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Estimado participante de CILCA 2011,

La contribución de cada uno de nosotros para promover el pensamiento de ciclo de vida en América Latina es sin duda el logro más importante de CILCA 2011. En esta ocasión la participación y el diálogo con el sector industrial son el eje del desarrollo de estrategias que dan como resultado la "Declaración de Coatzacoalcos: en el camino hacia Rio+20 con pensamiento de ciclo de vida".

Gracias por su asistencia, esfuerzo y entusiasmo para participar en CILCA 2011, lo cual reitera nuestro compromiso hacia la sustentabilidad y el desarrollo.

Cordialmente,

Nydia Suppen Reynaga

Presidenta Comité Científico CILCA 2011

Dear CILCA 2011 participant,

There is no doubt that CILCA 2011´s most important achievement is our personal contributions to promote life cycle thinking in Latin America. In this occasion the participation and dialogue with the industrial sector has been a key factor to develop strategies which will be highlighted in the "Coatzacoalcos Declaration: towards Rio+20 with life cycle thinking".

I thank you for your efforts and enthusiasm in attending CILCA 2011, which shows our commitment to sustainability and development.

Best regards,

Nydia Suppen Reynaga

CILCA 2011 Scientific Chair

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LIFE CYCLE ASSESSMENTE OF BIOFUELS PRODUCED IN PERU

Quispe Trinidad, Isabel[1, 2]
Yearwood Travezán Jessica[1, 3]
Matos Meza, Katherine[1,4]

[1] Red Peruana Ciclo de Vida (RPCV), Pontificia Universidad Católica del Perú. Av. Universitaria Nº 1801, San Miguel, Lima, Perú.
[2]E-mail: iquispe@pucp.edu.pe
[3]E-mail: jyearwood@pucp.edu.pe
[4]E-mail: k.matos@pucp.edu.pe

ABSTRACT

The aim of this study is to estimate and compare the environmental impacts of biofuels (biodiesel and ethanol) with fossil fuels (diesel, 84 octane gasoline, 97 octane gasoline and natural gas) produced and used in Peru.
The study took place in two regions of Peru. The first region is the Peruvian amazon for Palm oil and Jatropha crops. and in three scenarios: primary forest, secondary forest (purma) and degraded forest. The second region is the Peruvian coast (grassland) for Jatropha, Sugar Cane and Sweet Sorghum crops.
The Life Cycle Assessment (LCA) tool was used for the comparison of the environmental impacts, and the IPCC[1] was used for the evaluation of the environmental impacts. The used functional unit to perform all evaluations was 1 km traveled distance in a passenger's vehicle.

This study revealed that a main factor in the environmental impact is the previous use of the soils. In addition, it shows that the contribution to climate change during the stage of usage of biofuels is minimum in comparison with fossil fuels. The main reason behind this is that biofuels release carbon absorbed during his vegetation. This carbon does not contain so many pollutants (SO2, CO and NOx) as fossil fuels (Puppán, 2001).

Despite of the minimum emission during the use phase, there is a large amount of emissions associated to the production phase due agriculture activities. These emissions could be minimized by using a higher percentage of biomass along the life cycles of the product, increasing that way the activity performance.

Topic: Biofuels

[1] International Panel of Climate Change methodology based on the measure of green house emissions.

Keywords: Biodiesel, Life Cycle Assesment,Environental Impacts, Oil Palm, Jatropha.

INTRODUCTION

Nowdays, due climate change and uncertainity of hydrocarbon resources the development of alternative energy resources has been promoted. Also, the disadvantage of the burning of non renewable fuels is under discussion, especially hydrocarbon derivatives as diesel and petroleum. In this context, biofuels have gain more attention and importance.

Biofuels production has the potential to increase national exports income, to benefit small farmers and rural sectors; and also the environment. A consequence to these advantages is that biofuels production is increasing exponentially worldwide; and many countries are encouraging biofuels with political tools.

However, according to recent investigations biofuels can have a negative impact in the environment. Lian Pin Koh (2008) stated other risks associated to biofuels production such as CO_2 emission that are released along their life cycle, threats to the biodiversity, risk of deforestation and competition for water use. Also, biofuels have revealed a significant impact in the food safety. Thereby they represent a major economic risk for the population who lives in poverty (FAO, 2008).

In countries were the Amazon rainforest is located such as Peru, the impacts generated by the deforestation are a critical topic. Regions as the Peruvian Amazon have proper conditions for the production of biofuels. The conditions allow the crops to have high yields and multiple harvest can be done per year. Therefore, the use of degraded lands is an attractive option that can contribute to the energetic national safety, and also encourage the creation of employment in rural areas. Taking into account the factors mentioned before, and the need to reduce the environmental impacts generated by fossil resources, the Peruvian government established a Law of Promotion of Biofuels Market

(2003), which was regulated in 2007. This regulation establishes a mandatory blend of 2 % of biodiesel in the diesel for 2009 which should be increased to 5 % for 2011, and a 7.8 % blend of ethanol in the gasoline as well.

The existing studies of environmental impact of biofuels in Peru have son limitations; like energy efficiency and possible reductions of green house gasses along their life cycle are not taken into account. Therefore, it is necessary to have a current evaluation and comparison of the environmental impacts of using biofuels and fossil fuels. This evaluation must be performed with the participation of diverse stakeholders from the agriculture, transport and energy fields.

This study seeks to compare in an objective way the environmental impacts produced on biofuels and fossil fuels production processes in a way that the results can be used for the decision making and the development of local sustainable policies. In addition, the study aims to strengthen the local capacity in the development of the Life Cycle Assessment (LCA) methodology.

METHODOLOGY AND TOOLS

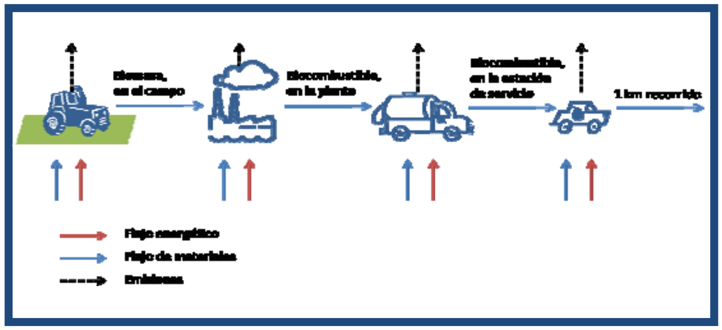
The aim of this study is to evaluate, estimate and compare the environmental impacts of biofuels with the fossil fuels produced in Peru, using the LCA as management tool that will contribute for informed decisions for governmental and local policies.

Specific goals are:

- To identify the alternatives with lower environmental impact between the evaluated scenarios..
- To identify and evaluate the opportunities to reduce the environmental impacts generated along the life cycle of biofuels, and to improve their chain of value.
- To create and strengthen the local capacity that allows future evaluation of the environmental impacts using the LCA as a management tool for the decision making.

The methodology used for the evaluation of the environmental impacts is the Life Cycle Analysis (LCA). The LCA is a methodology that allows the registration and evaluation of the environmental effects of human activities during the production of goods and services along their Life Cycle - from the acquisition of raw material, production and energy consumption, up to the final disposal. Figure 1 shows the phases of the Life Cycle of Biofuels.

Figure 1: Life Cycle of Biofuels



According to the international standard ISO 14040, LCA is an interactive cycle of knowledge and optimization comprising the steps included in Figure 2. The figure also shows graphically the interaction and direct applications of the LCA results.

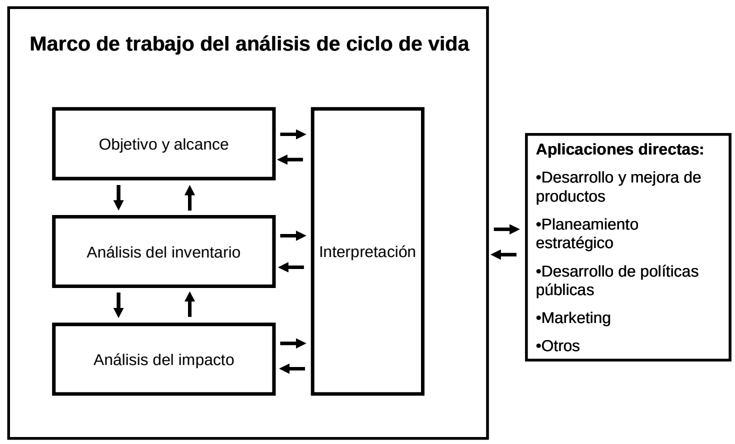


Figure 2: LCA Work Frame

Source: ISO 14040 (2006)

The methodology for the analysis the environmental impacts produced during the life cycle of biofuels is the IPCC 2007. This methodology was created by the IPCC and it quantifies the environmental impact category "Climate Change" in kilograms of CO_2 equivalent.

The software used for the LCA is SIMAPRO 7.1 which is a commercial software tool developed by Pré Consultants. SIMAPRO7.1 analyze and compares systematically and consistently the environmental aspects of a product according to ISO 14040. The database Ecoinvent was also used during the study, this database which covers more than 4,000 processes and is the result of a great effort by Swiss institutes to update and integrate the well known bases ETH-ESU 96, BUWAL250 and several other databases. Ecoinvent database has a very good documentation and specification of uncertain data. In the study Ecoinvent is used to model common processes such as transport and basic chemicals production, and also as a database that has been adapted to the Peruvian context in other processes.

The functional unit should be a measure for the comparison of the amount of necessary to perform the same function, providing a reference to normalize the inputs and outputs of the system. In the study the functional unit was 1km traveled distance in a passenger vehicle.

RESULTS

In order to determine whether biofuels have a lower environmental impact than fossil fuels, it is necessary to identify and analyze the environmental impact of all phases along their life cycle: agricultural, production, transportation and energy use. Table 1 shows the GHG emissions in kg CO_2 equivalent for biodiesel and diesel. For the biodiesel different scenarios were analized.

Table 1: CO_2 eq emission per production phase for the biodiesel and diesel systems

System		Scenario	LUC	Agricultural phase	Production Phase	Usage Phase	kg CO_2 eq
S1	Oil Palm	Primary Forest	0.272	0.050	0.038	0.023	**0.38**
S2	Oil Palm	Purma 15 años	0.030	0.034	0.039	0.023	**0.13**
S3	Oil Palm	Deforestated	-0.264	0.034	0.039	0.023	**0.17**
S4	Jatropha	Bosque primario	0.777	0.077	0.033	0.023	**0.91**
S5	Jatropha	Purma 15 años	0.302	0.051	0.034	0.023	**0.41**
S6	Jatropha	Deforestated	-0.288	0.051	0.034	0.023	**0.18**
S7	Jatropha	Grassland	-0.269	0.151	0.033	0.023	**0.06**
S10	Diesel	-	-	-	0.03	0.20	**0.23**

Table 2 shows the GHG emissions in kg CO_2 equivalent for ethanol, gasoline and natural gas. For the ethanol several scenarios were taken into account.

Table 2: CO_2 eq emission per phase for the Ethanol (E100), gasoline and natural gas

System		Scenario	LUC	Agricultural phase	Production Phase	Usage Phase	kg CO_2 eq
S8	Sugar Cane	Grassland	0.035	0.118	0.029	0.022	**0.20**
S9	Sweet Sorghum	Grassland	0.000	0.047	0.024	0.022	**0.09**
S11	G97	-	-	-	0.04	0.21	**0.25**
S12	G84	-	-	-	0.04	0.23	**0.27**
S13	Natural Gas	-	-	-	0.02	0.27	**0.19**

Comparing biodiesel with fossil fuels in terms of GHG emissions throughout the life cycle, the following results were obtained:

- The biodiesel obtained from palm oil release less greenhouse gases than diesel in the degraded lands scenario in the Peruvian Amazon, while the biodiesel obtained from Jatropha releases less greenhouse gases than diesel on degraded lands scenario in the Amazon and coast.
- The biodiesel obtained from palm oil and jatropha on degraded land and coast also have a positive effect on the environment due land use change.
- The biodiesel from Jatropha in primary forest has a high impact in GHG emissions compared with biodiesel from palm oil in primary forest. Both scenarios would emit more GHG gases than diesel.
- The biofuels made from palm oil, in both scenarios, have a less impact than biofuels made from jatropha.
- The agricultural phase biodiesel contributes in 46% to 82% of the total production process; the reason behind this result is the use of fertilizers, herbicides, fungicides and machinery that work burning fossil fuels.
- Land Use Change (LUC) is a relevant factor in terms of GHG emissions for biodiesel on a primary forest scenario where it was revealed that CO_2 emissions associated to LUC are over 70% .

Comparing ethanol with gasoline and natural gas, taking into account GHG emissions throughout the life cycle the following results were obtained:

- The sorghum-based ethanol releases less amount of greenhouse gases than ethanol made with sugar cane, both results are for a grassland scenario located in the Peruvian coast.
- GHG emissions associated with agricultural activities are the most representative with 59% for ethanol made from sugarcane and 52% for ethanol made from sorghum.
- The contribution of GHGs associated with agricultural activities are more representative for sugar cane due the amount of fertilizers, pesticides, machinery that are used during the agriculture phase and also because the burning of fields during the harvest.
- The cultivation of sugar cane in waste land associates GHG emissions due land use change In the other hand the GHG contribution of sweet sorghum is zero.

According Searchinger et. al (2008) in many previous studies on biofuels the environmental impacts only take into account the emissions generated during the agricultural and production phases, this way, the studies considered that agro-energy fuels can reduce GHG emission by capturing carbon from the atmosphere. However, deforestation incurred for energy crops released into the atmosphere a large amount of the carbon previously stored in plants and soils. The study calculated the environmental impacts including the emissions generated by land use change. For the calculation of the carbon debt of biofuels their emission must be disaggregate.

According to Fargione et al (2008) the transformation of primary and secondary forests or grasslands for the production of biofuels from energy crops generates a carbon debt due the increase of CO_2 annual emission in comparison of the annual GHG reductions obtained by displacing fossil fuels.

The formula to calculate the time of payment of the carbon debt (ECPT: Ecosystem 'Carbon Payback Time') is defined by Gibbs et al (2008) defined as the number of years required the avoided emissions by displacing fossil fuels to compensate the loss of ecosystem carbon due land use change, is as follows:

$$ECPT = \frac{C_{ecosystem} - C_{energy\ crop}}{\text{Saved emissions/ha/year}}$$

Table 3 shows the number of kg of CO_2 equivalent that stop being released by replacing fossil fuels with biofuels (a), the debt incurred by land use change (d) and the years required to pay that debt (e). To calculate the emission savings (a) the GHG emissions of B100 and E100 are calculated without taking into account the CO_2 emissions from land use change and are subsequently subtracted from the diesel and gasoline emissions respectively.

The results on Table 3 revealed that in primary forest scenarios the time period to pay the carbon debt is longer, while the degraded forest scenarios do not incur in a carbon debt. According to Fargione et al (2008) biofuels produced from perennial plantations such as palm oil and jatropha (grown on degraded lands) minimize the destruction of ecosystems and carbon debts associated with direct on indirect deforestation for biofuels production.

Table 3: Calculation of the carbon debt for biofuels (100%)

System	kg CO_2 eq *saved/* km	km/ ha año	tCO_2 eq *saved/* ha año	Debt (tCO_2/ha)	Dept (years)
	(a)	(b)	(c)=(a)x(b)	(d)	(e)=(d)/(c)
S1	0.116	53024	6.153	260	42.3
S2	0.132	53024	6.993	39	5.6
S3	0.132	53024	6.993	-329	-
S4	0.094	24459	2.292	383	167.1
S5	0.094	24459	2.930	170	58.0
S6	0.120	24459	2.930	-164	-
S7	0.021	24459	0.514	-153	-
S8	0.087	72633	6.302	51	8.1
S9	0.163	173814	28.336	51	1.8

The analysis of the carbon debt reveals that the biodiesel made from jatropha in primary forest takes four times longer to pay it carbon debt that biodiesel made from palm oil, while in a degraded lands scenario it does incur into a carbon debt.

If CO_2 emissions due land use change are not taken into account, then the biodiesel releases fewer amounts of GHG emissions than fossil fuels.

CONCLUSIONS

Early studies on energy efficiency and carbon balance of biofuels were published more than seven years ago, and revealed a significant reduction in greenhouse gases. Later, the LCA studies were extended to a full analysis of environmental impacts, including issues as air pollution, toxicity, soil degradation and biodiversity loss. If the loss of biodiversity associated with direct and indirect changes in land use is taken into account, in most cases dominate negative consequences to the environment (Fargione, 2008; Searchinger, 2008).

This study reveals that a predominant factor in terms of GHG emissions is the prior use of the soil. The alternative of replacing diesel with biodiesel made from palm oil and jatropha is a benefit on terms of GHG´s contribution if the crop is handled on deforested land or in the coast scenarios. The main reason why biodiesel from palm oil and jatropha on degraded land have a environmental benefit in comparison of the diesel is land use change. New plantations capture large amount of CO_2 giving a positive balance in relation of the production and energy use phases.

