2006) suggestions; in this way impacts are categorized in the: global, regional and local scale.

The indicators considered in the impact categories where used as a base frame to identify the potential life cycle phases of performance improvement.

Note:

As this study serves as a tool to identify stages of evaluation when measuring and reporting the environmental information of a product, the carried analysis may result basic for a LCIA report.

For further analysis of LCIA and to have a better comprehension of the system performance it is suggested to go upstream and downstream on the unit processes, to have more accurate results.

Life Cycle Assessment quantifies the inputs and outputs; however the interpretation of data depends on the product. The information obtained by the study is not going to be used for comparison of products, as mentioned before the importance of it is to develop the base frame of the steps and considerations when developing or evaluating a product.

LCA – GaBi results

The results from the life cycle assessment carried by GaBi, where categorized by: global, regional and local impacts. ***Figure 29*** shows the impact categories of the case of study.

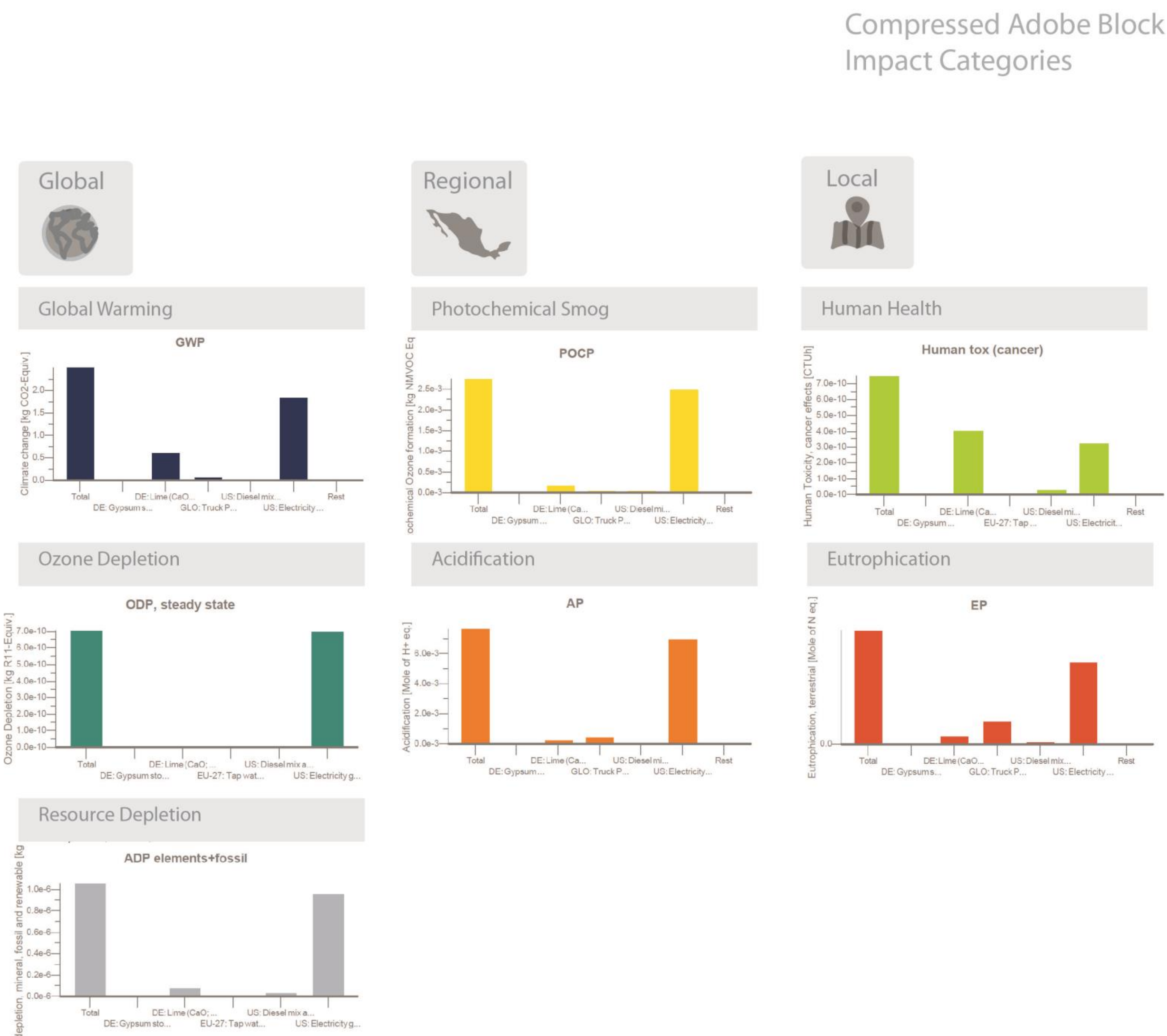


Figure 29 LCA Impact Categories - Compressed Adobe Block

Product Environmental Impact Guideline (Results)

Introduction

This guideline was developed in order to assess the development process of a product; it can be used at early stages (i.e., design process, product analysis before development) or as an assessment tool to find opportunities on products or services already developed regarding its environmental impact. The aim of evaluating a product or service performance is to reduce its impact on the environment and when possible in the social and economic aspects.

The guideline works as a tool that following: the definition of the problem, determination of its functions or desired performance, system evaluation and test analysis. It helps to oversee a specific system performance by analyzing each stage helping to detect the areas of improvement. At the end of the analysis process, environmental information regarding the product or system can be reported.

When needed, the information obtained can be reported in an Ecolabel (ISO type II).

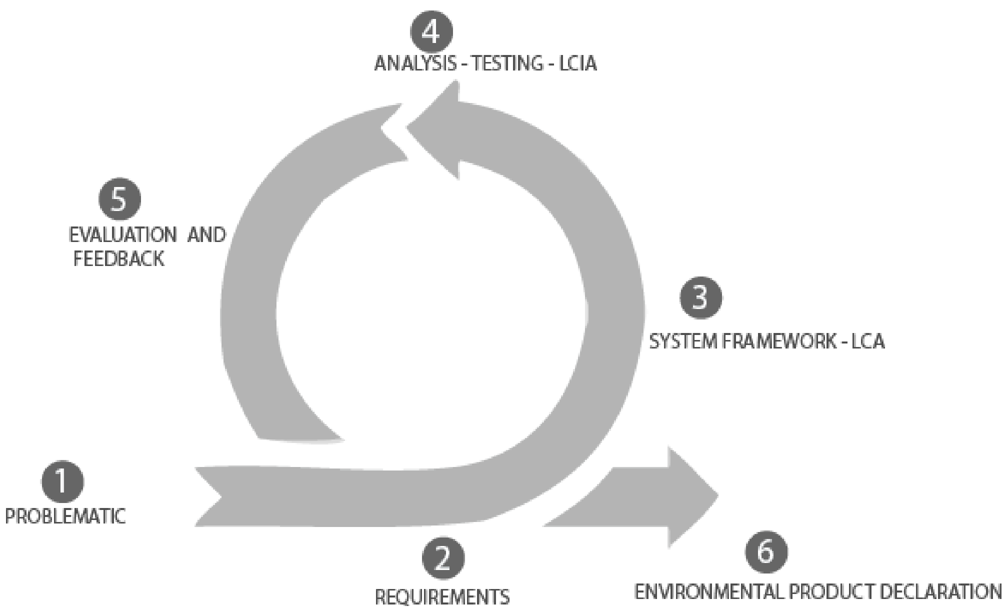


Figure 30 Product Environmental Impact Guideline Structure

PHASE 1

1. Identify the problem

The first step of the guideline is the definition of the problem and the needs, see ***Figure 31***. A problem emerges from specific needs, it could be said that a problem has an inherent solution, but to frame the case study the problem need to be stated as well asits inherent needs.