The study reveals that biofuels contribution to climate change during the usage stage is minimum compared to fossil fuels. A reason of this fact is that biofuels are considered to have a closed carbon cycle, the reason behind this is the carbon absorbed during their vegetation which does not contain much pollutants (SO_2, CO, NOx) as fossil fuels (Puppo, 2001) .

Despite the minimal GHG emissions during the use phase, there is a considerable environmental impact the production phase of biofuels due the agricultural activities. This could be minimized if a use a higher percentage of biomass is used increasing this way the efficiency of the process. According to Larson (2006), the main reason for poor performance of first generation biofuels is the fact that only a fraction of total biomass is used.

Regarding emissions from land use change, Gibbs et al (2008) states that agricultural expansion into tropical forest ecosystems guide to a net emission of GHGs, while cultivating in degraded lands often provide almost immediate GHG savings. The results shows that biofuels from crops cultivated in deforested areas have a low carbon debt or even a positive impact. The reason behind this is that the plantations biomass captures more carbon than the previous land scenario.

Due to the high carbon debts of biofuels produced from energy crops in forest areas, investigation of Searchinger et al (2008) highlights the value of biofuels produced from municipal, agricultural and industrial waste. According to this, the scenarios where natural ecosystems are turn to biofuels production could not be the best alternative.

Improvements in yields and production technologies for biofuels produced from energy crops will bring benefits in terms of GHG emission. However, if forests are deforested, the carbon debt still requires several decades to be paid. (Gibbs et al, 2008)

REFERENCE

- Food And Agriculture Organization of the United Nations. (2008). *El estado mundial de la agricultura y la alimentación*. Roma: FAO
- Fargione, J., Hill, J., Tilman, D., Polasky, S., Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. Science 319, 1235 (2008).
- Gibbs, H., Johnston, M., Foley, J.A., Holloway, T., Monfreda, C., Ramanmkutty, N., Zaks, D. (2008) Carbon payback times for crop-based biofuel expansion in the tropics: the effects of changing yield and technology. Environ. Res. Lett. 3 (2008) 034001 (10pp).
- Larson, E. (Junio de 2006). A review of life-cycle analysis studies on liquid biofuel systems for the transport sector. Energy for sustainable development, Volumen X No. 2.
- Ley de Promoción del Mercado de Biofuels D.L.Nº28054. (8 de agosto de 2003). *Diario Oficial el Peruano, Lima, Perú.*
- Puppán, D. (2002). Environmental evaluation of biofuels. Periodica Polytechnica Ser. Soc. Man. Sci. Vol. 10, No. 1, pp. 95-116.
- Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change.

Environmental performance of sunflower biodiesel in Chile

Iriarte, Alfredo[1] ; Villalobos, Pablo [2]

[1] Department of Industrial Management and Modelling. Faculty of Engineering. University of Talca. Casilla 747. Talca, Chile.
[2] Departament of Agricultural Economics. Faculty of Agricultural Sciences. Universidad de Talca. Casilla 747, Talca, Chile.
Contact e-mail: a.iriarte@utalca.cl (A. Iriarte)

ABSTRACT

The production of biodiesel is a potential option for diversifying the energy matrix in Chile. However, before this can be implemented, there is a need for environmental research within the framework of a sustainable national energy policy. This paper presents a research concerning the environmental analysis of the future production of sunflower-based biodiesel in Chile, on a national level. The main goal of this study is to compare, by means of Life Cycle Assessment (LCA) tool, eleven environmental indicators for sunflower biodiesel and diesel fossil. For the impact assessment, the CML 2 baseline 2000 method is applied. The results indicate that the biodiesel has less environmental impacts than fossil diesel in four indicators, such as global warming potential and energy demand. However, biodiesel has greater impact in the remainders eight indicators.

Topic: Biofuels

Key words: Biodiesel; life cycle assessment; sunflower; land use change

INTRODUCTION

Chile is developing an energy security policy with the aims of becoming more self-sufficient, diversifying energy matrix, and promoting national renewable energies in a framework of environmental sustainability. The government has worked towards promoting the future use of liquid biofuels [1]. In a context of short-term domestic production, sunflower *(Helianthus annuus L)* is a crop under consideration for the future production of biodiesel [2], particularly in the central Chile.

In the development of the sunflower biodiesel, it is necessary to evaluate its supply chain from an environmental point of view to identify strengths and weaknesses for a sustainable production.

The main objective of this work is to compare, by means of Life Cycle Assessment (LCA) tool, the potential environmental impacts of sunflower biodiesel and diesel fossil.

METHODOLOGY

The methodology used in this study is according to the ISO 14040 framework [3]. The Gabi 4.2 software program [4] has been used to calculate the environmental impacts as defined in the CML 2001 method [5].

Functional Unit

The functional unit (FU) in this study is defined as the supply, on a national scale, of sunflower-based biodiesel for 1 km driven by a truck, taken to be equal to 0.266 kg of biodiesel for a 28 t truck [6].

System boundaries and scope of the study

This study is a well–to–wheel LCA, with the sequence of biodiesel supply divided into the following stages: (1) production of sunflower, (2) sunflower transport from the field to the biodiesel plants, (3) drying of sunflower, (4) oil extraction, (5) oil transesterification, (6) transport and distribution of biodiesel from the plants to the final user, and (7) use of biodiesel in a 28 t truck

The most likely conditions for production and distribution of sunflower biodiesel in Chile, as published in national studies on its future implementation [7], are considered in this work.

Data quality

The agricultural stage of sunflower production is based on national agronomic data as published previously by Iriarte et al. [8]. Data for the oil extraction and transesterification stages are based on international standard technology, adapted to the situation in Chile, as production of sunflower biodiesel is currently only on a pilot scale here.

The study includes the background processes associated to the production and delivery of inputs. In our study, it emerges that several conditions of the background processes derived from the international databases (such as transport distances, means of transport, electricity matrix) are different from the conditions in Chile. This means that in order to draw up the inventory analysis, a previous data compilation on the national conditions of the supply chain of inputs had to be carried out. The national data are integrated into the Ecoinvent international database [9] to adapt partially its process module parameters to Chilean conditions.

Assumptions and considerations

For this study, direct land use change (LUC) is considered, associated with the conversion of non-degraded grassland to agricultural land under till farming. This is the most likely situation given the condition of the non-agricultural land in the central area of Chile. The CO_2 emissions associated with direct LUC are estimated according to the IPCC approach (tier 1) [10, 11].

The biogenic CO_2 captured by photosynthesis during sunflower growth, and its release during biodiesel combustion, are considered neutral; in agreement with the standard approach related to the biogenic carbon cycle [12].

RESULTS

Table 1 shows the potential environmental impacts and the energy demand of sunflower biodiesel in Chile. It also shows the impacts of fossil diesel. The results indicate that biodiesel has less impact in four indicators in comparison to fossil diesel: global warming potential (GWP), energy demand, ozone layer depletion potential and abiotic depletion potential. The GWP for biodiesel is 0.62 kg CO_2 equiv./km. This corresponds to a 32% saving in GHG emissions compared to fossil diesel. The energy demand of the biodiesel is 5.3 MJ/km. This represents an energy saving of 56% compared to fossil diesel.

In the eight remaining indicators, biodiesel has higher impact. The stage of biodiesel supply chain with the greatest impacts is the agricultural production of sunflower.

Table 1. Potential environmental impacts and energy demand of sunflower biodiesel and diesel in Chile.

Impact category/indicator	Biodiesel	Fossil diesel
Acidification (kg SO_2 equiv./FU)	1,4E-02	5,6E-03
Eutrophication (kg PO_4 equiv./FU)	4,4E-03	1,0E-03
Freshwat. aquatic ecotox. (kg DCB equiv./FU)	1,9E-00	5,0E-03
Global warming (kg CO_2 equiv)/FU)	6,2E-01	9,1E-01
Human toxicity (kg DCB equiv./FU)	7,1E-02	4,5E-02
Marine aquatic ecotox. (kg DCB equiv./FU)	9,4E+01	2,4E+01
Ozone layer depletion (kg R11 equiv./FU)	3,4E-08	1,3E-07
Photochem. ozone creat. (kg C_2H_4 equiv./FU)	9,6E-04	6,6E-04
Radioactive radiation (DALY/FU)	8,5E-10	3,4E-10
Terrestric ecotox. (kg DCB equiv./FU)	2,9E-03	6,7E-04
Abiotic depletion (kg Sb equiv./FU)	2,4E-03	5,9E-03
Energy demand indicator (MJ/FU)	5,3E+00	1,2E+01

CONCLUSIONS

This study, using a site-specific LCA, demonstrates that the future production of sunflower biodiesel in Chile, with the most likely production conditions, has less environmental impact than fossil diesel in four indicators: global warming potential, energy demand, ozone layer depletion potential and abiotic depletion potential. The GWP of biodiesel is 2.1 kg CO_2 equiv./kg; a 40% saving of GHG emissions compared to fossil diesel. However, biodiesel has greater impact in eight indicators: acidification, eutrophication, radioactive radiation and those associated with terrestrial, human, freshwater and marine ecotoxicity.

Future environmental studies of sunflower biodiesel should be concentrated on the agricultural stage, particularly the evaluation of fertilizer sources, agricultural practices and effects of land use change.

REFERENCES

[1] Rutz D, Thebaud A, Janssen R, Segura S, Riegelhaupt E, Ballesteros M, et al. 2006. Biofuel policies and legislation in Latin America. BioTop report Task 2. Berlin, Germany: WIP Renewable Energies.

[2] Ministerio de Agricultura Chile - ODEPA. 2007. Contribución de las Políticas Agrarias al desarrollo de los biocombustibles en Chile. Santiago, Chile: Ministerio de Agricultura Chile.

[3] ISO. International Organization of Standardization. 2006. ISO 14040-Environmental management - Life cycle assessment - Principles and framework. Geneva, Switzerland.

[4] PE Europe. 2006. GaBi 4 Manual. Leinfelden-Echterdingen, Germany: PE Europe GmbH - IKP of the University of Stuttgart.

[5] Guinée J, Gorree M, Heijungs R, Huppes G, Kleijn R, de Koning A, et al. 2002. Life cycle assessment; an operational guide to the ISO standards; Part 1 and 2. Den Haag and Leiden, The Netherlands: Ministry of Housing. Spatial Planning and Environment (VROM) and Centre of Environmental Science (CML).

[6] Jungbluth N, Faist Emmenegger M, Dinkel F, Stettler O, Doka G, Chudacoff M, et al. 2007. Life cycle inventories of bioenergy. Ecoinvent report nº 17. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

[7] CATA. Centro Avanzado de Gestión, Innovación y Tecnología para la Agricultura. 2007. Evaluación del potencial productivo de biocombustibles en Chile con cultivos agrícolas tradicionales. Santiago, Chile: Universidad Técnica Federico Santa María.

[8] Iriarte A, Rieradevall J, Gabarrell X. 2009. Life cycle assessment of sunflower and rapeseed as energy crops under Chilean conditions. Journal of Cleaner Production; 18(4):336-45.

[9] Frischknecht R, Jungbluth N, Althaus H, Doka G, Heck T, Hellweg S, et al. 2004. Overview and Methodology. Ecoinvent report nº 1. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

[10] IPCC. Intergovernmental Panel on Climate Change. 2006. Cropland. Volume 4, Chapter 5. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. IPCC Guidelines for National Greenhouse Gas Inventories. Hayama, Japan: National Greenhouse Gas Inventories Programme, IGES.

[11] IPCC. Intergovernmental Panel on Climate Change. 2006. Generic methodologies applicable to multiple land-use categories. Volume 4, Chapter 2. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. IPCC Guidelines for National Greenhouse Gas Inventories. Hayama, Japan: National Greenhouse Gas Inventories Programme, IGES.

[12] Cherubini F. 2010. GHG balances of bioenergy systems - Overview of key steps in the production chain and methodological concerns. Renewable Energy 2010;35(7):1565-73.

Estimation of the environmental impacts of the integrated Solid Oxide Fuel Cell technology with a sugar-ethanol factories using coupled LCA and Exergy Analysis.

Casas Yannay[1], Dewulf Jo[3], Arteaga Luis. E[1], Morales Mayra[1], Rosa Elena[2].
[1]Chemical Engineering Department. Central University of Las Villas. Road to Camajuaní Km 5.5. Santa Clara, c/p 54830, Villa Clara, Cuba.
[2]Applied Chemistry Center, Central University of Las Villas. Road to Camajuaní Km 5.5. Santa Clara, c/p 54830, Villa Clara, Cuba.
[3]Research Group ENVOC, Ghent University, Coupure Links 653, 9000 Ghent, Belgium
***corresponding author: yannay@uclv.edu.cu**
Telf: (53) (422)-81164 Fax: (53) (422)-81608

ABSTRACT
The integrated Solid Oxide Fuel Cell (SOFC) technology with sugar-ethanol factories is evaluated by a Life Cycle Assessment approach (LCA) to assess the environmental impact and by an Exergetic Life Cycle Assessment (ELCA) to account for the exergy efficiency of the system. The sugarcane is the primary feedstock and sugar, ethanol and electricity are the main products in the systems, which define the functional unit, being 9860 Kg/h of sugar, 2195 Kg/h of hydrated ethanol and 850 kWh of electricity.
The environmental impact (greenhouse gases and air pollution), exergy efficiency and renewability parameter have been taken into account as an indicator for the comparative assessment of the sugar, ethanol and electricity technologies. The results of the LCA show that, the use of a SOFC technology involves a reduction of the greenhouse gas emissions and non-renewable source with respect to the conventional integrated sugar and ethanol plant. A detailed list of material and energy inputs is done using data from local factory and completed using simulation data by Aspen-Hysys.
Topic:
Key Words: Life cycle Assessment, Exergy Efficiency, SOFC, Renewability parameter.

INTRODUCTION

Today, the effects of depletion of fossil fuel resources and global warming have pointed out the requirement of innovative energy generation systems that do not only increase efficiency and but also reduce harmful emissions and make use of renewable energy resources. Currently sugar cane is known likely the most productive biomass energy source by its rather efficient conversion of solar energy into high potential energy products (ethanol, bagasse and char). The bagasse released by sugar factories has long been a special feature on the electricity production through traditional cogeneration systems. Ethanol is the most widespread biofuel studied for a wide variety of energy systems, including recently also for fuel cells power plants. It is a point of discussion if ethanol, derived from sugar cane, maize (corn) and sugar beets, is a sustainable energy resource and if it offers environmental and long-term economic advantages over fossil fuels.

In Latin America, sugar cane is the main resource to obtain ethanol using the traditional two steps method: molasses fermentation with *sacharomises serevisiae* and distillation. However, ethanol is not the only product from sugar cane: there are different industrial valorization scenarios, such as sugar factories, alcohol distilleries, integrated sugar and alcohol plants, and electricity cogeneration plants using bagasse as fuel.

In previous papers published by Ensinas et al [1] thermal integration of the sugar and ethanol processes applying energy and exergy analysis was studied. Furthermore, four configurations of cogeneration systems (steam cycle, biomass gasification and combined cycle with biomass gasification) were evaluated by these authors.

Contreras et al. [2] quantified the environmental impact of four alternatives of conventional sugar production in Cuba, using Life Cycle Assessment methodology (LCA).

Solid oxide fuel cells (SOFC) are considered to be an emerging technology characterized by a high efficiency, low CO_2 emissions, and high flexibility in terms of fuel type and installation requirements.

The exergy tool has been used in the evaluation of SOFC running on biomass gasification gasses and ethanol [3,4]. Casas et al. [5] determined the effect of operational variables on the exergy efficiency and irreversibilities of an ethanol fueled solid oxide fuel cells system. Also, the comparison of methane and ethanol as fuels for a SOFC power plant by means of exergy analysis was studied by Douvartzides et al. [6]. On the other hand Meyer et al. [7] used the ELCA methodology to asses an integrated SOFC system to allothermal biomass gasification.

According to the explained above, the integration of traditional technology of sugar production, ethanol and bagasse cogeneration with a SOFC has not yet been studied considering the environmental impact. The aim of this paper is an environmental sustainability analysis through LCA and ELCA of a novel electricity generation system consisting in a solid oxide fuel cell unit integrated into a traditional sugar-ethanol production plants. The primary feedstock of the system is sugar cane. Several operational conditions in the SOFC system are evaluated to guarantee the defined functional units and to obtain the most feasible condition.

2. LCA METHODOLOGY

In the present paper two methods of assessing processes are integrated: LCA and ELCA. Life cycle assessment (LCA) is a method to define and reduce the environmental load from a product, process or activity by identifying and quantifying energy and materials usage and waste discharges, assessing the impacts of the wastes on the environment and evaluating opportunities for environmental improvements over the whole life cycle [7,8]. The exergy life cycle assessment (ELCA) is used to quantify the exergy input; it allows the quantification

2.1. Functional units

The sugar, ethanol and electricity are the outgoing products, a set of 9.86 ton/h sugar, 2.195 ton/h of hydrated ethanol (96% ethanol) and 847 kWh of electricity obtained from the sugarcane is considered as functional unit. See Figure 1.

2.2. Description of the studied cases

2.2.1 Scheme 1. Traditional sugar-ethanol factory

Traditional sugar production, with ethanol produced from molasses via fermentation and distillation, and steam and electricity production from bagasse combustion were considered in the scheme 1.

The sugar factory has a cane mill capacity of 105.00 ton/h, obtaining for this 9.86 ton/h of sugar, 4.12 ton/h of molasses and 31.50 ton/h of bagasse. The operation of the sugar mill is 100 d/year.

The non-sugar impurities of juice are separated in the flash tank and clarifier by the addition of several chemical additives as lime, sulfur, among others.

With respect to the ethanol process, chemical components used are nutrients (urea, sulfuric acid, etc) in the saccharomyces cerevisiae yeast growth. The fermented liquor has around 4-5 %w/w of ethanol concentration and is directed to the distillation process. The installed capacity of the distillery is 550 hL.day^{-1} of hydrated ethanol (96 ºGL), being mostly used by the liquor industry, in pharmaceutical applications and in the chemical industry.

Steam and electricity are produced by bagasse combustion (31.5 ton h^{-1}), steam cogeneration and supplemented with other fuels (0.105 ton h^{-1} of diesel). The flue gases are considered as harmful emissions; their composition and quantities are obtained from a local factory and completed using simulation data by Aspen-Hysys. Bagasse with 50% of moisture content, 23.50% of carbon, 3.23 % of hydrogen, 22.00 % of oxygen and 1.25% of ash was assumed according to laboratory characterization. The surplus of electricity (315 kWh/hr) is distributed along of the National Network.

The ashes from bagasse combustion and the filter cake from the sugar process are used to substitute chemical fertilizers (avoided products) in the agriculture stage; such as urea, triple super phosphate and potassium chloride [2]. Wastewaters from the sugar and ethanol processes are treated by means of a biological process (oxidation lagoon), using the liquid product in ferti-irrigation, avoiding the use of fresh water and fertilizers. Due to its high protein content, yeast waste is considered as an avoided products as animal feed.

2.2.2 Scheme 2. SOFC technology integrated in a sugar-ethanol factory.

In Scheme 2, a SOFC system is integrated in the traditional sugar cane-ethanol production as follows. From the ethanol process, 0.310 ton h^{-1} ethanol (56 % w/w) is transferred to the SOFC that produces 1.6 MJ/h heat (in exhaust gases), 486.18 kWh/hr electricity and 2.248 ton h^{-1}of emissions to air.

The SOFC system consists of a vaporizer, a reformer, fuel cell and post-combustor. In the vaporizer, the liquid mixture (water and ethanol) is vaporized and preheated before to the reformer inlet, where is converted into synthesis gases. The mixture leaving the reformer is fed and oxidized with air within a solid oxide fuel cell module; obtaining electricity, heat and exhaust gases by an electrochemical conversion. Finally, the fuel cell depleted gases reacts into a post-combustion unit to fulfill the energy requirements of the process.

Input and output data for this SOFC system have been calculated based on the works of Arteaga et al. and Casas et al. [9,10]. Critical is the ethanol steam reforming stage: changes of operating temperature and the water-ethanol fed molar ratio affects its efficiency and hence its environmental performance as well. Therefore, four operational water-ethanol fed molar ratios (R_{AE}) are investigated, resulting in alternative 2A, 2B, 2C and 2D. For each of these alternatives, operations at four different operational reactor temperature (T_{SR}) are considered, resulting into 16 variants for scheme 2; e.g. at R_{AE}=5, operations at 823, 873, 923 and 973 result in the four alternatives 2A1, 2A2, 2A3 and 2A4, respectively.

3.RESULTS AND DISCUSSION

The comparison of the alternatives was carried out using three criteria: environmental impacts (GHG and AP), exergy efficiency and renewability parameter

The GWP evaluated over 100 years is equal to 1 for carbon dioxide (CO_2) and 21 for CH_4 [9].

Direct emissions are calculated from the system mass balance according to:

$$m_{GHG}^{Total} = \sum_{j=1}^{n} \left(f_j^{GHG} \cdot GWP_j \right) \quad (1)$$

The renewability parameter (α) is defined as the relationship between the renewable exergy consumption ($R_{Renewable}^{inlet}$) and the total exergy consumption of process (R_{Total}^{inlet}), which is showed in the following equation:

$$\alpha = R_{Renewable}^{inlet} \big/ R_{Total}^{inlet} \quad (2)$$

The exergy efficiency is defined as:

$$\eta_{exergy} = \sum_{p=1}^{3} f_p \cdot e_p^o \Big/ \sum f_j^{inlet} \cdot e_j^o$$ p_1 = sugar, p_2 = ethanol and p_3 = electricity (3)

3.1 Global warming potential.

The CO_2, green house gasses (GHG) and air pollution (AP) emissions are estimated for all the explored alternatives.

The total CO_2 amounts emitted to the environment exceeds 26.00 $ton_{CO2eq}\ h^{-1}$, in all studied cases. The Alternative 2 (sugar-ethanol-SOFC) presented higher values (27.247 $ton_{CO2eq}\ h^{-1}$) at all operational conditions. The biogenic CO_2 are higher in the second alternative (variants from 2A1 to 2D4) than in Alternative 1 (1.494 $ton_{CO2eq}\ h^{-1}$).

As can be seen, higher greenhouse gases (GHG) emissions (0.646 $ton_{CO2eq}h^{-1}$) are observed for Alternative 1. This difference is mainly due to additional exhaust gases from non-renewable resource combustion (diesel) installed to fulfill a gap of 531.71 kWh of electricity (63 % of the functional unit). As the input of fossil fuel energy is lowered, the CO_2 emissions contributing to the GHG are reduced.

The integration of the SOFC power plant with a conventional sugar–ethanol process has a positive effect on GHG emissions. The GHG emissions reaches values of 0.309 and 0.289 $ton_{CO2eq}h^{-1}$ for the variants 2A1 and 2D4 respectively, allowing reducing the CO_2 emissions in 0.360 $ton_{CO2eq}h^{-1}$ in comparison to the maximum reported for the Alternative 1 (integrated sugar-ethanol factory).

3.2 Lifecyle exergy efficiency.

Figure 2 shows the comparison of the exergy efficiency of the discussed industrial schemes.

The use of the SOFC technology has a positive effect on the exergy efficiency with respect to conventional sugar-ethanol process. The efficiency varied between 19.0 % and 18.10 % for Alt. 2 and Alt.1 respectively. According to the definition written previously (Eq. 3), the resources and their quality have a strong influence (proportional inversely) on the exergy efficiency; for this reason, the exergy efficiency of Alternative 1 presents lower values, which means that the resource consumption is higher in comparison with all the operational variants for of Alternative 2.

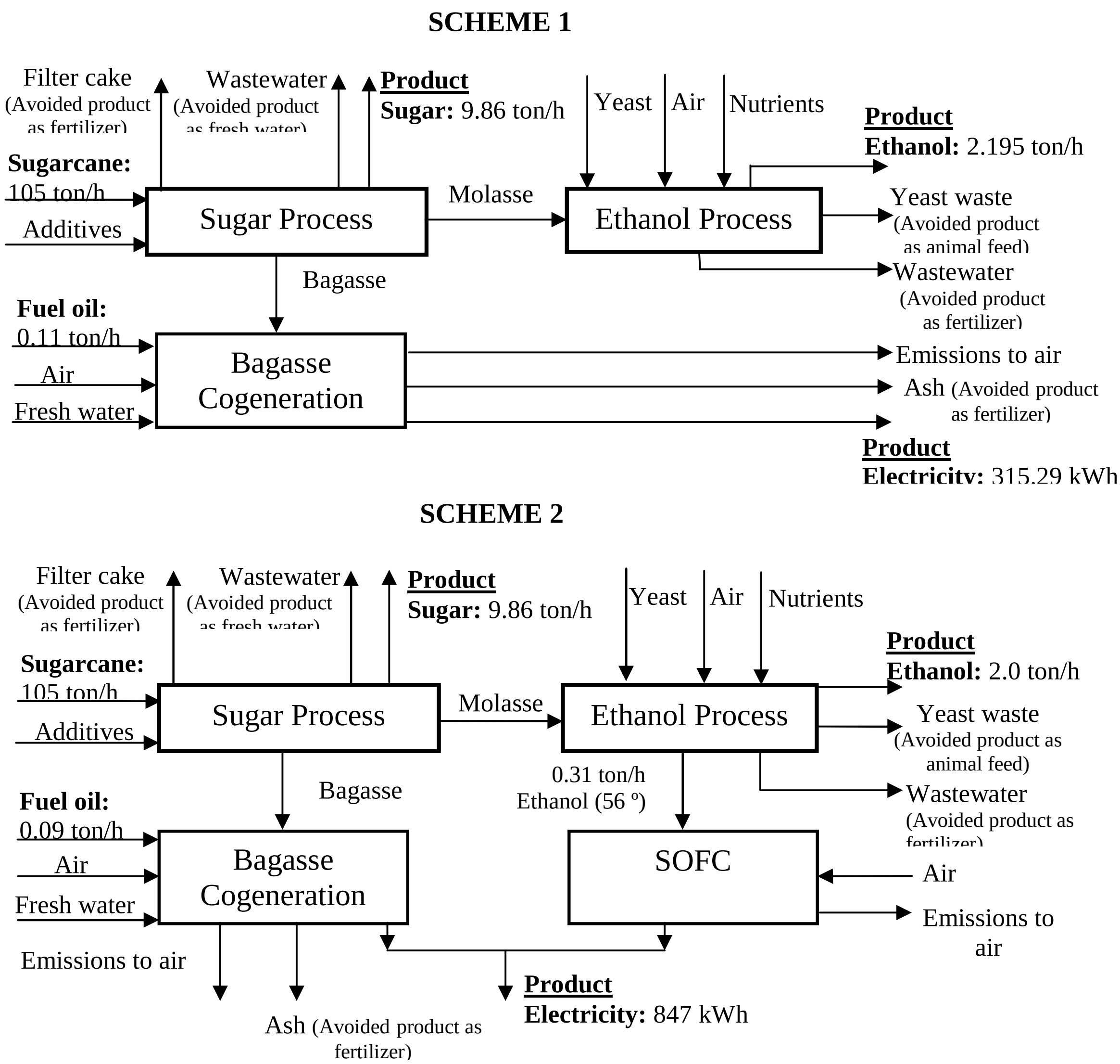


Figure 1. Technological schemes.

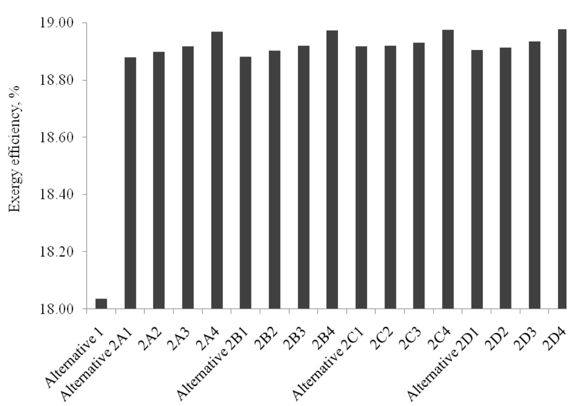


Figure 2. Exergy efficiency for alternatives studied

The change of the reformer temperature and R_{AE} slightly affects the process efficiency, obtaining the maximum result for 2D4 (18.98 %). These little differences are related to changing diesel consumption, being lower at higher temperature and higher R_{AE}.

3.3 Renewability parameter.

Figure 3 reports the renewability parameter for each Alternative. The renewability degree of the alternatives is associated to the amounts of fossil fuels and chemicals, which in the present paper are considered as non-renewable resources.

The fossil fuel and chemicals used to produce the deficit of ethanol and electricity from CSS are added to the inlet stream for all alternatives so that for Alt.1 only fossil fuel used by the CSS is added, while chemicals necessary to produce 0.180 ton h^{-1} of ethanol are included for all variants of Alternative 2. For this reason the chemicals consumptions are lower for Alt.1, while the diesel, lubricant oil and coolant are higher for Alt.2.

The reduction of non-renewable resources increases the renewability character of the process. Indeed, Alternatives 2 with integration of SOFC technology are more renewable than the traditional sugar-ethanol production, obtaining indexes near to 0.93 and 0.85 for Alt.2 and 1 respectively.

On the other hand, the fuel cell power is directly proportional to the hydrogen obtained in the reformer (hydrogen yield); and this last is strongly improved when the reactor temperature and R_{AE} are increased.

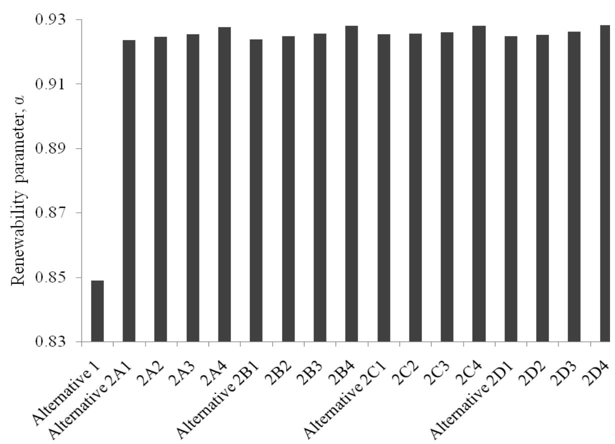


Figure 3. Renewability parameter for each alternative.

4. CONCLUSIONS.

The analysis of the sugar and ethanol processes by the traditional method, including cogeneration with bagasse (Alternative 1) and the integration with a Solid Oxide Fuel Cell technology (Alternative 2) was performed based on different indicators: global warming potential, air pollution, exergy efficiency and renewability. It was demonstrated that the integration of SOFC technology with the traditional sugar-ethanol process and electricity using bagasse cogeneration are likely to be environmentally superior to Alternative 1, specifically with respect to greenhouse gas emissions, renewability and exergy efficiency.

Sugar, ethanol and electricity from sugarcane are renewable sources of energy only to a certain extent, since about 15.10 % and 7.6 % of the total inlets feedstock comes from fossil sources for Alternative 1 and 2 respectively.

5. Acknowledgments.

The authors wish to acknowledge to the editor and unknown referees. This work has been financially supported by the VLIR Program, Project 7, (Environmental Education and Development of Clean Technologies) Ghent University, Faculty of Bioscience Engineering.

6. References.

[1]. Ensinas, A. V., Nebra, S. A., Lozano, M. A., Serra, L. M., 2007. Analysis of process steam demand reduction and electricity generation in sugar and ethanol production from sugarcane. Energy Conversion and Management. 48, 2978–2987.

[2]. Contreras, A. M., Rosa, E., Pérez, M., Van Langenhove, H., Dewulf, J., 2009. Comparative Life Cycle Assessment of four alternatives for using by-products of cane sugar production. Journal of Cleaner Production. 17, 772–779.

[3]. Sordi, A., Silva, E. P., Milanez, L. F., Lobkov, D. D., Souza, S. N. M., 2009. Hydrogen from biomass gas steam reforming for low temperature fuel cell: Energy and exergy analysis. Brazilian Journal of Chemical Engineering. 26, 159 – 169.

[4]. Sordi, A., Da Silva, E. P., Neto, A. J. M., Lopes, D. G., Araújo P. D., Pinto, C. S., 2009. Thermodynamic simulation of biomass gas steam reforming for a solid oxide fuel cell (SOFC) system. 26, 745 – 755.

[5]. Casas, Y., Arteaga, L. E., Morales, M., Rosa, E., Peralta, L. M., Dewulf, J., 2010. Energy and exergy analysis of an ethanol fueled solid oxide fuel cell power plant. Chemical Engineering Journal. 162, 1057–1066.

[6]. Douvartzides, S., Coutelieris, F., Tsiakaras, P., 2004. Exergy analysis of a solid oxide fuel cell power plant fed by either ethanol or methane. Journal of Power Sources. 131, 224–230.

[7]. Meyer, L., Castillo, R., Buchgeister, J., Tsatsaronis, G., 2009. Application of Exergoeconomic and Exergoenvironmental Analysis to an SOFC System with an Allothermal Biomass Gasifier. Int. J. of Thermodynamics. 12, 177-186.

[8]. Azapagic, A., Clift, R., 1999. Life cycle assessment and multiobjective optimisation. Journal of Cleaner Production. 7, 135–143.

[9]. Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., Suh, S., 2009. Recent developments in Life Cycle Assessment. Journal of Environmental Management. 91, 1–21.

[10]. Arteaga, L.E., Casas, Y., Peralta, L.M., Kafarov, V., Dewulf, J., Giunta, P., 2009. An auto-sustainable solid oxide fuel cell system fueled by bio-ethanol Process simulation and heat exchanger network synthesis. Chemical Engineering Journal. 150, 242–251.

Life Cycle Assessment for the Production of Second Generation Bioethanol from Eucalyptus wood in Chile

Wiche, Pia A.[1+], **Dewulf, Jo**[2], **Aroca, German E.**[3], **Conejeros, Raul**[3].