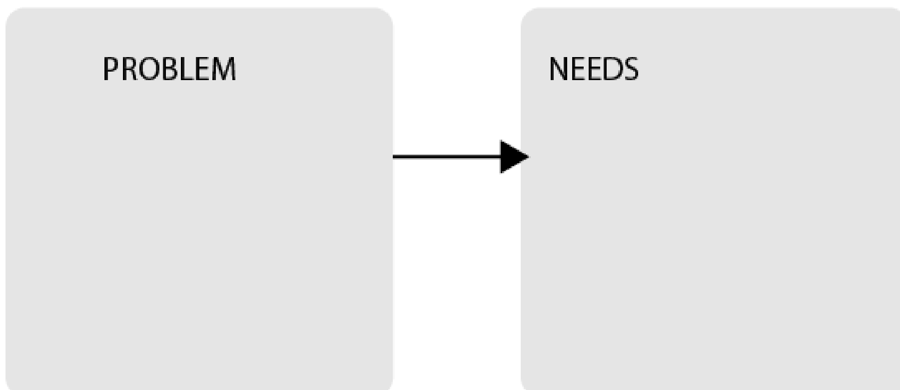


Figure 31 Problem and needs chart

1.1 Function and Functionality

In this step the function and functionality of the product or service, should be addressed, both come from the problem and needs previously stated.

In fact this step is related and inherent to the definition of the problem and the needs. This step is a complement of the system/ product requirements, it can be developed parallel to requirements; but for a better guide it is appropriate to describe the desired function and functionality, as it will help to have a better understanding of the system where it is going to be subscribe.

2. System / Product Requirements

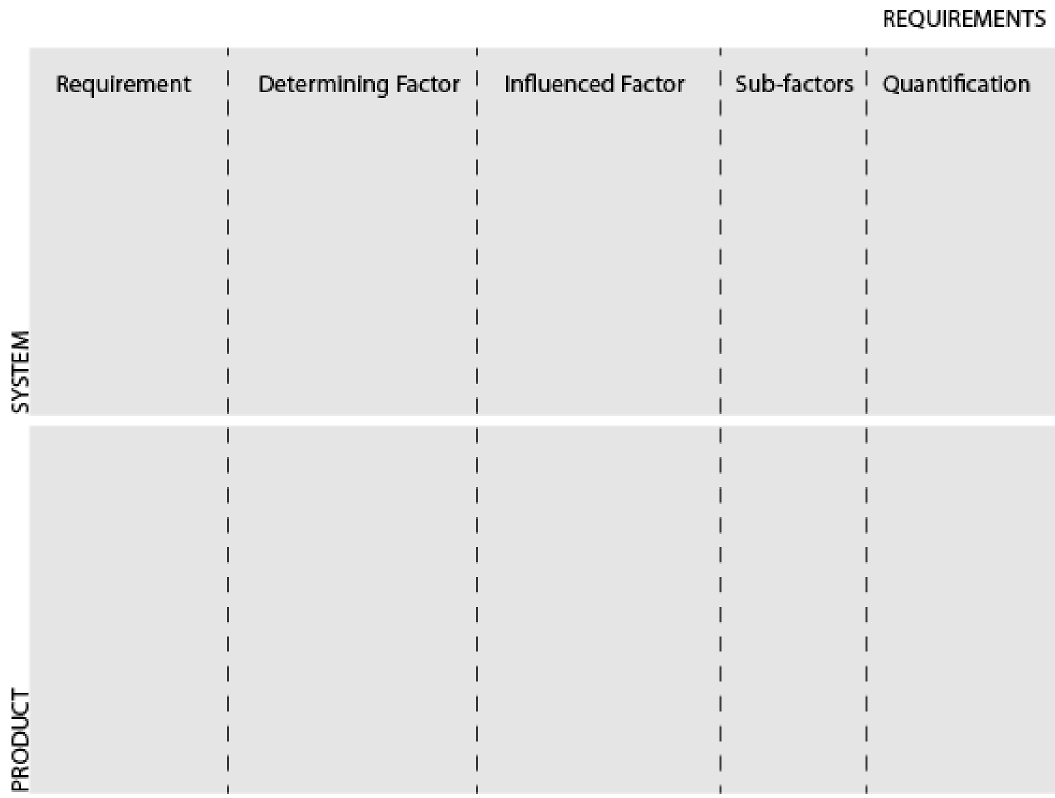


Figure 32 Requirements

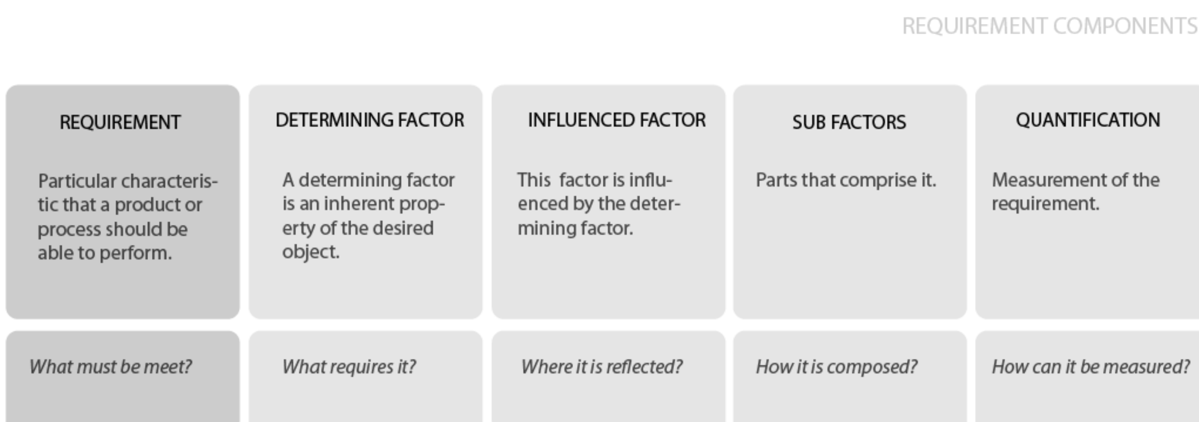


Figure 33 Requirement Components .
Note: Adapted from (Bonsiepe, 1978)

At the beginning of a design process, the requirements of use and functionality have to be defined and structured. Requirements are the desired characteristics of the product or service that cover the function or functionality; they assure the expected performance previously determined. Requirements are interdependent and influence each other (Bonsiepe, 1978).

The following definitions are explained to introduce the requirement chart displayed in ***Figure 32*** and ***Figure 33*** :

Requirement: Is a particular characteristic that a product or process should be able to perform.

- **Determining Factor:** A determining factor is an inherent property of the desired object. *What requires it?*

- **Influenced Factor:** This factor is influenced by the determining factor. *Where it is reflected?*

- **Sub-factors:** Parts that comprise it. *How it is composed?*

- **Quantification:** Measurement of the requirement. *How can it be measured?*

3. System Framework (LCA framework- parallel methodology)

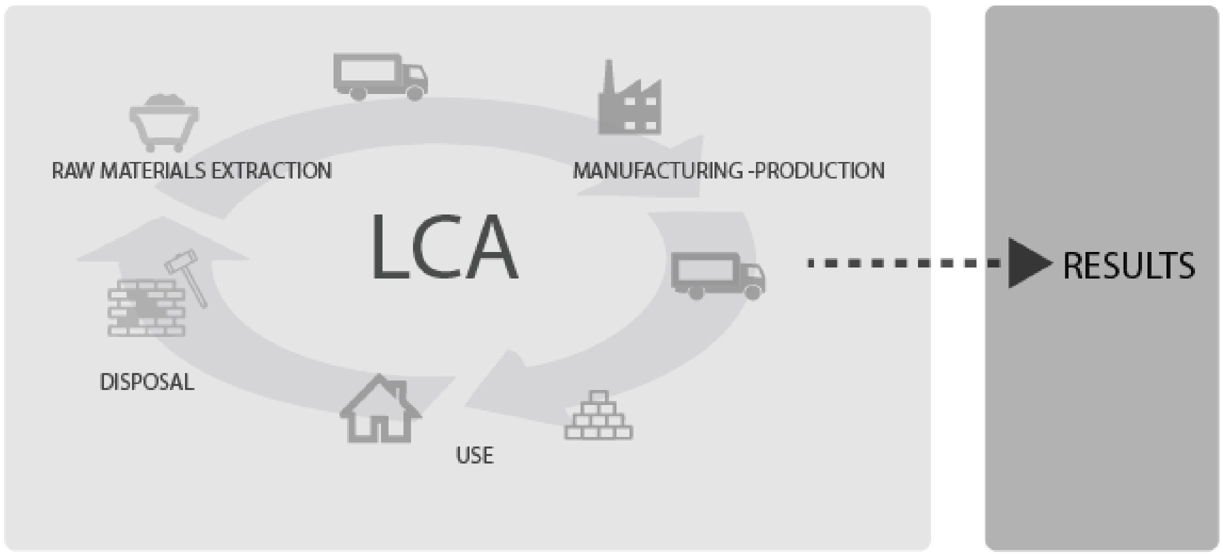


Figure 34 System- LCA Framework

This system framework helps to achieve the vision of the study which is the “cradle to cradle” perspective of a product life cycle, see ***Figure 34***.