[1] **King Abdullah University of Science and Technology 4700, P.O. Box 2626, Thuwal, Saudi Arabia 23955-6900**

[2] **Department of Organic Chemistry, Faculty of Agricultural & Applied Biological Sciences, Ghent University, Coupure Links 653,B-9000 Ghent, Belgium**

[3] **Escuela de Ingenieria Bioquimica, Pontificia Universidad Catolica de Valparaiso, General Cruz 34, Valparaíso, Chile**

[+] **Corresponding author (pia.wiche@kaust.edu.sa)**

Abstract

The following paper deals with the life cycle assessment (LCA) for the production of second generation bioethanol from lignocellulosic material in Chile. This is, care was taken to design and assess the situation considering tree production conditions of the country and a theoretical ethanol production process based on an acid steam explosion under weak acidic conditions and a separate downstream treatment process for the resulting sugar streams. Limits of the system in the LCA included raw materials, tree production, ethanol production and use. Mixing of the ethanol in gasoline and later commercialization were not considered. The assessment was done with the software package SimaPro using EcoIndicator 99 (Hierarchical), and with the CEENE method for assessment of exergy and determination of exergetic efficiency. Results were strongly influenced by the use of fossil fuels, which increased the impact. On the other hand, use of lignin and biogas as replacement for fossil fuels in the process rendered high environmental credits. Finally, the exergetic efficiency of the process against fossil fuels was positive, which sheds light over the possibility of obtaining better efficiencies provided process optimization.

Keywords: LCA, bioethanol, lignocellulose, exergy.

Introduction

Chile has historically depended on external sources of energy to supply for internal consumption. Projections of difficulty for the supply of fossil fuels have motivated the need for alternative, renewable sources of energy, produced inside the country. For this reason, several research lines are being explored, one of thembeing the production of second generation bioethanol from lignocellulosic material, which is a readily available resource in the country. The production of second generation bioethanol is a topic of active research nowadays, with several pilot and commercial scale plants being built around the world (e.g. Iogen, Canada; Izumi, Japan; Biogasol, Denmark; Verenium, U.S.). In Chile, BioEnercel S.A. is one of the consortia dealing with the problem. This work presents the preliminary LCA for the production of bioethanol from high density *Eucalyptus nitens* plantations, as well as a proposal for a production process.

Bioethanol production requires two steps: the production of biomass, and the treatment of this biomass for the production of bioethanol. One critical stage in the process is wood pretreatment, which facilitates later fermentation by microorganisms. The processes use acids, bases, fertilizers, water and other chemical substances that can greatly affect the environment if not carefully treated. In order to assess the effects of these substances, LCA is used. This is a tool that helps to obtain an index measure of the effect a production process can cause over the environment, human health or the availability of resources, but also, it can be used as a means for discovering inefficiencies in the production process. Several methods are available for the calculation of these features, such as EcoIndicator 99[1] and CEENE[2] (Cumulative Exergy Extraction from the Natural Environment), which were used in this study. EcoIndicator is an endpoint method describing the effects caused by the discharges to the environment. On the other hand, CEENE is a resource oriented method, so comparing both makes it possible to see the effects at both ends of the production process.

It was found that the greatest impacts were produced by the same processes in both analysis methods, and were linked to the use of fossil fuels, as in the production of fertilizers, ammonia salts, sulphuric acid and sodium hydroxide. The analysis played an important role in identifying possible sources of inefficiency in the process, shown as excessive exergy requirements or environmental impacts.

The results indicate that LCA is a useful tool when assessing the damage to the environment, and exergetic analysis is a powerful tool for finding points of inefficiency in the process.

Methods

The process was designed using information available in the literature for *Eucalyptus* or related trees, when necessary, and from information published by INFOR (Instituto Forestal – Forestry Institute).

The study considered raw and database information for the LCA. The preferred database was EcoInvent, mainly because the CEENE method is associated to it. EcoInvent was used to describe most materials in the study. Importantly, water was differentiated if coming from the natural environment or the chemical industry, depending on the stage.

A plantation density of 1.111 [trees/ha] was considered for the study. For its production purposes, 2 fertilizers, 2 herbicides and 2 fungicides, as well as plastic bags for germination, compost, and other chemicals for intermediate steps were taken into account. The consumption of CO_2 and the production of O_2 were added as credits for the process. The system boundaries can be seen in Figure 1.

The temporal limit of the system was set in 2015, mainly to avoid distortion by variations in the market and the speed of change in bioethanol production technology. The estimated consumption by the market for that year was 243.158 [m^3/y], the equivalent to a volumetric replacement of 5% on gasoline, if the energy delivered into the system were equal to that of gasoline alone.

This system was analyzed using the software SimaPro, with EcoIndicator 99 in Hierarchical mode and CEENE[2] as impact assessment methods.

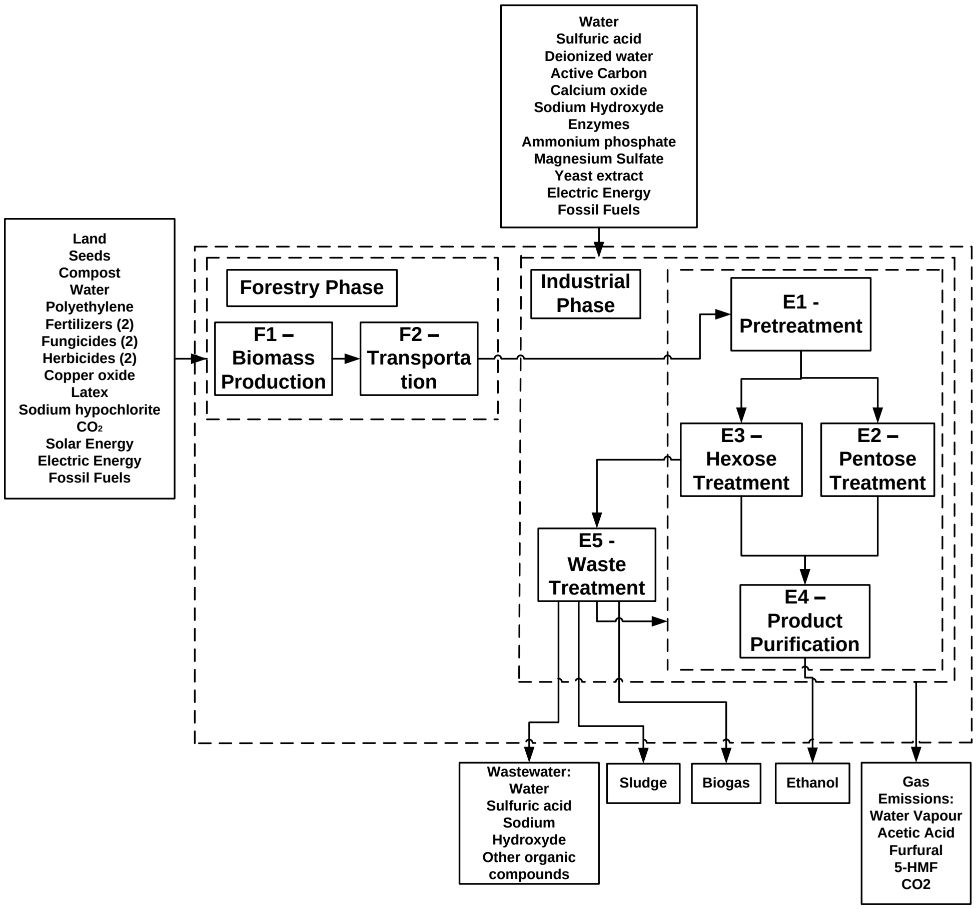


Figure 1. System boundaries.

Results and Discussion

The main aim of this study was to determine in a preliminary stage, whether the production of ethanol would make sense exergetically and environmentally. For such, a base case was designed in which the ethanol production process had a minimum of reflux and reuse flows. This would present the 'worst case scenario' for the production process, which should improve the results (i.e. decrease in the overall impact and an increase in the exergetic efficiency) when using a more efficiently designed process. However, the mixing of ethanol in gasoline and later commercialization were not considered.

In this case, the ethanol production process from wood presented an efficiency of 51.9% with respect to the theoretical maximum reported[3].

The ethanol production stage considered acid steam explosion of wood chips, followed by separate treatment of the hexose rich and pentose rich streams. Lignin was separated from the hexose rich stream and was later incinerated to generate energy for the process. The rest of the stream was fermented for the production of ethanol. A detoxification process was included for the pentose rich stream, which considered the use of membrane filtration, evaporation, lime, and charcoal. The resulting stream, comprised mainly by sugars and water, underwent fermentation for the production of ethanol. The ethanol containing streams were submitted to distillation for obtaining an ethanol rich stream which was later dehydrated in a zeolite bed. Waste water was treated in an anaerobic fermentation stage, producing biogas which was later used in the process.

Results obtained by both impact assessment methods show that the most critical stages were forestry, for the use of fertilizers, diesel-depending machinery, and soil; steam explosion, for the use of sulphuric acid; lignin extraction, for the use of sodium hydroxide and sulphuric acid; ammonia salts used during fermentation; steel, for the production of equipment and machinery; and charcoal, mainly for the land use associated to its production. On the other hand, carbon fixation by trees, and use of biogas, lignin and ethanol as replacement for fossil fuels, were important sources of environmental credits when analyzed by the EcoIndicator 99 method. The three latter were taken as 'avoided products' compared to the use of different fossil fuels. Effects over analysis results can be seen in Figure 2.

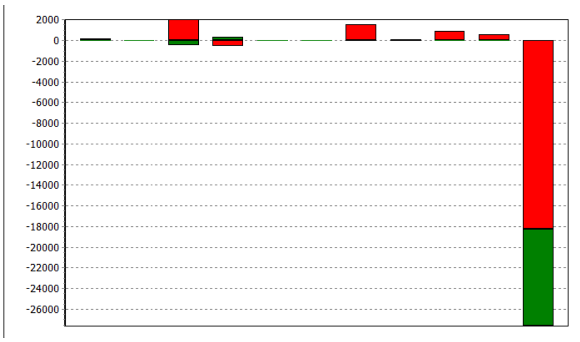


Figure 2. Normalized score, by category for the EcoIndicator 99 method. From left to right: carcinogens, respirable organics, respirable inorganics, climate change, radiation, ozone layer, ecotoxicity, acidification / eutrofication, land +use, minerals, and fossil fuels. Red: ethanol production; Green: ethanol use.

Moreover, CEENE only measures the extraction of exergy from the natural environment, so it did not consider credits. CEENE results, broken down by category, are shown in Figure 3. The main contribution to the overall result is Land Use, with over 70% of total. Land occupation and transformation in concentrated in both the tree and charcoal production, and accounts for the extraction of solar energy, incident over such an area of soil. Fossil energy and water resources are also important, and may be reduced improving the recycling of streams in the system.

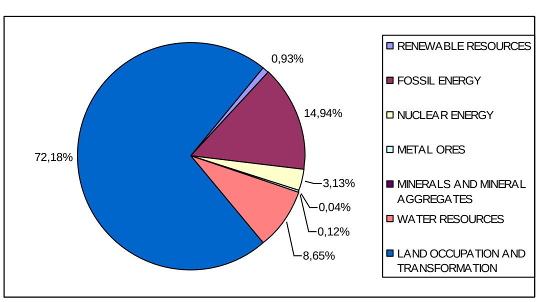


Figure 3. Contribution per category to the total CEENE score.

The exergetic efficiency of the process was found to be 15.6% [exergy obtained in ethanol/exergy extracted]. Other studies presented higher exergetic efficiencies than in this work, with different feedstock such as banana[4] or corn[5]. This may account for the greater complexity of the cellulosic matrix in *Eucalyptus* compared to the other materials. Overall efficiency *versus* fossil fuels resulted in 1.04 (this is, a 4% above the null line), which means there is greater exergy in ethanol than the exergy wasted by fossil fuels in its production. The result was considered positive, as the analysis was done over a 'worst case scenario' (most inefficient process design).

A small sensitivity analysis over the CEENE results showed that the density of plantation has a much greater effect over the extraction of exergy from the environment than does the average distance from the greenhouse to the plantation spot.

Better accuracy will be obtained as more life cycle information is made available for the region (Chile). As well, it is necessary to improve the assessment over important stages such as enzyme production of charcoal production. On the other hand new information on the tree production process is becoming available, which will improve the results on future LCA refinements.

Conclusion

It was observed that the production of bioethanol by the proposed process renders more renewable energy than invested fossil energy, which presents a promising future for more efficient processes and supports the production of bioethanol as a good alternative to fossil fuels.

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References

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[1] Pré Consultants. 2001. Eco – indicator 99, 1999. Amersfoort, Netherlands: Pré Consultants.

[2] Dewulf, J., M. E. Bösch, B. Demeester, G. Vandervorst, H. Van Langenhove, S. Hellweg and M. A. J. Huijbregts. 2007. Cumulative Exergy Extraction from the Natural Environment(CEENE): a comprehensive Life Cycle Impact Assessment method for resource accounting. Environmental Science and Technology. 41: 8477 – 8483.

[3] Rodríguez, J. 2008. Uso de Biomasa Forestal: Bioetanol. www.cormabiobio.cl. Accesed 24th, April, 2009.

[4] Velásquez A., H. I., Ruiz C., A. A, Oliveira J., S. 2009. Ethanol Production from Banana Fruit and its Lignocellulosic Residues: Exergy and Renewability Analysis. International Journal of Thermodynamics 12:155 – 162.

[5] Ferraro, D. 2008. Evaluación exergética de la producción de etanol en base a grano de maíz: un estudio de caso en la Región Pampeana (Argentina). Ecología Austral 18: 323 – 336.

CARBONFOOTPRINT FOR BIOETHANOL FROM CASSAVA IN COLOMBIA.

Botero, Jaime. MBA[1]
Castaño, Hader. MSc[2]
Naranjo, Carlos. Esp[3]
Gallego, Sonia. MSc[4]
[1,2]Politécnico Jaime Isaza Cadavid-Medellín, Colombia.[1] jlbotero@elpoli.edu.co, [2] hicastano@elpoli.edu.co.
[3]GAIA Servicios Ambientales Medellín - Colombia. cnaranjo@gaiasa.com
[4]CLAYUCA-CIA, Palmira – Colombia, s.gallego@cgiar.org

ABSTRACT

In this study, the life-cycle energy and environmental assessment was conducted for bioethanol production from cassava in Colombia. The scope covered all stages in the life cycle of bioethanol production including cultivating, chip processing, transportation and bioethanol conversion. The input–output data were collected at plantation sites and ethanol pilot plant which included materials usage, energy consumption, and all emissions. From the energy analysis, the results show that cassava-based bioethanol has a carbon footprint of 0,345kgCO_{2e} per kilogram of ethanol. The carbon footprint for the bioethanol from Cassava is 65gCO_{2e}/MJ, while the carbon footprint for conventional gasoline is 82gCO_{2e}/MJ. The energy conversion efficiency of Fuel ethanol is 1.34, indicating that the energy from ethanol out of these raw materials is higher than the energy supplied during its production

Keywords: Bioethanol, Cassava, Greenhouse gas, Life-cycle assessment

1. INTRODUCTION

Since 2004, Colombian government is promoting the development of biofuels energy resources for sustainable energy supply. The government has set the National renewable energy plan which aims to increase the use of renewable energy with tax incentives for investment. (Minminas, 2004[i]). Actually Colombia has production of Biodiesel from palm oil and Bioethanol from sugarcane.

The principal Bioethanol crop in Colombia is the sugarcane, Colombia has a capacity of 1.05 million liters per day. For 2010, began the first Plant of bioethanol from Cassava in Colombia, with a production of 25.000 liters per day and needs 3,6ton cassava per day for requirements of the plant. (GPC, 2010[ii])

The bioethanol in Colombia replace the 8% the national consume for transport and it represents near of 263.340 gallons per day (Fedebiocombustibles, 2010iii). However, to build a national guideline for sustainable production and use of biofuels in order to minimize the negative effects and to maximize the positive potential, the Transportation Fuel Obligation RTFO of the United Kingdom (Dehue, Hamelinck et al. 2007), the Swiss Mineral Oil Tax Redemption for Sustainable Biofuels (Leuenberger and Huber-Hotz 2006), guidelines for U.S. renewable energy, the California standard for low emission fuels and voluntary standards of the bench for the sustainable development of biofuels (CARB, 2009).

Biofuels, by using renewable energy, emerge as an alternative to stop the oil dependence and decrease the impact on climate change by the sequestration of CO_2 in the crops. However, there are studies that evaluate the entire life cycle of biofuel production and found that the relationship between renewable energy and fossil energy is less than one, implying that the dependence on oil will continue (Pimentel, 2005).

In this perspective, life-cycle assessment or LCA is widely known to be an effective technique to thoroughly and fairly evaluate the environmental impacts of product or process and can appropriately be applied to evaluate alternative fuels or biofuels. The Colombian government will need to evaluate the prospect with life cycle thinking. This assessment, it's parallel to different international certifications for biofuels like Renewable.

1. METHODOLOGY

Carbon footprint methodology for this study was based in the PAS2050 (BSI, 2008). The PAS2050 is based on the ISO14040 and ISO14044 framework. The PAS2050 Methodology consists of five steps to calculating the carbon footprint: process map, boundaries and priorization, data, calculation and uncertainty.

The goal of this study is to assess the carbon footprint to commercial bioethanol production from cassava in Colombia based on a life-cycle approach. The functional unit (FU) of this study is 1 L of 99.5% bioethanol production from cassava as octane improvement fuel.

1.1. PROCESS MAP

For this study, at the farm production, the data were collected as primary data by surveys to farmers in Urabá Colombia (PROTRACOY), and Antioquia´s Agriculture Secretary. These data include land preparation, cassava plantation and Cassava harvest

Fort the bioethanol production, until ends of 2010 Cantaclaro Project began operation, the data were collected for a pilot plant in Palmira, with capacity for 200-250 liters per day. These data includes raw material used, energy consumption, etc.

The secondary data were used in this study with data from literatures, calculation, and Ecoinvent database for some items such as the production of fertilizers, herbicides, etc.

1.2. BOUNDARIES AND PRIORIZATION

The system boundary defines the scope for the product carbon footprint, i.e. which life cycle stages, inputs and outputs should be included in the assessment. The Figure 1 is a process map for this study and includes the different life cycle stages like land preparation, planting, harvest, packed and transport to ethanol plant. And in the ethanol plant, the drying, milling, hydrolysis and fermentation, distillation and storage.

1.3. DATA.

The life-cycle inventory analysis was performed on the material and energy inputs, air emission, wastewater, and solid wastes involved in the life cycle of cassava-based bioethanol production based on 1 liter of 99.5% bioethanol. The Table 1 presents the Life Cycle Inventory to produce 1kg of Cassava in Colombia, and the Table 2 presents the Life Cycle Inventory to produce 1kg of Ethanol in Colombia

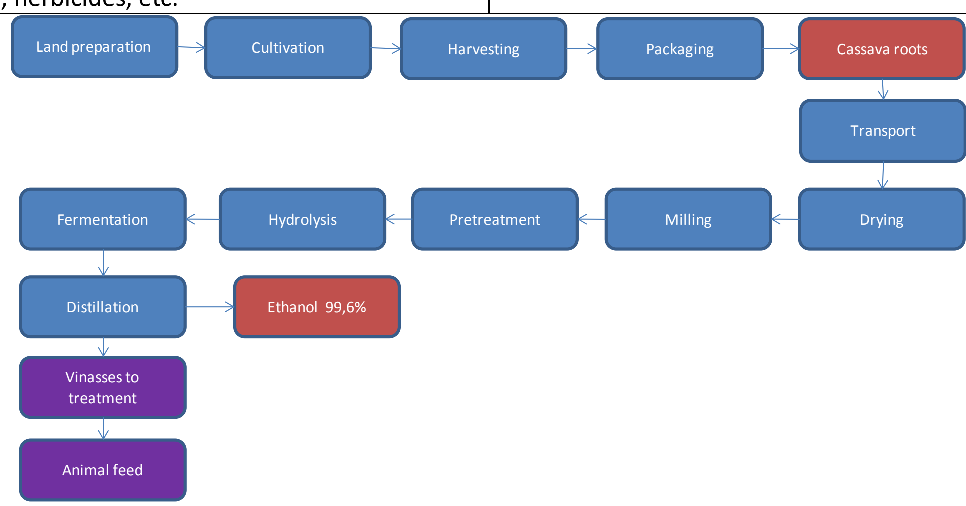


Figure 1. Process map for Ethanol production from Cassava

Table 1. Life Cycle Inventory to produce 1kg of Cassava in Colombia.

Material	Amount	Unit
INPUT		
Seed	0,77	seed
Fertilizer N	2,3 E-03	Kg
Fertilizer P_2O_5	4,6 E-03	Kg
Fertilizer K_2	4,6 E-03	Kg
Alachlor	2,3 E-04	Kg
Glyphosate	1,5 E-04	Kg
Paraquat	2,3 E-4	Kg
Diuron	8,3 E-05	Kg
Fungicide-Insecticide	7,7 E-05	Kg
Polypropylene bags	2,59E-4	kg
Raw material transport	0,8076	tkm
OUTPUT		
Cassava roots	1	Kg
Cassava reject	0,135	Kg
N_2O sintetic fertilizers	3,6 E -05	Kg
N_2O cassava at direct land appl	2,5 E -05	Kg
Hazardous waste	2,2 E-05	Kg

Table 2. Life Cycle Inventory to produce 1kg of Ethanol from Cassava in Colombia

Material	Amount	Unit
INPUT		
Cassava roots	13,2	kg
Water	1651,0	kg
HCl (36%)	3,7E-02	kg
Enzymes	1,9E-02	kg
Yeast	1,3E-02	kg
Urea (46%)	9,4E-03	kg
Steam	11,0	kg
Electricity	4,9E-01	kWh
OUTPUT		
EtOH 96%	1,0	kg
Waste water	1,7	kg
Husk	6,6E-01	kg
Steam	8,1	kg
Gravel	1,1	kg
CO_2 fermentation	1,0	kg
Vinasses	3,1	kg
Condensed	11,0	kg
Plastic bags to landfill	2,59E-4	kg

1.1. CALCULATION

Using the Simaprov7.2.2 software and the Evaluation Method IPCC 2007 GWP 100a, developed for the IPCC (International Panel on Climate Change). For this, use the IPCC characterization factors for the direct global warming potential of air emissions. They are:

-not including indirect formation of dinitrogen monoxide from nitrogen emissions.

-not accounting for radiative forcing due to emissions of NOx, water, sulphate, etc. in the lower stratosphere + upper troposphere.

-not considering the range of indirect effects given by IPCC.

For this study not considering biogenic CO2 uptake as negative impact, because the cassava is a temporal crop.

For life cycle assessment, from cradle to grave, plantation to ethanol production, the carbon footprint is 0,395kgCO_{2e} per kg of ethanol.

The carbon footprint for the bioethanol from Cassava is 65gCO_{2e}/MJ, while the carbon footprint for conventional gasoline is 82gCO_{2e}/MJ. The energy conversion efficiency of Fuel ethanol is 1.34, indicating that the energy from ethanol out of these raw materials is higher than the energy supplied during its production

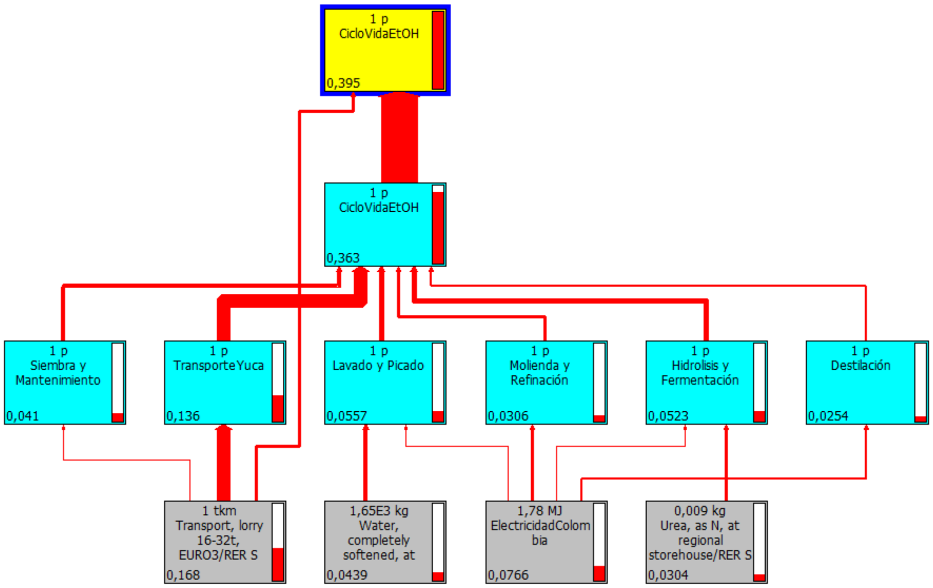


Figura 1. Results of Carbon footprint of 1kg of Ethanol from cassava.

CONCLUSIONS

The carbon footprint for the bioethanol from Cassava is 65gCO2e/MJ, while the carbon footprint for conventional gasoline is 82gCO2eq/MJ. The energy conversion efficiency of Fuel ethanol is 1.34, indicating that the energy from ethanol out of these raw materials is higher than the energy supplied during its production

The Bioethanol from Cassava is an efficient energy option for Colombia, since his cultivation don´t requires irrigation and needs lower quantity of fertilizer for its production. Furthermore, the Cassava has a high demand of manual labor and do not compete with food products.

REFERENCES

[i] Minminas 2010. Ley 939 de 2004. Por la cual se estimula la producción y comercialización de biocombustibles de origen vegetal o animal para uso en motores diesel.

[ii] GPC Group. Complejo Agroindustrial Cantaclaro. Consulta en línea. http://www.gpc.com.co/index.php?option=com_content&view=article&id=31&Itemid=46

[iii] Fedebiocombustibles, 2010. Biocombustibles aumentará porcentaje de mezclas. 14 Oct.2010. En línea <http://www.fedebiocombustibles.com/v2/nota-web-id-543.htm>

Pimentel D, Patzek TW. Ethanol production using corn, switch-Grass, and wood; biodiesel production using soybean, and sunflower. Natural Resources Research 2005;14(1):65–76.

J.C. Escobar et al. / Renewable and Sustainable Energy Reviews 13 (2009) 1275–1287 1287

Cherubini F, et al. Energy- and greenhouse gas-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. Resour Conserv Recy (2009), doi:10.1016/j.resconrec.2009.03.013

Abstract

The world interest in biofuels has been growing during the later years, not only due to the resources depletion as well as the climate change. As a result, Brazil increased the biodiesel production, mostly from soy oil. The current study is focused in evaluating the environmental impacts occurred in the agricultural phase. In order to do so, an LCA was performed. The functional unit used was to produce 1 t of soybeans. Then data was added in an LCA software and CML 2001 was selected for comparing the results with ecoinvent's current LCI for Brazilian soybeans. The results showed significant differences between the two inventories in some aspects, while in others, there were very few influences, showing which environmental flows are more relevant.

Keywords: life cycle assessment, life cycle inventory, soybeans, sensibility analysis

Introduction

The world interest in biofuels has been growing during the later years, not only due to the resources depletion as well as the climate change. As a result, Brazil increased the biodiesel production [1], mostly from soy oil. Due to this fact, in Figure 1 it is presented the Brazilian soybeans production from 1990 to 2006 that increased during the period from 19.9 million tons to 52.4 million tons [2, 3].

Figure 1: Soybeans Production and Area in Brazil [2, 3]

The current study is focused in evaluating the environmental impacts occurred in the agricultural phase, which is a part of the total project to evaluate the environmental impacts of soy biodiesel in Brazil as shown in Figure 1.

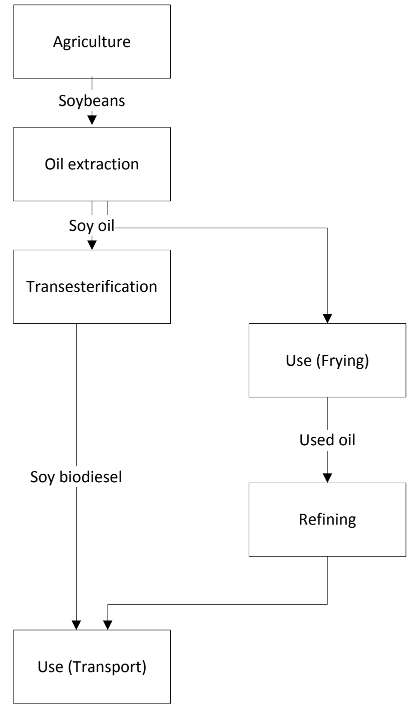


Figure 2: Soy biodiesel product system

Life Cycle Assessment

The functional unit selected was to produce 1 t of soybeans which needs as a flow reference one production unit that produces 1 t of soybeans. Data collected refers to the year 2006 for Brazil. Average technology was taken into account.

Despite the land use, no further information about infrastructure is presented in this study.

Seeds

In 2006, almost 1 million tons of seed was produced, which resulted in 18.3 kg of seeds per ton of soybeans.

Fertilizers

The consumption of fertilizer to produce soybeans corresponded 33.9% of all Brazilian consumption in 2006 [4]. The mostly used fertilizer in soya culture is 0-20-20, summing up 7.1 million tons of fertilizers. Considering the proportion of each type of fertilizer as shown in Table 1 [4], the consumption per ton of soybean was 61 kg of DAP, 39.3 kg of SSP, 21.7 kg of TSP and 6.8 kg of phosphate rock and NPK.

Table 1: Fertilizers per ton of soybean

Fertilizer	%
DAP	5,7%
MAP	24,0%
SSP	51,9%
TSP	18,4%

Source: [4]

According to Embrapa, however, each ton of soybean needs 15.4 kg of P_2O_5 and 38 kg of K_2O. The difference between the application and the plant needs is considered to be released in the environment. As for K_2O, the amount applied is comes from KCl.

Water

Water availability is critical to soybean, demanding from 450 to 800 mm/cycle, which results in 1958 – 3,481 m^3/ton of soybean. Pimentel et al. [6] give a value of 2 t/kg of soybean.

Other raw material

Beside P, K, the plant also demands other substances as Mo, Fe, Mn and S, as shown in Table 2. In this study all these inputs were obtained considering the amount necessary to the soybeans and the plant.

Table 2: Plant absorption

Substance	Soybean	Plant	Total	Unit
Ca	3	9.2	3	g/kg
Mg	2	4.7	2	g/kg
S	5.4	10	10	g/kg
B	20	57	77	mg/kg
Cl	237	278	515	mg/kg
Mo	5	2	7	mg/kg
Fe	70	390	460	mg/kg
Mn	30	100	130	mg/kg
Zn	40	21	61	mg/kg
Cu	10	16	26	mg/kg

Source: [7]

Pesticides

Information about pesticides used in the field are quite different. Menten et al. [8] say that the consumption of pesticides in 2009 was over 300 thousand tons, an amount that results in 6.4 kg/t. Soares et al. [9] provides a yearly consumption of 4 kg/ha for this crop, that is 1.7 kg/ton of soybean close to the amount obtained by [10] in 5 farms in São Paulo region. Nevertheless, the study of [11] present the figures respectively as 2.82 kg/t for the Brazilian situation.

Table 3 and 4 show detailed information about the consumption of pesticides, obtained by [12] following the quantities suggested by Embrapa, summing up 1.8 kg/t .

Table 3: Fungicides per ton of soybean

Fungicides	g/t
Captan-C	90
Thiram	70
Tolyfluanid	50
Carbendazin	30
Carbendazin + Thiram	100
Carboxin + Thiram	150
Difenoconazole	5
Fluxdioxonil + Methanlaxi-M	45
Thiabendazole	17
Thiabendazole + Thiram	77
Tiofenato metílico	70
TOTAL	704

Source: [12]

Table 4: Insecticides and herbicides per ton of soybean

Flow	g/t
Acifluoren-sodium	0.44
Alachlor	3.05
Bentazon	0.52
Bentazon + Acifluoren-sodium	0.52
Clomazone	0.87
Cyanazine	1.31
Baculovirus anticarsia	21.76
Beta cifutrina	1.09
Beta cipermetrina	2.61
Carbaril	83.54
Acefato	97.90
Endossulfan	190.36
Fenitrotiona	217.56
Metamidofós	130.53
Triclorfom	348.09
TOTAL	1100.14

Source: [12]

Land use

The soybeans productivity in Brazil increased from 1.7 t/ha to 2.4 t/ha, although the highest value was 2.8 t/ha in 2003, which reduced the amount of land needed to produce the same amount of soybeans [3]. Even so, the high growth of production implied in an area expansion as shown in the same Figure. Considering the average value, land occupation in 2006 was 4,351m^2/t.

As no detailed information about what type of land was transformed, it was estimated the same percentages established by Jungbluth et al. [13]. IBGE [3] informs that more than 9 million ha were transformed from 2001 to 2005, that is an average of 1,527 million ha/year.

Energy consumption

According to Gazzoni [14], 66 kg of fossil fuel are consumed to produce 4 t of soybeans.

Heavy metal

No information about heavy metal was available and therefore, it was estimated according to the proportion in fertilizers given by [13], which resulted in the emissions presented in Table 5.

Table 5: Heavy metal emissions

Flow	kg/t
Cd	2.16 E-06
Cu	5.28 E-06
Zn	3.44 E-05
Pb	2.42 E-06
Ni	4.35 E-06
Cr	2.49 E-05

Air flows

CO_2 sequestration was 1.25 t/t of soybean. CO_2 emissions due to land transformation is 12 kg / m^2 of land transformed according to [13].

Data quality

The Pedigree Matrix presented by Weidema and Wesnaes [15] was used to evaluate the quality of data. The values for all the flows are presented in Table 6.

Table 6: Pedigree matrix for Brazilian Soybeans LCI

Flows	Pesticide, fungicide, heavy metals, water and air flows	Fertilizers, energy consumption, land use and other raw material
Reliability	4	2
Completeness	2	2
Temporal correlation	1	1
Geographical correlation	1	1
Technological correlation	1	1

Life Cycle Impact Assessment

Data collected was included in SimaPro 7.1 and the intermediary flows were selected from ecoinvent´s database as shown in Table 7. CML 2001 was selected for the evaluation. Then data was compared with current ecoinvent LCI for Brazilian soybeans. In the case of pesticides, herbicides and insecticides, there was no disaggregation in ecoinvent and therefore, it was considered as pesticides.