Because of the complexity of a system it can be difficult to identify the main aspects that can be evaluated; as a first approach a simple system can be defined, even though it is important to consider that the analysis can be extended upstream or downstream. The more complexity a system has, a better understanding of the product performance and more accurate information will be reported.

Note: For more information regarding LCA methodology see: **Life Cycle Assessment**

System Framework and Life Cycle Assessment

The system framework was developed in base on the LCA methodology previously explained, LCA system definition demand the identifications of unit process, and the reference flow that emerge from its interactions.

The unit process have to be identified in each stage:

- Raw Materials Extraction
- Manufacturing
- Use
- Disposal
- Transport (in different stages of the life cycle)

4. Analysis of Results (Testing)

After analyzing the system and making the LCA assessment, the LCIA output serves as a tool to: report, compare and analyze the implications of the stages of a product.

LCIA phase analyze the potential impacts on environment and human health; it also helps to identify the relationship between processes and potential impacts. The aim is not to quantify but to recognize the link between the system and its potential impacts *(EPA, 2006).*

To report the impact of the life cycle assessment, impact categories indicators are used. ***Table 3*** summarizes the most used, classifying them in: global, regional and local impact.

Impact Categories and Associated End Points

Global	Regional	Local
		
Global Warming: polar melt, soil moisture loss, longer seasons, forest loss/change, and change in wind and ocean patterns.	**Photochemical Smog:** "smog," decreased visibility, eye irritation, respiratory tract and lung irritation, and vegetation damage.	**Human Health:** increased morbidity and mortality. Terrestrial Toxicity - decreased production and biodiversity and decreased wildlife for hunting or viewing.
Ozone Depletion: increased ultraviolet radiation.	**Acidification:** building corrosion, water body acidification, vegetation effects, and soil effects.	**Aquatic Toxicity:** decreased aquatic plant and insect production and biodiversity and decreased commercial or recreational fishing.
Resource Depletion: decreased resources for future generations.		**Eutrophication:** nutrients (phosphorous and nitrogen) enter water bodies, such as lakes, estuaries and slow-moving streams, causing excessive plant growth and oxygen depletion.
		Land Use: loss of terrestrial habitat for wildlife and decreased landfill space. Water Use: loss of available water from groundwater and surface water sources.

Table 3 Impact Categories and Associated End Points, Note: Adapted from (EPA, 2006).

5. Evaluation and Feedback

In the evaluation and feedback step, areas of improvement or points to assess are identified. This section covers: reports of indicators, opportunity phases and possible improvements.

LCA results

As this method uses the quantitative output to assess the qualitative part, results must be reported. It is important to mention that without a comparable source it is difficult to find the accurate relevance of this results.

The following analysis of the data is suggested:

- Data obtained from LCIA impact categories, need to be identified.

  By analyzing this information, the stages with more impact can be identified. This data can be organized and categorized in terms of its relevance in the global, regional and local scale.

PHASE 2

The second phase of the guideline covers the report of results obtained from PHASE1. This information can be reported to consumers by a provider of products or services, based on Ecolabel Type II requirements.

6. Environmental Product Declaration

The information obtained from the analysis carried at PHASE 1, can be used to develop an environmental product declaration, see ***Figure 35***; two main categories of information regarding the product can be reported: the product brief and the environmental declaration.

Product Brief

The product brief describes the product or service, in a brief the next things need to be reported:

- Product Name
- Origin
- Function
- Technical Specifications
- Components /materials: (Place of origin)
- Features

Function and Functional Unit: In order to describe the product, function and functional unit as described in the LCA should be described.

Note: For more information look at LCA : **Figure 23 Functional Unit Components.**

Environmental declaration

In the environmental declaration, it is suggested to report the product life cycle stages and its main implications.

This implications were previously identified by the use of the LCA, and the LCIA impact categories. A general report of the information in every stage, can help the consumer to understand the overall performance of the product to be purchased.

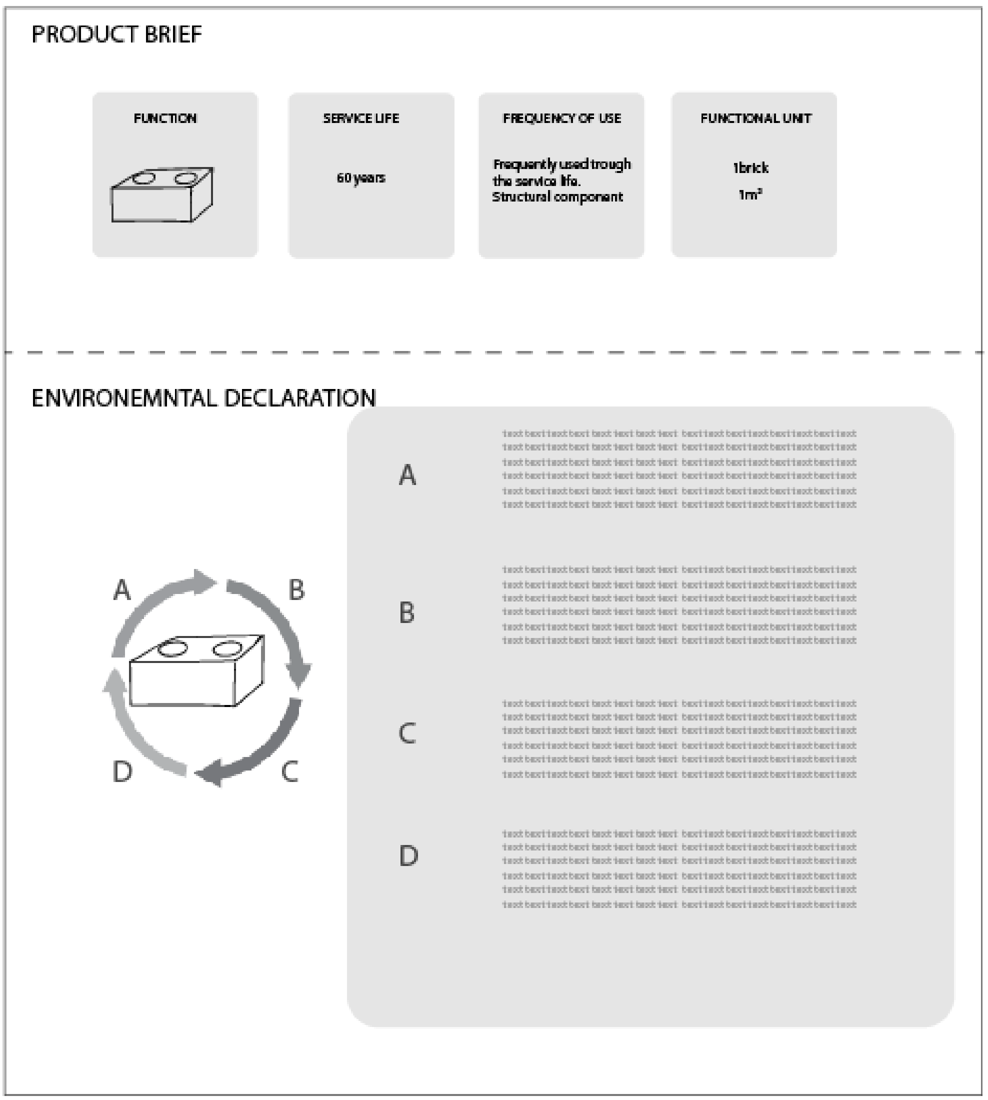


Figure 35 Environmental Product Declaration – possible structure of the information obtained by the study of the product.

Guideline and case study “Compressed Adobe Block

PHASE1

1. Problem and needs /Function and functionality

PROBLEM

Use of materials for housing that give structure and appropriate thermal conditions for the place of intended use.

Materials used for construction nowadays need a considerable amount of energy to be manufactured. This also carries with polluting emissions to earth and environment.

→

NEEDS

To be protected against environmental influences.