Table 7: Intermediary flows selected in ecoinvent database

intermediary flows	ecoinvent
DAP	Diammonium phosphate, as P2O5, at regional storehouse/RER U
SSP	Single superphosphate, as P2O5, at regional storehouse/RER U
MAP	Monoammonium phosphate, as P2O5, at regional storehouse/RER U
K_2O	Potassium chloride, as K2O, at regional storehouse/RER U
Land transformation	Provision, stubbed land/BR U
Fungicides, herbicides, insecticides	Pesticide unspecified, at regional storehouse/RER U
TSP	Triple superphosphate, as P2O5, at regional storehouse/RER U

The results are shown in Figure 3. As it can be seen, data from the present study caused a higher impact in all environmental categories, except eutrophication.

These results were mainly due to the difference between the type of fertilizer included in ecoinvent database, which was based on FAO [5], whereas the present study was based on the Brazilian consumption given by FAEP [4]. As a consequence of this difference, the amount of heavy metals also changed significantly.

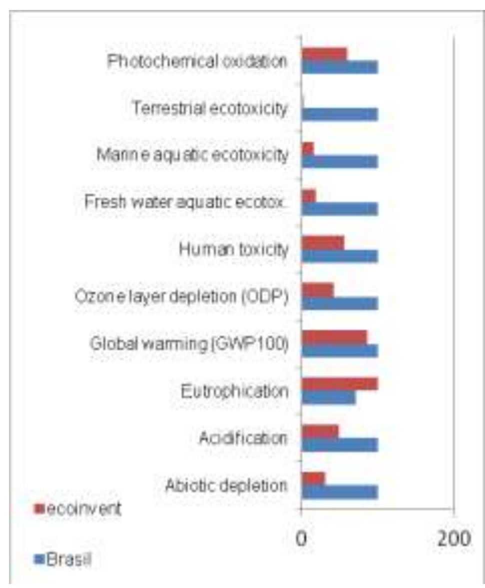


Figure 3: Comparison of Brazilian soybeans LCI

In Table 8 it is summarized the materials and processes that contributed the most for each impact category, where it is noticed that most of them are caused by the supply chain of fertilizers.

Table 8: Material and processes main contribution

Impact category	Material	Process
Abiotic depletion	SSP	Electricity
Acidification	SSP	Sulphuric Acid
Eutrophication	MAP	Phosphoric Acid
Global warming (GWP100)	PSL	PSL
Ozone layer depletion (ODP)	SSP	Transport
Human toxicity	PSL	PSL
Fresh water aquatic ecotox.	SSP	Chemical plant
Marine aquatic ecotoxicity	SSP	Chemical plant
Terrestrial ecotoxicity	SSP	Phosphate rock
Photochemical oxidation	PSL	PSL

PSL: Provision stubbed land

A further evaluation about the pesticides might be necessary as it contributes with more than 5% in abiotic depletion and ozone layer depletion, human toxicity and marine aquatic and terrestrial ecotoxicity, and more than 1% in acidification and fresh water ecotoxicity.

Conclusions

There were significant differences between the two inventories, mainly related to fertilizer, showing that detailed information about the type of fertilizer is relevant for such an LCI. Furthermore, the land transformation was also a very important aspect that must be taken into account.

Acknowledgements

The authors sincerely thank CNPq and CAPES for funding this study.

References

[1] BNDES (2006) Visões Ambientais para o Financiamento de Biodiesel no Brasil Disponível em: http://www.fbds.org.br. Acesso em 16/7/2007.

[2] IBGE - Instituto Brasileiro de Geografia e Estatística (2006), Pesquisa Industrial, v.25, n.2, Produto, 2006.

[3] IBGE - Instituto Brasileiro de Geografia e Estatística (2007), Produção Agrícola Municipal 2007, Rio de Janeiro.

[4] FAEP Federação da Agricultura do Estado do Paraná (2010) Encarte. Disponível em: http://www2.faep.com.br/downloads/enc_fertilizantes.pdf

[5] FAO (2004) Fertilizer Use by Crop in Brazil. Land and Plant Nutrition Management Service. Land and Water Development Division FAO, Rome.

[6] PIMENTEL, D.; BERGER, B.; FILIBERTO, D.; NEWTON, M. et al (2004). Water Resources: Agricultural and Environmental Issues. Bioscience, n. 10.

[7] EMBRAPA (2007) Boletim de Pesquisa e Desenvolvimento 177- Compactação do Solo e Produtividade da Cultura da soja em área irrigada no Cerrado – Planaltina: Embrapa Cerrado, 31p. ISSN 1676-918X.

[8] J.O.M. Menten, Ivan A. Sampaio,Henrique Moreira, Daniela Flôres e Marcella Menten (2010) O Setor De Defensivos Agrícolas No Brasil

[9] SOARES, LHB ; ARAÚJO, E.S.; ALVES, B.J.R.; BODDEY, R.M.; URQUIAGA, S. (2008) Eficiência Energética Comparada das culturas do girassol e da soja com aptidão para a produção de biodiesel no Brasil. Circular Técnica 25. Embrapa. ISSN 1519-7328. 6p.

[10] MOURAD, A. L. (2008) Avaliação da Cadeia Produtiva de Biodiesel obtido a partir de soja. Campinas. Disponível em: http://libdigi.unicamp.br/document/?code=vtls000445752 Acesso em: 06 set. 2009.

[11] CAVALETT, O.(2008) Análise do Ciclo de Vida da Soja. 2008. 245 f. Tese (Doutorado em Engenharia de Alimentos) – Faculdade de Engenharia de Alimentos, Universidade Estadual de Campinas, Campinas, 2008.

[12] RAMAZZOTTE, V.C.B. (2010) Avaliação do Ciclo de Vida da Soja: estudo de caso da qualidade do uso do solo no Brasil. Dissertação de Mestrado. UTFPR/PPGEM. 93p.

[13] JUNGBLUTH, N. (2007) Life Cycle Inventories of Bioenergy. Ecoinvent.

[14] GAZZONI, D.L. Balanço energético das culturas de soja e girassol para produção de biodiesel. Disponível em: http://www.biodiesel.gov.br/docs/congressso2006/agricultura/BalancoEnergetico.pdf Acesso em Abril 2009.

[15] WEIDEMA, B. and M. S. WESNAES (1996). Data quality management for life cycle inventories - an example of using data quality indicators. International Journal of Cleaner Production 4(3-4): 167-74.

Preliminary study for the production of bioethanol from the shell of pineapple (*Ananas comosus*)

Méndez López Emely de los Ángeles

Director: Hernández Quiróz Teresa

Codirector: Cocotle Ronzón Yolanda

E-mail: angeles5343@hotmail.com

Abstract

On average, each year are produced in Mexico 737 000 70 tons of pineapple (Ananas comosus (L.) Merr), which is a major commercial fruit products in the country. However, there are several parts of the pineapple that are not used, in particular, the shells are considered as waste contributing to the problem of garbage pollution in the country. On the other hand, oil is a nonrenewable resource, for which demand is increasing every year while our supplies are being rapidly depleted. One possible solution to these two problems is the production of ethanol from pineapple shells. This work established the conditions for hydrolysis with sulfuric acid from flour pineapple shells, obtaining a lignocellulosic hydrolyzate rich in xylose and glucose which was used as a substrate for a mixed culture of S. cerevisiae and P. stipitis for ethanol production. We tested different culture conditions such as agitation and dilution of hydrolyzed pineapple shell. The best results were obtained when two volumes of pineapple peel hydrolyzate was diluted with a volume of water, starting the fermentation with S. cerevisiae and inoculating P. stipitis after 24 hours of fermentation, yielding 5.23 g / L of ethanol. It was also observed for xylitol production and consumption of acetic acid.

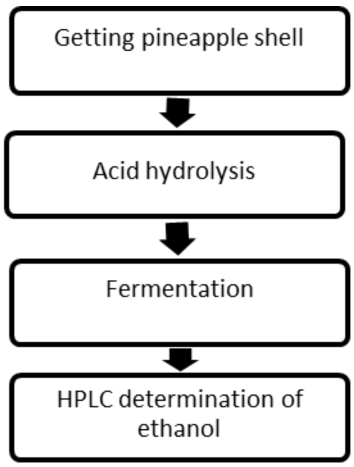
Introduction

Plant biomass is a renewable source of energy-rich carbohydrates that can be efficiently converted by microorganisms into biofuels, of which only ethanol is currently produced on an industrial scale. The leading countries in this area are the United States (36% of world production), closely followed by Brazil (33.3% of world production) (Antoni et al., 2007; Aycachi et al., 2009).

Bioethanol is currently a strong candidate to replace fossil fuels, especially oil. Its clear advantages over fossil fuels came to light: they are clean energy, renewable, have a more complete combustion and less waste in general, have a wide variety of substrates and ultimately generate a lot of jobs especially in rural areas. Can be used pure (hydrated alcohol) or mixed with gasoline up to 20% (then called gasohol), and its yield equal to pure gasoline. The greater their ecological importance as it would help greatly to reduce emissions of greenhouse gases (CO and CO2) in addition to indirectly reduce greenhouse gas emissions containing lead and sulfur into the environment.

The bio-ethanol from pineapple shell as an alternative for the proper management of solid waste and to reduce environmental degradation. In this work we obtained a hydrolyzate of pineapple peel and preliminarily established the conditions for its use as substrate for bioethanol production using a mixed culture of Saccharomyces cerevisiae and Pichia stipitis.

Methodology



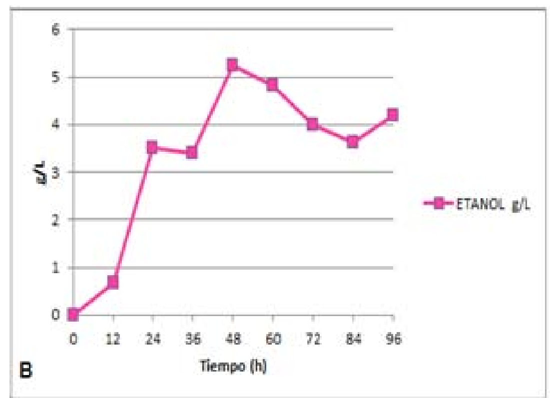
Results and discussion

Once established the conditions for the pineapple peel hydrolyzate (HCP) was collected for quantification of components by HPLC, the results are shown

Component	Amount (g / L)
Xylose	20.16
Glucose	8.23
Arabinose	3.0
Acetic acid	3.7

Because xylose is the main component of the hydrolyzate, was thought to use a microorganism that use this carbohydrate as a carbon source so it was decided to work with the yeast Pichia stipitis NRRL-Y7124, which is capable of fermenting glucose, xylose , mannose, galactose and cellobiose (Agbogbo and Coward, 2008).The best conditions of fermentation were carried out with P. stipitis NRRL-Y7124 and S. cerevisiae used as fermentation medium pineapple peel hydrolyzate (1:2) or 15 mL of distilled water and 30 hydrolyzed, without agitation in a fermentation time of 72 hours.

Table. P. fermentation conditions stipitis NRRL-Y7124 and S. cerevisiae used as fermentation medium HCP (1:2)



Ethanol production using Saccharomyces cerevisiae and Pichia stipitis NRRL-Y7124 ranged from 0.4 to 5.84g/L. It may suggest that the condition gave best results is one in which the hydrolyzate was diluted 1:2, and that although the xylose concentration is 8 g /L, was obtained almost the same production of ethanol (5.23 g/L) than when using undiluted medium (5.84 g/L), which contained 20.16 g/L of xylose, indicating that there are environmental components that may act as inhibitors of the process of bioconversion of xylose to ethanol, which at be diluted diminish their effect.

It was important to include S. cerevisiae in fermentations and that helped that some of the glucose consumed, which, as mentioned negative effects on the transport of xylose, the major component of hydrolyzed pineapple shell, inside the cells and the main carbon source P. stipitis. S. cerevisiae produces ethanol when sugar concentration is relatively low, even under aerobic conditions (Agbogbo and Coward-Kelly, 2008). In this work could not be established if some of the ethanol produced was the effect of enzymes present in S. cerevisiae due to a lack carry out a fermentation where only the use of this organism, but we assume that most of the bioethanol comes from the fermentation of xylose by P. stipitis NRRL-Y7124.

The results obtained in this study are comparable to those reported by Moniruzzaman (1995) who used a 3-liter fermentor, rice bran as substrate and P. stipitis obtained 6 g / L of ethanol. As mentioned, there are reports in the literature where they have obtained ethanol yields up to 41 g / L, however the conditions used are highly variable so it cannot compare, but what if you can compare all work is the yield, which varies from 0.31 to 0.48 g of ethanol per g sugar consumed. Our performance is 0.47, which makes a process comparable to that reported in the literature. For a fermentation process to be successful performance on an industrial scale has to be above 0.8, so further work is needed on improving fermentation conditions.

Conclusion

Conditions were established for a pineapple shell hydrolyzate whose components could be used by S. cerevisiae, P. stipitis and C. tropicalis as a carbon source.

The use of a mixed culture consisting of S. cerevisiae and P. stipitis was the best option for obtaining ethanol from a hydrolyzed pineapple shell.

The increased ethanol production was obtained when two volumes of pineapple peel hydrolyzate was diluted with a volume of water, starting the fermentation with S. cerevisiae and inoculating P. stipitis after 24 hours of fermentation, yielding 5.23 g / L.

In fermentations where they got the best production of bioethanol were glycerol and xylitol, also products of metabolism of xylose.

During fermentation was observed that acetic acid, a byproduct of the hydrolysis of the pineapple shell and potential microbial growth inhibitor, was used, indicating the potential detoxifying the yeast P. stipitis.

The fermentation process provided herein is comparable in performance obtained (g ethanol produced / g sugar consumed) to most of those reported in the literature when using lignocellulosic hydrolysates P. stipitis, but needs improvement.

References

1. Agbogbo F., Coward G., (2008), Cellulosic ethanol production using the naturally occurring xylose-fermenting yeast, Pichia stipitis, USA, *Biotechnol Lett* 30:1515–1524
2. Antoni , D., Vladimir V., Schwarz W., (2007), Biofuels from microbes, Germany.
3. Aycachi R.(2009), Producción de bioetanol ,Lambayeque, 2-60.

Building

CILCA 2011
MÉXICO

Environmental impacts of a concrete wall built with Muro-R and a traditionally built concrete wall using LCA software
Mexico

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Environmental impacts of a concrete wall built with Muro-R® and a traditionally built concrete wall using LCA software

Abstract

Background, aim and scope. The volume of concrete-built facilities worldwide makes LCA analysis of concrete products an important issue. However, their environmental impacts have not been fully studied.

The goal of this LCA is to determine whether a concrete wall built with a new system, Muro-R®, has a lesser environmental impact when compared against a traditionally built concrete wall.

Materials and methods. Two concrete walls of similar structural, dimensional, thermal and acoustic characteristics were compared, one built with Muro-R® system (two precast forms, steel reinforcement and a poured concrete core), and a traditionally built wall (10 cm thick concrete poured in a traditional wooden form with steel reinforcement; acoustic and thermal insulation provided with polystyrene slabs, adding 4 cm to thickness). Finishing, maintenance and disposal is considered to be the same for both walls. Impact assessment method used was CML-2000; input data provided by manufacturer and calculations.

Results. Muro-R® wall resulted in lesser environmental impacts than the traditionally built concrete wall for all the environmental impacts studied, except for Terrestrial Toxicity. Therefore it should be considered a cleaner technology.

Discussion. The traditionally built concrete wall has a higher environmental impact due to the higher amount of steel used in its construction. As materials differ in only one element, polypropylene, this result can be assumed to result from this.

Conclusions. Overall, Muro-R® has less environmental impacts than the traditionally built wall. Therefore, use of this system should contribute significantly to mitigate the environmental impacts when used in large construction sites

Recommendations and perspectives. A deeper analysis of production and fabrication of different inputs will allow determining which the main contributors are, and their impact in the different EI categories in order to improve the overall environmental performance of the system. Data for the Mexican industry are unavailable; therefore there is a degree of uncertainty to this LCA.

Topic: LCA Industrial Applications: Building and construction

Keywords: concrete, wall, building, LCA.

INTRODUCTION

Background, aim and scope

The volume of facilities built with concrete worldwide makes LCA analysis of concrete products an important issue. New building technologies are introduced into the market every day; however, their environmental impacts have not been fully studied.

The goal of this LCA is to determine whether a concrete wall built with a new system, Muro-R®, has a lesser environmental impact when compared against a traditionally built concrete wall (Muro-T). As using Muro-R® translates into time and economic savings, as well as a cleaner job site, it is supposed to be a better alternative than the traditionally built wall.

LCA goal and scope

The objective is to determine which of the two systems to be studied has a better environmental performance when measured against each other, comparing a concrete wall built with Muro-R® technology versus a traditionally built concrete wall (Muro-T) using TEAM®.

The scope covers the environmental impacts caused by the construction of $1m^2$ of concrete wall with each of the constructive systems under study, considering all the necessary materials. Impacts will be assessed after reception of materials at the factory where Muro-R® is produced, until the building of 1 m^2 of concrete wall is finished at the construction site. Then, they will be compared with a similar wall built with a traditional method after reception of materials at the construction site.

Figure 1 shows the system boundaries, where material extraction and production will not be considered due to the inherent complexity of the processes involved and the time and resource limitations available for this LCA.

Maintenance and disposal of the walls is also not considered in the LCA because the average life of a concrete wall is over 50 years and maintenance is considered to be similar in both cases.

Geographic boundaries are assumed within Mexico, as follows: Muro R® production takes place in San Pedro de la Laguna, Zumpango, Estado de México, and building will be considered to take place in the city of Oaxaca, Oaxaca. This was decided because Oaxaca is a city where Muro R® has been used constantly. Time limits are from September to November, 2010.

The wall built with Muro R® technology uses two precast forms made of concrete, polystyrene and polypropylene that form a monolithic block when concrete is poured between them. It uses minimal steel reinforcement and there is almost no waste at the construction site.

Acquisition of building materials is assumed to happen locally for the traditionally built wall, which will be hereinafter called "Muro-T". This concrete wall is built using recoverable wooden forms. The forms must be covered with form oil to remove them after the concrete has been poured and is dry. Traditionally in Mexico, diesel oil is used to this end. The wall core is made of concrete and steel, and two 2 cm thick polystyrene panels are added to the finished wall for thermal insulation. The assumed travelled distance from supplier to the construction site is 20km on a freight truck (Figure 2).

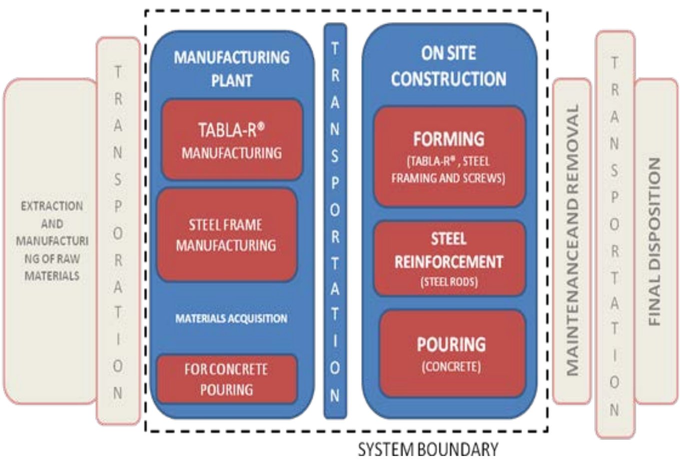

Figure 1. System boundaries for Muro-R®

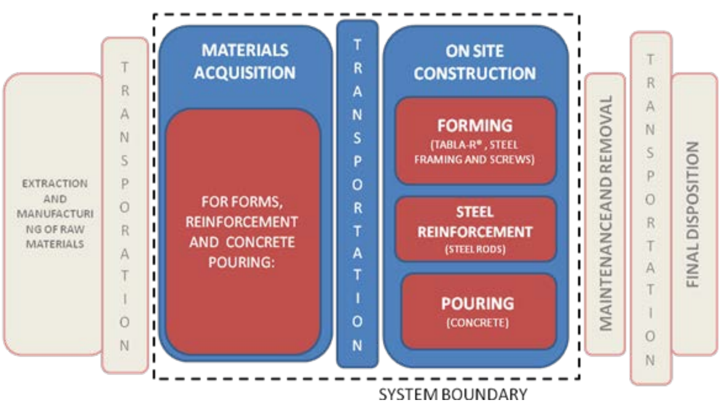

Figure 2. System boundaries for Muro-T

Functional unit

The functional unit to be used in this LCA is $1m^2$ of concrete wall built using Muro-R® technology, with a 10.35cm thickness, made of reinforced concrete —cement, sand and gravel, precast concrete forms (Tabla-R®), steel framing and steel rods—. The Muro-R® wall will be compared 1 m^2 of concrete wall built using Muro-T (traditionally built wall) made of reinforced concrete —cement, sand and gravel, steel rods, wooden recoverable forms, and form oil—with a 10 cm concrete thickness that in order to provide similar acoustic and thermal insulation characteristics will have two 2cm polystyrene slabs adhered to either side of the wall with steel angles and glue. The resulting Muro-T wall will be 14 cm thick.

Materials and Methods

Both systems will be considered as having identical foundation slabs. Both systems require steel reinforcement within the concrete core. An intermediate wall segment will be evaluated in order to avoid differences in reinforcement needs due to load bearing or shear, and only a reinforcement to withstand temperature changes will be assumed for both systems.

For the building of the traditionally built wall (Muro-T), a recoverable wooden form must be used, as mentioned. For Muro-R® there is no wooden form involved as the precast panels act as a form that will adhere perfectly when the cement mix is poured into the core.

It was also assumed, that in order to provide thermal and acoustic insulation similar to Muro-R®, 2cm polystyrene slabs will be adhered to either face of the Muro-T wall with an adhesive and steel angles and screws, and an additional cover of glass fibre net will be used to provide a base for the finishing [1]. This is not necessary for Muro R®.

Data quality

As LCA data is nonexistent for some inputs, data for general materials were used instead. For example, when accounting for the polystyrene slabs, only polystyrene data was considered as opposed to the finished slab data. For the glass fibre net, the data were obtained from Ecoinvent [2]. Cement and glue data were obtained from the DEAM® database, as were the data for the polypropylene net used in Muro-R®.

Air emissions caused by electricity generation were considered to be the same as those of the USA according to available data in the DEAM® database, since this information is not available for Mexico.

Other data were obtained directly from Muro-R®'s manufacturer according to product specifications. Energy requirements were estimated according to machinery HP and average machine working hours

Methodology

The LCA methodology is used to assess all environmental impacts associated with a product, process or activity by calculating and evaluating resource consumption and emissions [3].

The classification and caractherization methods used was CML-2000 [4]. The selected impact categories are as follows: Air Acidification, Aquatic toxicity, Depletion of abiotic resources, Depletion of stratosphic ozone, Eutrophication, Global warming potential, Human toxicity potential, Photo-oxidant formation, and Terrestrial toxicity potential.

Other local impacts such as contribution to urban heat island, potential loss of biodiversity and others are neither considered by CML 2000 nor properly agreed and have not been included in this analysis.

RESULTS

Inventory data

The transportation distances and fuel consumption for building materials are 500 km for Muro-R® system and 20 km for locally acquired products (cement, sand, gravel, steel rods) and for Muro-T it was considered that all building materials were acquired locally and travelled only 20 km.

For Muro-R® the steel reinforcement was considered vertically every 30 cm and horizontally every 40 cm using 3/8" steel rod diameters with *fy*= 4200 kg/cm^2. For Muro-T, it was considered every 25 cm on both directions with the same *fy*= 4200 kg/cm^2. Table 1 indicates the materials and energy content for 1 m^2 for the two systems.

Table 1. Total inputs for each of the systems

Muro-R®			
Stage	**Input**	**Quantity**	**Units**
Manufacturing	Cement	21.8774	kg
	Gravel	47.3908	kg
	Sand	47.9279	kg
	Steel	7.03503	kg
	Polystyrene	0.325	kg
	Polypropylene	4.83	kg
	Electricity	0.67838	MJ
	Water	5	litres
Transportation	Diesel	5.038	liters
Construction	Electricity	2.232	MJ
	Water	9.02682	litres

Muro-T			
Stage	**Input**	**Quantity**	**Units**
Manufacturing	Cement	19.1571	kg
	Gravel	76.4368	kg
	Sand	42.2222	kg
	Steel	25.1825	kg
	Polystyrene	0.762	kg
	Glass fibre	0.26	kg
	Glue	2	kg
	Diesel	1.328	kg
	Wood	62.9947	kg
Transportation	Diesel	5	litres
Construction	Electricity	3.803	MJ
	Water	14.55	litres

Interpretation of LCA impact assessment

Results for Muro-T and Muro R® for air acidification are presented in Figure 3, for aquatic toxicity, and in Figure 4, for depletion of abiotic resources. Figure 5 shows results for depletion of abiotic resources. Depletion of stratosphic ozone is presented in Figure 6. Eutrophication results are presented in Figure 7, and Greenhouse effect in Figure 8. Results for human toxicity are shown in Figure 9. Photo-oxidant formation results are presented in Figure 10, and terrestrial toxicity results in Figure 11. Table 2 summarizes these results and it is easy to determine which of the two building systems has a better environmental performance according to the applied methodology.

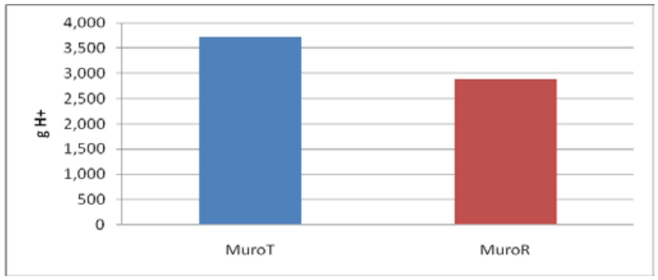

Figure 3. Results for air acidification.

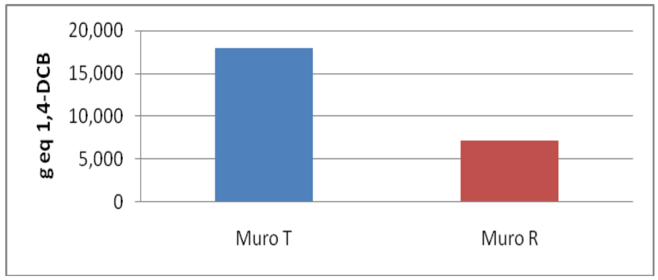

Figure 4. Results for aquatic toxicity.

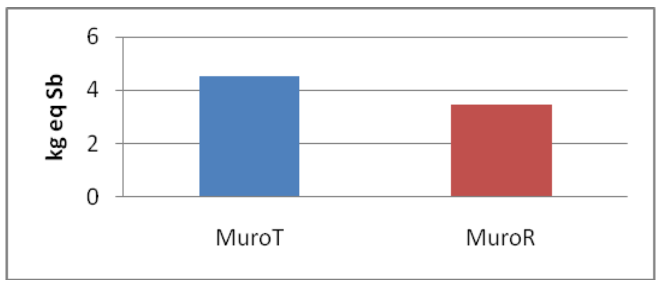

Figure 5. Results for depletion of abiotic resources.

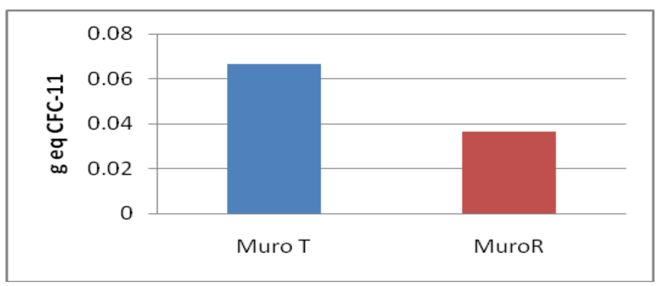

Figure 6. Results for depletion of stratosphic ozone.

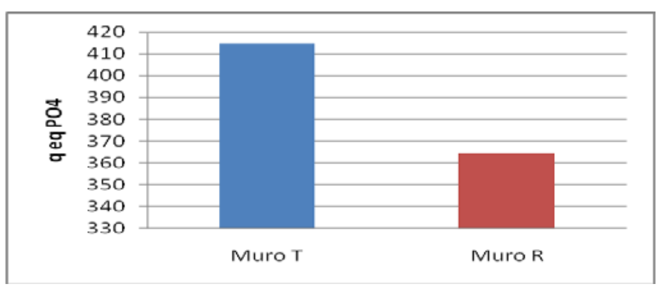

Figure 7. Results for eutrophication.

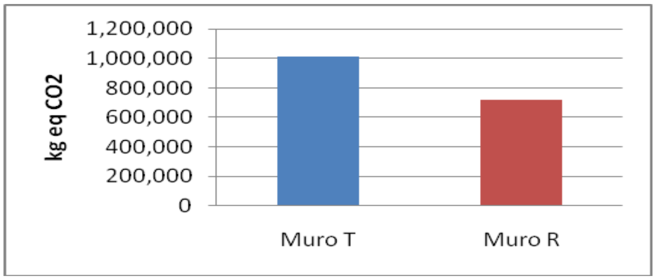

Figure 8. Results for greenhouse effect.

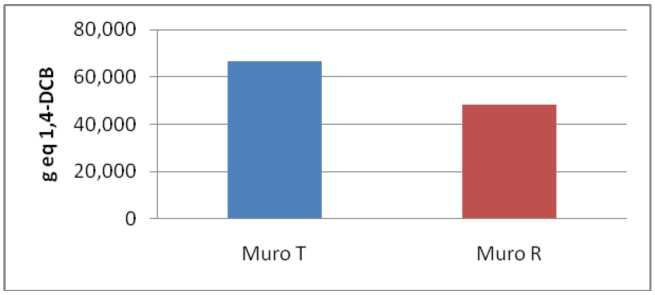

Figure 9. Results for human toxicity.

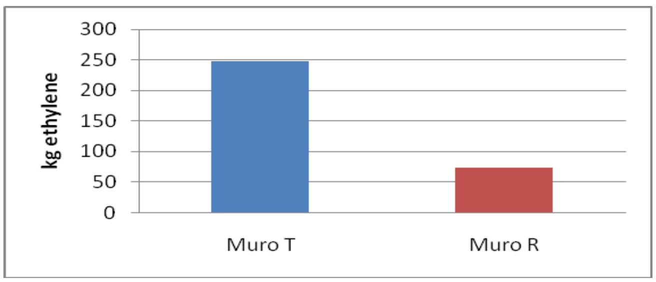

Figure 10. Results for photo-oxidant formation.

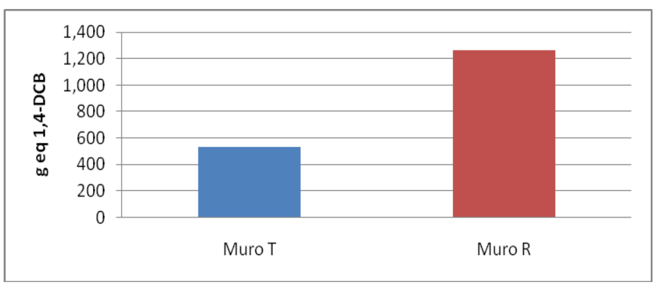

Figure 11. Results for terrestrial toxicity.

In terms of acidification, aquatic toxicity, depletion of abiotic resources and stratosphic ozone, eutrophication, greenhouse effect, human toxicity and photo-oxidant formation it is preferable to use Muro R® technology when building concrete walls. In terms of terrestrial toxicity, it is Muro-T the one with better environmental performance.

CONCLUSIONS AND RECOMMENDATIONS

According to the presented results, Muro R® has a better environmental performance overall than does Muro-T, as shown in Table 2, and therefore is a better alternative to build concrete walls with thermal and acoustic insulation. The use of this system can be considered to produce lesser environmental impacts, especially when speaking of large building projects. Muro-T's performance is affected because of the larger amount of steel that is needed in order to build one functional unit.

Table 2. Summary of results for all EI categories evaluated.

IMPACT CATEGORY	MURO-T	MURO R ®
Acidification	3723.356 g H+ eq	2887.044 g H+ eq
Water toxicity	17928.66 g 1,4-DCB eq	7170.025 g 1,4-DCB eq
Depletion of abiotic resources	4.542402 kg Sb eq	3.443479 kg Sb eq
Depletion of stratosphic ozone	0.06668376 g CFC-11 eq	0.03632592 g CFC-11 eq
Eutrofication	414.7069 kg PO_4^{-3}eq	364.4849 kg PO_4^{-3}eq
Greenhouse effect	1,009,599 kg CO_2 eq	718,713.9 kg CO_2 eq
Human toxicity	66646.88 g 1,4-DCB eq	48328.95 g 1,4-DCB eq
Photo-oxidant formation	248.4144 kg ethylene	73.10717 kg ethylene
Terrestrial toxicity	530.72 g 2,4DCB eq	1263.54 g 2,4DCB eq

This LCA assumed a longer travel distance for walls built with Muro R®, so it can be assumed than in construction sites that are within a shorter distance of the manufacturing plant, impacts caused by transportation will be inferior.

A deeper analysis of the contribution of different materials or inputs will allow determination of the ones responsible for most impacts and their categories, which in turn will allow improvements in the manufacture of Muro-R® and its environmental performance. This is especially true for Terrestrial toxicity, the only aspect where Muro R® was outperformed by Muro T. Due to the lack of information for Mexico for many of the materials and inputs considered, it is recommended to make a deeper analysis in order to obtain data that reflects the Mexican reality.

REFERENCES

[1] Silva Conde, Miguel. 2010 «Uso del aislamiento térmico en la vivienda.» *Comisión Nacional de Vivienda.* http://www.conafovi.gob.mx/img/taller%20aislamiento%20termico/CuartoModuloUsodeAislamientoTermicoenlaVivienda.pdf Accessed 10 /october/2010.