Structure for housing

FUNCTION

Give structure
Isolation

2. Requirements

System

Requirement	Determining Factor	Influenced Factor	Sub-factors	Quantification
Local Materials	Availability of Natural Resources	Components of the product	Percentage of local materials that compose the product	% of the total composition of the final product.
Energy reduction	Manufacturing Processes	Machinery used and type of energy fuel	Type of energy Source of energy used	--
Social Responsibility	Production Practices	Type of labor Implications on social sphere	Local /Community impact in the region	--
Continuous cycle of materials (as natural systems)	System effectiveness for reducing the environmental impact	System flows Feedback loops	Interaction between processes.	--

Product

Requirement	Determining Factor	Influenced Factor	Sub-factors	Quantification
Durable (Long Lasting for service life)	Environment	Material characteristics	Abrasion Resistance	--
Give structure	Number of stages to be constructed (3 stages for urban housing)	Load capacity	Material characteristics	(kgf/cm2)
Thermal properties	Outside temperatures	Material characteristics	Porosity, thermal characteristics of material.	--

3. Life Cycle Assessment

Defining the system framework: Once the function and functionality of the desired object is identified, in accordance to requirements, the product system can be established. For this purpose the LCA framework is used (Inventory Phase, see ***Figure 36***).

This steps helps to envision the operating system.

Note: For further information view LCA inventory phase chapter:

Figure 25 Product System Representation

Figure 26 Compressed Adobe Block - Allocation Proceddures

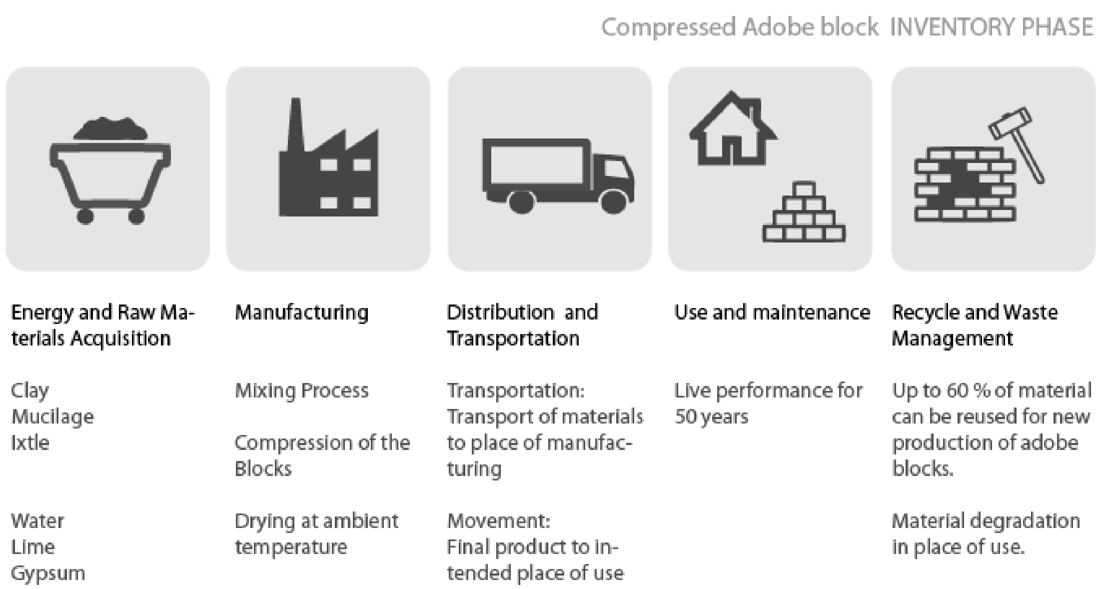


Figure 36 Compressed Adobe Block Inventory phase

As the desired output of this guideline is to have an overall view of the product interactions and its possible consequences in each point, it is important to remember that the vision of the system is subscribed into the "cradle to cradle" model, see ***Figure 37***.

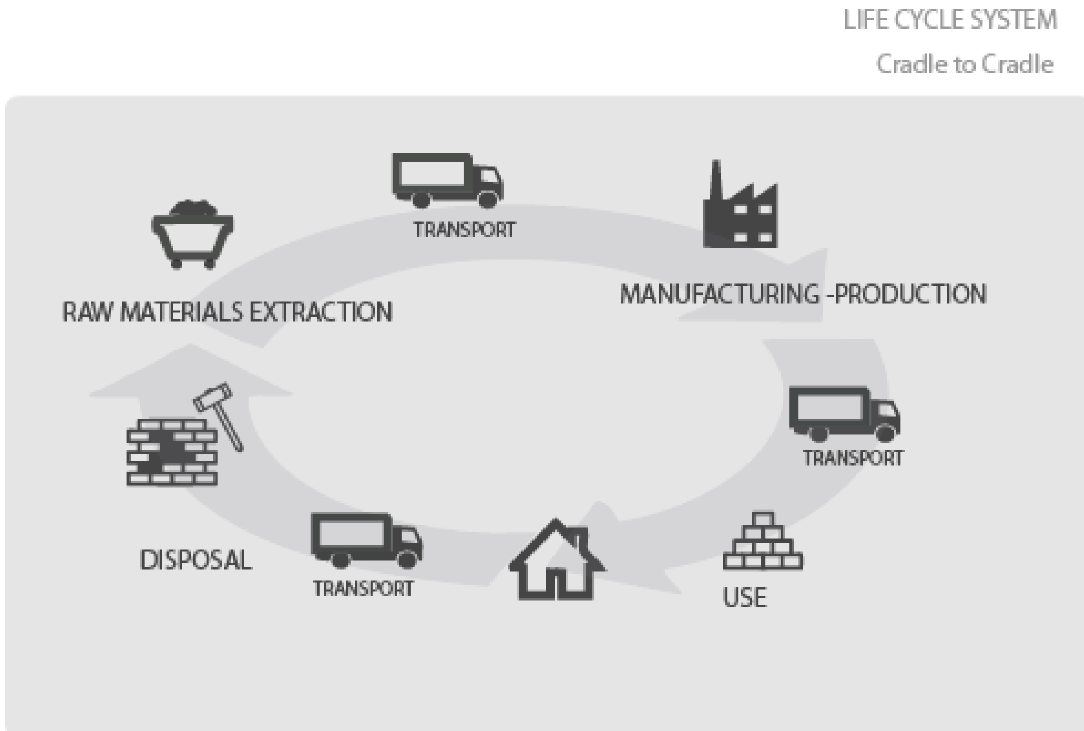


Figure 37 "Cradle to Grave" and " Cradle to Cradle" representation

Life Cycle Assessment Considerations: View chapter of case of study for further details.

Note: For information about the life cycle assessment of the compressed adobe block, information is reported in: **Case of study- Compressed Adobe Block**

4. Analysis - Life Cycle Impact Assessment

Once the LCA studied was carried, impact categories of environmental performance are obtained; by using the LCIA categories, stages and its implications can be structured.

Figure 38 is a matrix of the results obtained from the LCA, where impact categories and stages of life cycle are contrasted. Even when this matrix does not represent a quantitative interpretation; it helps to identify the stages of the product life cycle where an environmental impact can be assessed and improved.

LCA serves as a tool to quantify this impacts; however, the interpretation of this data helps to find: weak points, points of influence, touch points, etc. The impact categories relevance rely in the scope of the study, as the case of study is related to construction materials for social housing, the impact categories presented represent the global, regional and local scale.

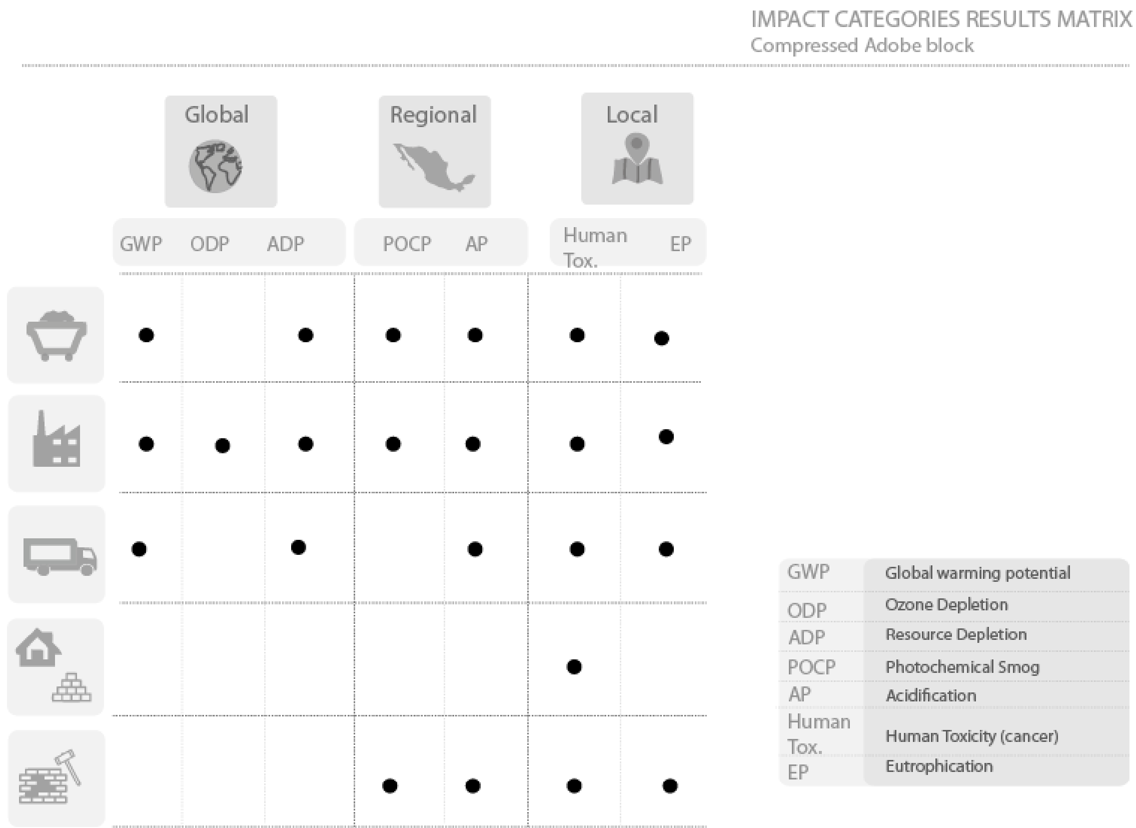


Figure 38 Impact Categories- Result Matrix -Compressed Adobe Block

5: Evaluation and Feedback

The impact assessment is defined as a subjective characterization of the case; what is important is to have an overview of the system performance to identify points of improvement and impact factors on the environment and its repercussions.

In the case of the compressed adobe block, the following points in life cycle stages where identified for further improvement:

Raw Materials: The bank of materials cause the major impact on the environment because of transport fuel consumption, a nearer bank source will reduce it, however the social impact on nearer zones should be considered.

As positive factors, the use of local materials facilitate its integration in the region once the service life is finalized.

Also the materials are aligned with the needs on the region because of the environment (i.e., temperature, solar radiation, weather ability, etc.).

Manufacturing: In social terms illegal practices related to the manufacture of the traditional brick will be avoided, because the compressed adobe block does not need the use of furnaces. In terms of environmental impact, polluting emissions related to the use of furnaces avoided.

Transportation: As not every material could be tracked, the material identified as the one with a higher impact on the environment was the soil; first because it is the largest component used for a compressed adobe block, and secondly because of the environmental impact reported for the transport from the bank of resource to the manufacturing place.

Use: The use phase represents the most efficient phase of the product life cycle. The function is completely covered during the service life; even though, in some cases maintenance can be needed but still it doesn´t represent a high impact.
Therefore, the use phase can be defined as successful.

Disposal: This stage was estimated. Because of the characteristics of the material, the recovery of material can represent the 60 – 70 % of the original product. Still, erosion should be considered.
It is estimated that at the end of the use stage, the material would not have significant repercussions on the local environment.

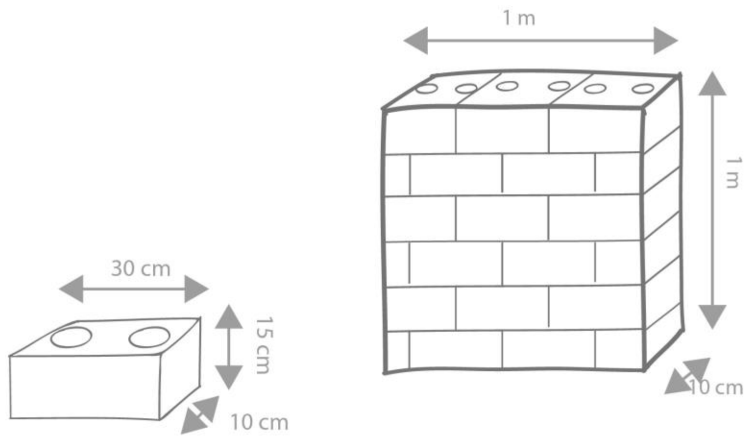
PHASE 2

In this section a layout of the information obtained from the guideline procedures is suggested; in this document: the product brief is stated in the first page, to continue with an overview of the product system performance, and finishes with the impact categories matrix developed in PHASE 1.

6: Environmental Product Declaration

Figure 39 Environmental Product Declaration - Page 1
Figure 40 Environmental Product Declaration - Page
Figure 41 Environmental Product Declaration - Page 3

COMPRESSED ADOBE BLOCK



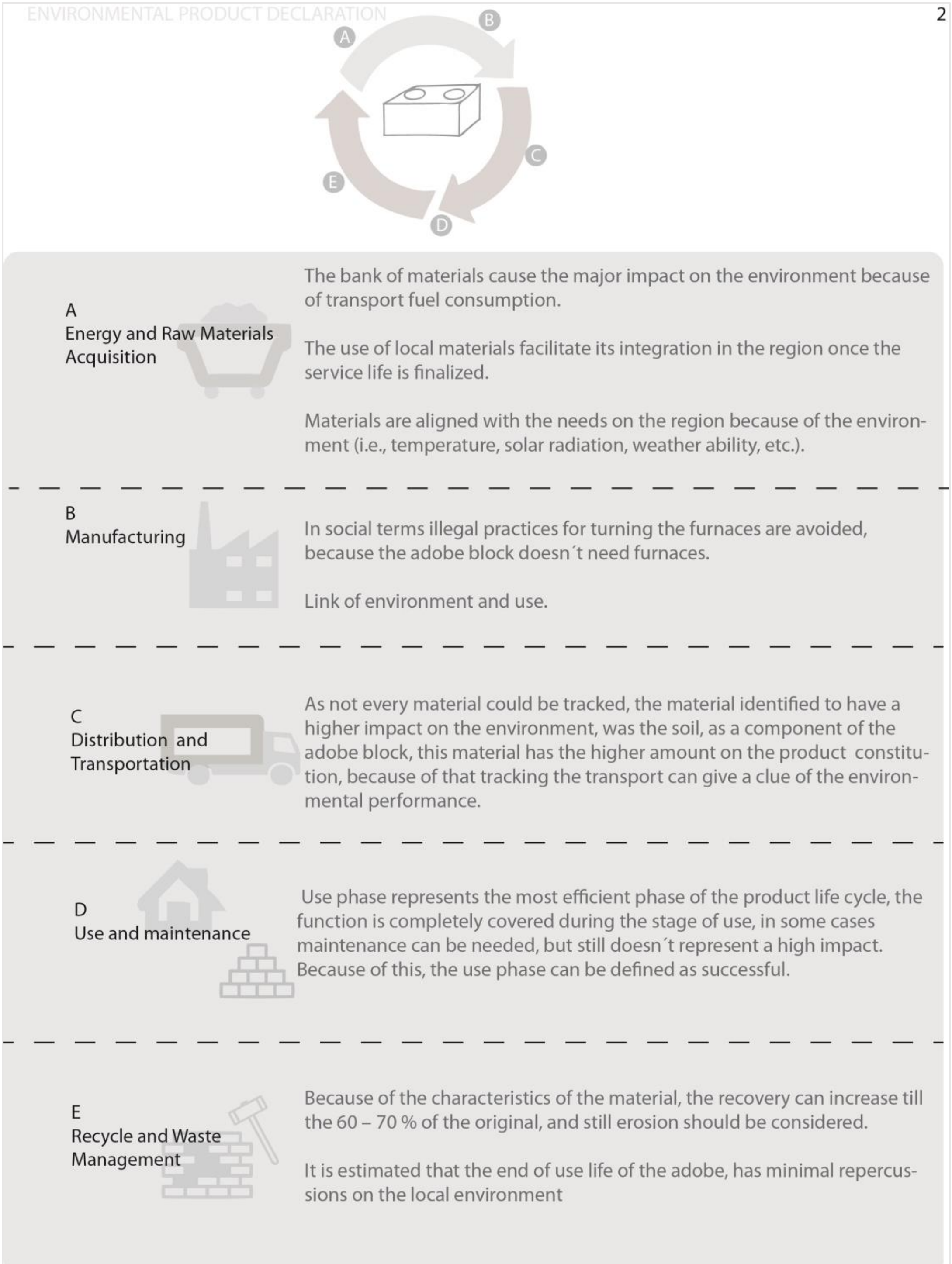
Functional Unit measures
*aprox .20 compacted adobe bricks per wall.

FUNCTION	SERVICE LIFE	FUNCTIONAL UNIT	FEATURES
Structural component Construction Material	50 years	1brick $1m^2$	For up to 3 levels of construction. Load Capacity: 90 kg/cm2

Place of origin and
of intended application : San Luis Potosí , México

PRODUCT MATERIALS	
	Clay Mucilage Ixtle Water Lime Gypsum

Figure 39 Environmental Product Declaration - Page 1



ENVIRONMENTAL PRODUCT DECLARATION 2

A
Energy and Raw Materials Acquisition

The bank of materials cause the major impact on the environment because of transport fuel consumption.

The use of local materials facilitate its integration in the region once the service life is finalized.

Materials are aligned with the needs on the region because of the environment (i.e., temperature, solar radiation, weather ability, etc.).

B
Manufacturing

In social terms illegal practices for turning the furnaces are avoided, because the adobe block doesn´t need furnaces.

Link of environment and use.

C
Distribution and Transportation

As not every material could be tracked, the material identified to have a higher impact on the environment, was the soil, as a component of the adobe block, this material has the higher amount on the product constitution, because of that tracking the transport can give a clue of the environmental performance.

D
Use and maintenance

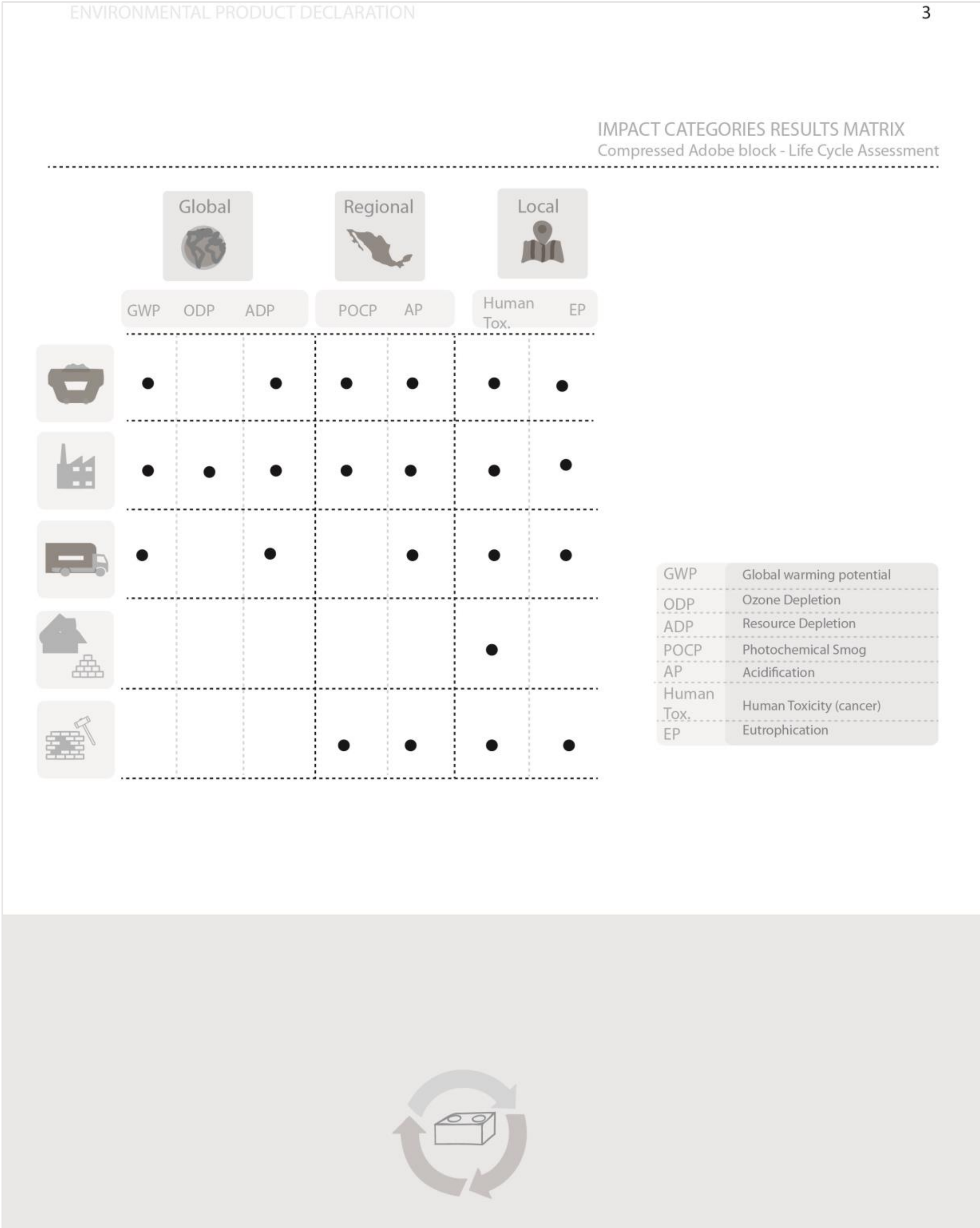
Use phase represents the most efficient phase of the product life cycle, the function is completely covered during the stage of use, in some cases maintenance can be needed, but still doesn´t represent a high impact. Because of this, the use phase can be defined as successful.

E
Recycle and Waste Management

Because of the characteristics of the material, the recovery can increase till the 60 – 70 % of the original, and still erosion should be considered.

It is estimated that the end of use life of the adobe, has minimal repercussions on the local environment

Figure 40 Environmental Product Declaration - Page 2



IMPACT CATEGORIES RESULTS MATRIX
Compressed Adobe block - Life Cycle Assessment

	Global			Regional		Local	
	GWP	ODP	ADP	POCP	AP	Human Tox.	EP
	●		●	●	●	●	●
	●	●	●	●	●	●	●
	●		●		●	●	●
						●	
				●	●	●	●

GWP	Global warming potential
ODP	Ozone Depletion
ADP	Resource Depletion
POCP	Photochemical Smog
AP	Acidification
Human Tox.	Human Toxicity (cancer)
EP	Eutrophication

Figure 41 Environmental Product Declaration - Page 3

Results

The proposed guideline, as a result of the present study, synthetize a number of steps that help to analyze a product performance. Design methodology and life cycle assessment had an important role for the guideline framework establishment.

The guideline highlights the importance of project planning with the aim of reducing the environmental impact of a product; it also suggest a basic framework to present this information to consumers. These results confirm the association between considering the implications of processes and the performance of a product.

The study was designed to determine the main stages and implications of a product life cycle, with the aim of assessing each stage in an environmental impact perspective. Two broad themes emerged from the study: the importance of planning a product at early stages, which means having a better understanding of the complexity it implies; and the tendency of products to become services.

Regarding PHASE 1 of the guideline, one main consideration is the design stage. On this point it is important to highlight some hints related to the topic: one is the consideration of the implied service life time of products that should be coherent with their use. If this point is covered, ideally most of its requirements will be aligned with this purpose improving the implications trough life cycle, either upstream or downstream.

Another point detected is that by analyzing the product performance rather than a particular function, a better understanding of the product is achieved. Hence, it could conceivably be hypothesized that redefining the problem and needs regarding the product system, has the major impact in the life cycle of a product.

Regarding PHASE 2 of the guideline, which covers the environmental claim declaration; the study aims to use the information obtained from the guideline, to approach consumer to better understanding of product implications. Even when the output of the guideline is a basic framework, it serves as an attempt to communicate consumers about a product implications towards sustainable practices.

Taken together, these results suggest that there is an association between the different scale of a product considerations: environmental, social and economic when looking for sustainable practices.

If industry practices are regulated regarding the environmental, social and economic perspective of their products, better practices can be achieved raising industry standards.

Discussion

As mentioned in the literature review, awareness regarding the environmental impact related to products has been increasing in the last decades; this appears to be a growing concern for: industry, government, communities and consumers. As a response, industry practices are being regulated; one example of this are the ecolabelling programs, where environmental information is showed to the public, giving an overall report of some environmental implications of a product. Ecolabelling appears to be one of the few tools for consumers to make better and more informed purchasing decisions.

Regarding environmental claims of products, information declared to consumers should be a continuously open door; which means that the environmental implication of a product should be available if required. It is not about giving the “know how”, but informing the precedence and fidelity of practices.

To approach consumers to sustainability notions towards sustainable consumption patterns, an initial objective of the project was to identify the relationship between stages of a life cycle assessment in order to identify its repercussion in terms of environmental impact to later report this information to the consumer with the purpose of reducing the gap of information between consumers and producers. It is somewhat surprising that even when the guideline was designed to support the environmental performance of a product in different stages of its life cycle, it can have more relevance and positive implications if it is carried in the development stage of a product or a service.

One example is the stage of design; hence the importance of “good design”, some authors object that the fundamental need of certificate that a product has an environmental performance just reflects the essence of one problem, which is that good design wouldn´t require to be labeled and that by itself a “good design” should be reflected in a product and its performance through all the life cycle.

Prior studies that have noted the importance of production and consumption patterns show that nowadays industry models are on a transition point, where a change of view regarding products is occurring. The difference between product and services has risen lately, the trend in the market is to offer services instead of “products” itself.

One interesting finding is the transition of “product” as a concept; a “product” becomes a “service” and the “consumer “becomes a “user. Understanding this change of conception leads to different solutions and innovations. To give an example, in “cradle to cradle”, the authors mention the case of transport, where the user or the experience given by the service (transport) is relevant than the product per se.

Regarding the consumer, it’s worth mentioning that to engage consumers into this practices their purchasing decisions should be matched with their ethical considerations (remember the social and cultural practices and the relationship between man and nature).

These findings may be somewhat limited because of the direction of the research, as it mainly considerate the environmental impact, it must be said that also the social implications and the economical can give a better perspective and understanding of the problem; although, exclusion of LCC S-LCA did not impede the study of the environmental performance, these results should be interpreted with caution.

In general, it seems that rethinking the way products are conceived lead to innovation and creative solutions. The transition from product to service should be a major consideration, in terms of economy this goes with the functional service economy model, where this transition to “services” helps to achieve a more complex approach and a shift form linear to circular economy. This goes in accordance to Ellen MacArthur Foundation, 2013 that affirm that this transition will substitute the consumption of products in the linear way.

The change of paradigm also implicates not a “soft solution”, as mentioned by Mc Donough & Braungart (2002), it is not about an end- solution but a shift in perspective. It can be therefore assumed that the paradigmatic transition that is mentioned (from products to services) and the shift of perspective (“cradle to grave” to “cradle to cradle”) is being carried; however, it requires the involvement of participants within the system.

One of the issues that emerges from these findings is that to achieve the change of consumption paradigm, all the stakeholders need to involved, the environmental assessment is one of the tools for the transition of way of thinking; however, it should not be seen as the ultimate solution.

This combination of findings provides some support for the conceptual premise that changing the paradigm in which products are conceived can lead to better industry and consuming practices. There is abundant room for further progress in determining methodologies of assessment, the existing quantitative sources have been successfully proved; however, the interpretation of this data is influenced by particular direction of carried studies. A question that arises here is how to validate this information within the involved parties in production-consumption schemes, this is an important issue for future research.

To develop a full picture of a product impact, additional studies will be needed to cover the social aspects as well as the economic one. The link between them will help to get a full picture of interactions and implications. For this purpose a further study with deeper analysis in these topics is suggested.

Decision making in industry should be completed by other parties, in this way a wider perspective into product information regarding environmental issues can be achieved.

Conclusion

This study has argued that environmental information regarding products is nowadays a topic of relevance for consumption practices; however, as this is a growing field, is still difficult to enhance the consumer interest and objective interpretation of environmental data.

In this investigation, the aim was to asses a product life cycle in order to identify the relationship between processes and interactions and its implication on an environmental performance, so that at the end an overall view of the product system performance could be stated in an environmental claim with the purpose of addressing the consumer.

This study was undertaken to design a product environmental impact evaluation guideline to analyze and evaluate the performance of every stage of its life cycle. By assessing a product system in a “cradle to cradle “perspective, the study has identified that the assessment of a product, enhances an improved environmental performance.

It has also shown that early stages of product development help to enhance more sustainable practices. A better understanding of a product life cycle give rises to more effective design of the system.

The study has also found that a transition of paradigms is occurring; this means that the linear model of production and consumption is shifting towards a circular model, strengthening the “circular economy “paradigm.

In general, it seems that this shift of perspective occurs as a response to nowadays problems. As once lineal production-consumption was developed in a specific historic moment, the growing problem related with industry practices and consumption practices demand innovative and effective solutions.

The results support the idea that the relationship between industry and consumer can be strengthened by provision of product information, not just at the use stage (i.e., function of the product in the service life), but also in the other stages and at different scales (economic and social).

The study provides a framework for the exploration of sustainable practices, whether on production or consumption. Despite the exploratory nature, this study offers some insight into products environmental implications; as a basic framework the guideline can serve as a directional guide, it can be used by designers to take into account the whole performance of a product in development or by industry stakeholders, to identify the impact of their products and a way to present to the consumer this information.

It is unfortunate that the study did not include the social and economic analysis, because of this, the scope of this study was limited in terms of broadness. However, as the case study “compressed adobe block” was developed with the purpose of reducing the energy consumption and the use of local materials, it can be said that the project represents an economic benefit. Further analysis should be carried to assess the possible demand of the product and the pressures that it can have in local resources.

It was not possible to assess the social implications in a broad way; however, as in the case of the economic study, some positive implications of the case study product are identified; the regulation of the activity in the region leads to better practices and better implications in terms of manufacturing operations, which at the same time affect the communities that are involved nowadays in the manufacturing processes of tradition brick for social construction.

Further work needs to be done to establish whether making environmental claims certainly address the consumer and attempt to be a trigger for the purpose of consumer behavior towards sustainability, or if different actions need to be taken to make this understanding of today´s consumption implications a comprehensible and significant information for consumers. Greater efforts are needed to ensure that sustainable practices regarding not just production but extraction of raw materials, transport, use and disposal are being transparent to every part involved. At this transition point, unless governments adopt regulations, sustainable practices will not be attained. Ensuring appropriate systems, services and support for this objective, should be a priority for policy makers to regulate the way industry operates nowadays.

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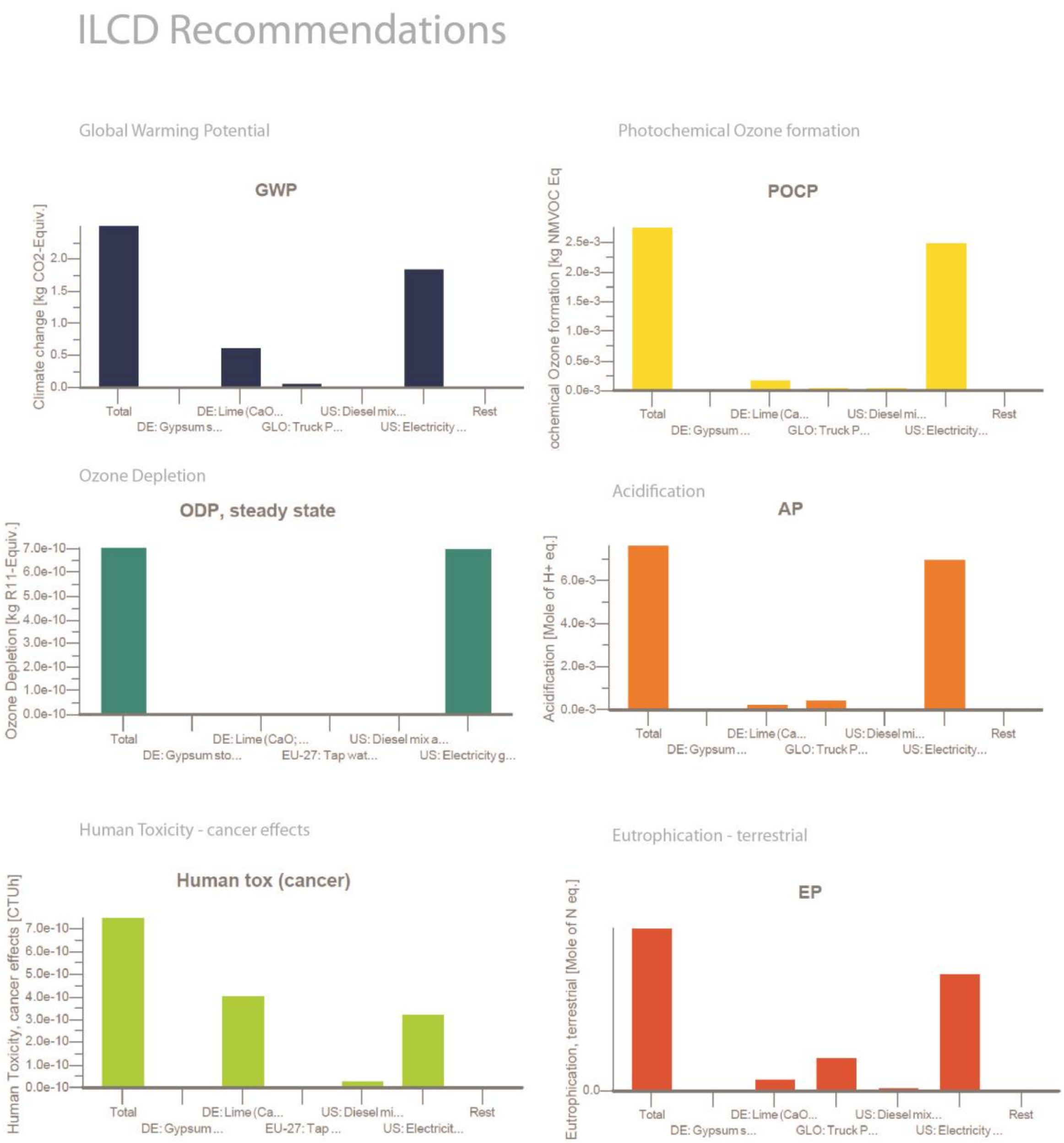
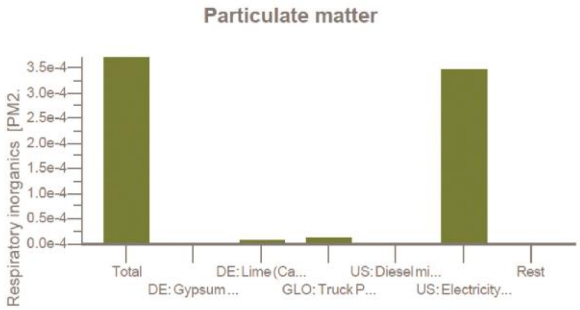
Appendices

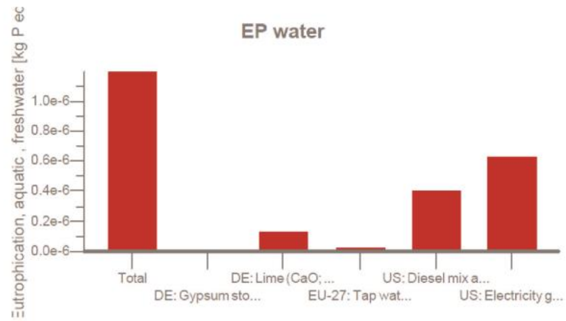
GaBi Results from “Compressed Adobe Block” life cycle assessment.



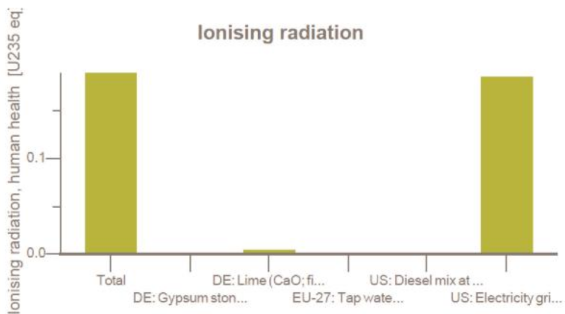
Human Toxicity - non -cancer effects



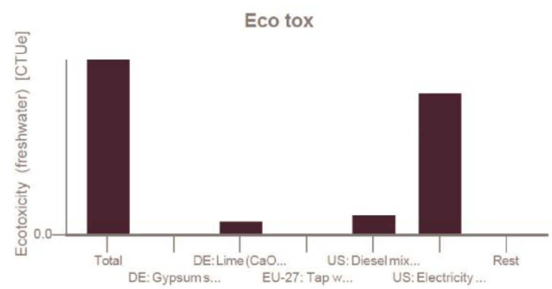
Eutrophication, aquatic



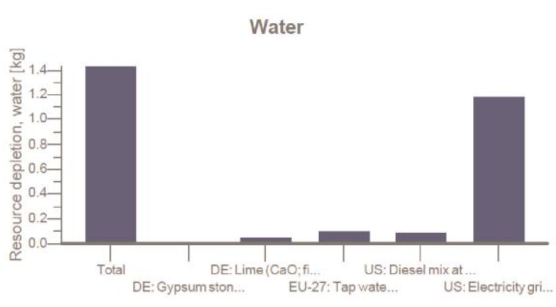
Particulatte matter- Respiratory Inorganics



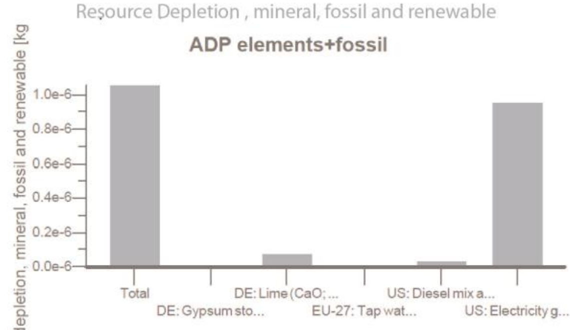
Ecotoxicity



Resource depletion water

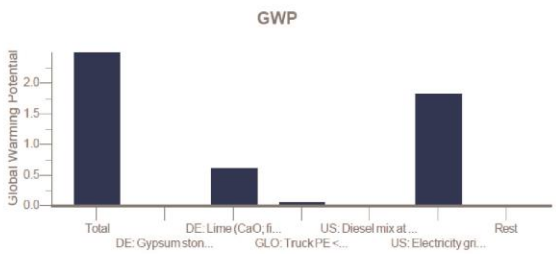


Resource Depletion , mineral, fossil and renewable

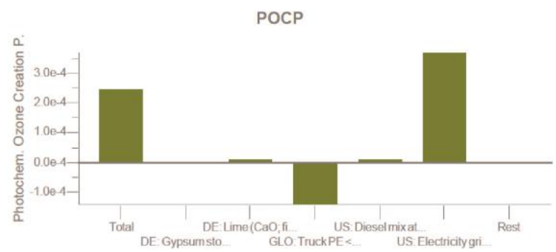


LCIA

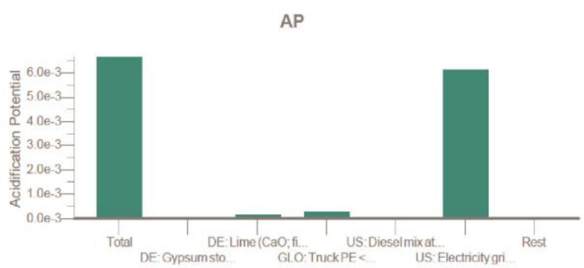
Global Warming Potential



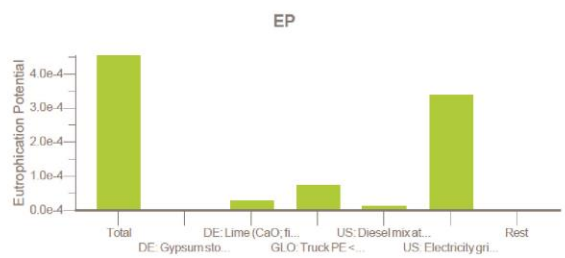
Photochemical Ozone formation



Acidification



Eutrophication - terrestrial



Ozone Depletion