[2] Kellenberger, Daniel, Hans-Jörg Althaus, Niels Jungbluth, Tina Künniger, Martin Lehmann, and Philipp Thalmann. Life Cycle Inventories of Building Products; Final Report Ecoinvent Data v.2.0 No. 7. EMPA Dübendorf: Swiss Centre for Life Cyce Inventories, 2007.

[3] Oliver-Solá, Jordi, Alejandro Josa, Joan Rieradevall, and Xavier Gabarrell. «Environmental optimization of concrete sidewalks in urban areas» International Journal of Life Cycle Assessment 14 (2009): 302-312.

[4] Antón Vallejo, Ma. Asunción. 2004 «Utilización del análisis de ciclo de vida en la evaluación del impacto ambiental del cultivo bajo invernadero mediterráneo.» http://www.tdr.cesca.es/TESIS_UPC/AVAILABLE/TDX-0420104-100039/ Accessed 28/november/2010.

Life cycle analysis of concrete pavement with or without Hidratium technology (self-curable), and its relation to the environmental assessment tool "CEMEX Ecological Footprint."

Gutiérrez Galán, Ibsan
Candelas Pons, María Guadalupe
Email: ibsan.gutierrez@ext.cemex.com

The aim of this study was to evaluate two types of concretes; conventional concrete pavement and concrete pavement with Hidratium technology (self-curable). This study will determine which of the sub-processes are the most contaminant. It will also assess whether Hidratium technology helps minimize the environmental impact of concrete pavement, the removal of the curing membrane and other processes of curing concrete. This investigation will be achieved by the CEMEX assessment tool for special Concretes.

The CEMEX assessment tool, also known as the Ecological Footprint assessment tool is based on a ready-mix concrete design. This study will determine the environmental efficiency of concrete based on the following five parameters; sustainable construction, lower CO2 footprint, cost, water savings and energy savings. The use phase is not included in this study because it is considered that the concrete during this phase is inert. The phase of demolition and final disposal are also not included due to lack of reliable information.

The results that were reached from this study are as follows;

1) The phase of cement production has the greatest environmental impact on the concrete production throughout its life cycle,

2) Hidratium technology helps to improve the environmental performance of concrete pavements

3) By including the results of the life cycle assessment and the CEMEX ecological footprint tool, provides significant benefits to Hidratium technology. These results are currently not considered in the conventional concrete pavement.

Topic: Building and construction

Keywords: CEMEX ecological footprint, life cycle assessment, concrete pavements, Hidratium

References:

- PE International. 2009. GABI 4 - 4.3.87.1.: Lean DB and Ecoinvent 2.0.
- Sjunnesson Jeannette. 2005. Life Cycle Assessment of Concrete. Lund, Sweden. Lund University

Inventarios para análisis del ciclo de vida de materiales para la construcción en el sureste de México: una contribución

Domínguez Lepe, José Antonio[1]
Juárez Chan, Maritza[2]
1 Profesor Investigador del Instituto Tecnológico de Chetumal, México
2 Egresada de la Maestría en Construcción del I. Tecnológico de Chetumal
jadlepe@hotmail.com

Resumen. El presente trabajo presenta inventarios fundamentales como una contribución al Análisis de Ciclo de Vida de los materiales de la construcción, particularmente se estudiaron la producción de agregados, bloques huecos, viguetas y bovedillas que son los materiales más utilizados en la construcción de viviendas de interés social en la región. El estudio se desarrolló en el Estado de Quintana Roo, en el sureste de México. Como es sabido, el ACV es un procedimiento objetivo de valorización de las cargas ambientales y energéticas y sus impactos referentes a una actividad o proceso. Se desarrolla a través de la identificación y cuantificación de la energía, de los materiales usados y de los desechos vertidos al ambiente. Aquí se midieron las emisiones de polvo, de bióxido de carbono y los consumos energéticos. Los límites del sistema quedan enmarcados exclusivamente en la fabricación de los materiales, no se toma en cuenta el transporte de los mismos hacia las obras.
Tema: Edificación y Construcción.
Palabras Clave. Inventarios, materiales, construcción

Introducción

Uno de los satisfactores fundamentales de la sociedad es la vivienda, sin embargo, su construcción genera grandes consumos de recursos naturales y energía, al mismo tiempo genera residuos y emisiones. Tanto la energía consumida como los residuos y emisiones, pueden ser reducidos, minimizando así el impacto que tienen al medio ambiente [1].

Un proceso objetivo para evaluar las cargas ambientales asociadas a un producto, proceso o actividad permitiendo identificar, cuantificar y con ello estar en posibilidad de tomar decisiones para minimizar impactos y consumos de materia y energía es el Análisis del Ciclo de Vida (ACV). [2]

La metodología del ACV comprende [3]:

- La definición de los objetivos y el alcance del análisis, a fin de programar correctamente el estudio.
- El análisis del inventario, en el cual el sistema o cada una de sus partes se resume en forma gráfica.
- La evaluación de impacto del ciclo de vida considerado, en dónde se resumen y ponderan las capacidades de afectación al medio ambiente, según una serie dada de categorías de impacto.
- La interpretación consiste en la presentación final (generalmente gráfica) de las conclusiones y de las propuestas de mejoras.

Las tipologías de vivienda que predominan en el Estado de Quintana Roo, son de muros de block con losas de vigueta y bovedilla y las de concreto monolítico, hecho que nos define el tipo de materiales y viviendas a estudiar.

El estado de Quintana Roo se localiza en la Península de Yucatán en el Sureste de la República Mexicana con las coordenadas geográficas extremas al norte 21° 35’, al sur 17° 49’ de latitud norte; al este 86° 42’, al oeste 89° 25’ de longitud oeste. Colinda al norte con Yucatán y con el Golfo de México; al este con el Mar Caribe; al sur con la Bahía de Chetumal, Belice y Guatemala; al oeste con Campeche y Yucatán [4]. Su ubicación geográfica se muestra en la figura 1.

Figura 1.- Localización del Estado de Quintana Roo.

Para poder proponer mejoras y propuestas de reducción de consumos en la construcción de viviendas en nuestra región, se hace necesario cuantificar los impactos que se generan al medio ambiente ya sea como residuos o en consumo de energéticos, identificando los puntos en donde se genera la mayor cantidad de residuos y consumos de energéticos. Este trabajo tuvo el objetivo de generar los inventarios de los materiales más utilizados en masa, como una contribución para el desarrollo de su ACV.

Materiales y Métodos

El trabajo se rigió por las normas e informes técnicos producidos por ISO dentro de la serie 14040 Análisis de Ciclo de Vida, particularmente:

- ISO 14040: Principios y marco general.[5]
- ISO 14041: Definición de Objetivos y Ámbito y Análisis de Inventario [6]

Las emisiones de partículas (polvo) durante la fabricación de los agregados pétreos (polvo de piedra, grava y gravilla) se midieron con ayuda del equipo DustTrak II modelo 8532 con filtro de partículas de hasta 4µ los resultados se presentaran en mg/m^3; expresión de concentración en masa del contaminante (en microgramos) en un volumen de aire (metro cúbico) a condiciones locales de temperatura y presión. La calibración de este instrumento fabricado por la TSI se ha hecho con aceite de lima y nominalmente se ha ajustado a la masa respirable de la norma ISO 12103-1, A 1 prueba de polvo (polvo de Arizona). La relación de calibración por parte de TSI es mayor que 1.2:1, en marzo 6 de 2009.

Con relación al consumo de energía eléctrica durante el proceso de transformación de piedra caliza a agregados pétreos y el proceso de fabricación de las piezas constructivas (block vibroprensado, viguetas y bovedillas) se midió con ayuda del equipo analizador trifásicos de calidad eléctrica Fluke 434. El analizador se ha diseñado y probado conforme a la norma EN61010-1 2a edición (2001), para instrumentos con requisitos de seguridad para equipos eléctricos de medida, control de las medidas y uso en laboratorio, clase III, grado 2 de contaminación.

Las emisiones de bióxido de carbono se realizaron con el equipo CARBOCAP8 Hand-Held Carbon Dioxide Meter GM70, el equipo mide volumen de concentración de gas CO_2, calibrado el 17 de abril de 2009. La sonda de dióxido de carbono ha sido calibrada en nitrógeno embotellado y con concentraciones de dióxido de carbono. El gas de nitrógeno de alta pureza se utilizó para calibrar el valor cero de la sonda. Para el valor de calibración, se utilizó una mezcla exacta de nitrógeno y dióxido de carbono atribuible al Instituto de Medición Países Bajos (NMI).

Resultados

Emisiones de Polvo.

La materia prima utilizada para la fabricación de los agregados pétreos en nuestra localidad se basa en la extracción de rocas calizas obtenidas de la explotación de bancos de materiales cuyo principal recurso natural es la roca caliza. Para seleccionar las plantas procesadoras se manejaron los siguientes criterios:

1.- Características similares en capacidad de transformación (tolva de trituración).

2.- Características similares en la maquinaria empleada en sus instalaciones para el transporte de la materia prima a la trituradora

3.- Facilidades otorgadas por los dueños y encargos para realizar las mediciones y estudios necesarios en las instalaciones.

Con base en lo anterior se seleccionan 5 plantas transformadoras de materia prima. El tiempo de lecturas de partículas suspendidas tomadas con ayuda del equipo DustTrak II modelo 8532 es de 10 minutos, que a su vez obtiene lecturas cada segundo por lo consiguiente se tiene un total de 600 lecturas durante los 10 minutos por punto, dando 14,400 lecturas por planta en los tres días de medición y 72,000 lecturas por las 5 plantas.

Unidad funcional		1000 kg		
Volumen de piedra	Entra		7m3	
	Sale		5m3	
BALANCE DE MATERIAL				
	Piedra caliza	Polvo	Gravilla	Grava
Peso volumétrico	1,075.0000	1,245.0000	1,153.0000	1,061.0000
Volumen necesario		0.8032	0.8673	0.9425
M^3 de piedra necesarios para producir 1000 kg de agregado		1.1245	1.2142	1.3195
Kg de piedra para producir 1000 kg de agregado		1,208.8353	1,305.2905	1,418.4731
BALANCE DE ENERGIA				
Consumo promedio de energía (kW/h)			252.96	
Promedio de duración de ciclos (min)			18.9379	
m3 de producción por hora			15.8413	
Consumo de energía (MJ) por m3 de producción			57.4858	
		Polvo	Gravilla	Grava
Consumo de energía por 1000 kg de material pétreo		46.1733	49.8576	54.1808
EMISIONES AL AIRE				
Promedio de emisiones de partículas <4µ (mg/m3)			0.062	
BALANCE DE EMISIONES DE CO_2				
Promedio de emisiones de co2 (ppm)			34,266.67	
Promedio de duración de ciclos (min)			12.6252	
Producción de CO_2 por ciclo (ppm)			216,312.5215	
Kg de CO_2 producidos por m3 de material			0.0433	
		Polvo	Gravilla	Grava
kg de CO_2 por material pétreo producido		0.0347	0.0375	0.0408

Medición de Consumo Energético

Las mediciones de consumo de energía se toman por un periodo de 1 hora, se localiza el centro de cargas de cada una de las trituradoras y se instala el equipo de medición eléctrica analizador trifásico de calidad eléctrica Fluke 434. Cabe mencionar que las plantas cuentan con diferentes equipos en sus instalaciones algunas de ellas cuentan con bancos de capacitores los cuales les ayudan a equilibrar el factor de potencia de las trituradoras y las bandas de transporte del agregado, se toman tres lecturas por planta en tres distintos días.

Medición de Emisiones de CO_2

Para tomar lecturas de emisión de bióxido de carbono se utiliza la ayuda del equipo CARBOCAP8 Hand-Held Carbon Dioxide Meter GM70, el equipo mide el volumen de concentración de gas CO_2, dentro del sistema productivo de agregados pétreos se considera únicamente los camiones de volteo para el transporte local (dentro de las fabricas)de materia prima y material pétreo y la maquinaria para cargar dichos volquetes (retroexcavadora y cargador frontal).

Tabla1. Matriz de inventario de agregados pétreos

Los inventarios obtenidos se sintetizan en las tablas 1 a la 3.

Tabla 2. Matriz de inventario para block y bovedilla.

Unidad funcional	Pieza	
BALANCE DE MATERIAL		
	Block	**Bovedilla**
Gravilla kg	8.7172	12.11
Polvo de piedra (kg)	8.16	11.34
Cemento (kg)	2.00	2.78
Agua (kg)	0.375	0.947
BALANCE DE ENERGIA		
	Block	**Bovedilla**
Consumo promedio de energía (kW/h)	17.215	16.05
Promedio de duración de ciclos (seg)	23.75	17.81
producción por ciclo (piezas)	5.00	3.00
Consumo de energía por pieza	0.0227	0.0240

Tabla 3. Matriz de inventario para vigueta

Unidad funcional	Metro lineal
BALANCE DE MATERIA	
Agua (kg)	1.857
Gravilla (kg)	3.102
Polvo de piedra (kg)	4.892
Cemento (kg)	1.923
Varilla de 1/4 in (kg)	2.237
BALANCE DE ENERGIA	
Consumo de energía (kW/h)	2.3

Conclusiones

Se logró el objetivo de definir los inventarios fundamentales para los materiales más utilizados en masa para la construcción de viviendas de interés social en la región, se espera sea una contribución para integrarlos con otros trabajos similares, y así en conjunto, ser una herramienta para el logro de Análisis de Ciclo de Vida más completos de los materiales aquí estudiados. Para que una vez integrados los inventarios, lograr el fin último de obtener los impactos correspondientes y las propuestas de mejora, para esta importante rama de la industria de la construcción.

Reconocimientos

Los autores agradecen a los Fondos Sectoriales CONACYT-CONAFOVI el apoyo financiero otorgado para el desarrollo de este proyecto y al Instituto Tecnológico de Chetumal por todo el apoyo logístico e Institucional brindado.

Referencias

[1] Comisión Nacional de Vivienda. (2007). *Comisión Nacional de Vivienda.* Recuperado el 2008 de Noviembre de 2008, de Comisión Nacional de Vivienda: http://www.cmic.org/mnsectores/vivienda/2008/conavi/cev%20001-332.pdf

[2] Klees, D. R., & Coccato, C. A. (2003). Ciclo de vida sostenible de los materiales de construcción.- 1º Etapa -. Chaco, Argentina: Comunicaciones Cientificas y Tecnológicas 2003.

[3] Espí, J. A., & Seijas, E. (2001). El Análisis del Ciclo de Vida aplicado a los materiales de construcción: " El granito de la comunidad de Madrid". Madrid: UPM.

[4]Municipal, C. N. (1999). *Enciclopedia de los municipios.* México: Centro Nacional de desarrollo municipal.

[5] ISO 14040: 1997. Gestión Medioambiental. Análisis de Ciclo de Vida. Principios y Estructura. AENOR.

[6] ISO 14041:1998, ISO 14042:2000, ISO 14043: 2000. Gestión Medioambiental. Análisis de Ciclo de Vida.Definición del objetivo y alcance y el análisis de inventario, Evaluación de impacto de ciclo de vida, Interpretación de ciclo de vida. AENOR.

LCA of Brick, Emboided energy and carbon footprint

CILCA 2011 MÉXICO

ABSTRACT

The poster presents the results from a study that was focused on the enboided energy content and kg of CO_2 equivalent emitted in the different processes that constitute the production of bricks, ranging from raw material extraction to the finished product, released for sale.

LIFE CYCLE ASSESSMENT METHODOLOGY

The funtional unit used was 1 brick released for sale.

Inventory data life cycle stages of extraction and production are presented in Table 1.

The impact assessment was performed using SimaPro 7.2, selecting the IPCC 207 methodology for estimating kg CO_2 eq (100 years) and the method of Cumulative Energy Demand (MJ) of Ecoinvent version 2.0.

Table 1. Summary data life cycle inventory

Process	Resources	Performance/ Capacity	Fuel / Energy	Consumption	Consumption/ bricks
Clay extraction	Excavator	315 m^3/day	Diesel	0,2698 L/m^3	-
Preparation and Finishing	3 conveyor belts Mixer Laminator Extruder Automatic cutter	73.967 bricks/ month	Electricity	11.67 kWh/ month	0,158 kWh/ bricks
Continuous kiln dried	Kiln	1.6 bricks/day	firewood	1,8 m^3/day	0,00113 m^3/ bricks
Baking	Kiln	6 bricks/ day	firewood	1,3 m^3/day	0,0002 m^3/ bricks
Packing and shipping	Wood Pallet	480 bricks/ pallet	-	-	0,00208 pallet/ bricks
	Plastic film	0,1776 kg/pallet	-	-	0,00037 kg/ bricks
	Yale	14 Pallet/ hr	Diesel	6 L/h	0,0009 L/bricks

RESULTS

It was estimated a Carbon Footprint of 0.173 kg CO_2 eq/brick, indentifying the dried process as the stage that contribute the maximum load to the impact category. (Figure 1).

On the other hand, the emboided energy or cumulative energy demand was estimated in 4.75 MJ/brick, by kilograms 1.63 MJ/kg less than 2.63 MJ/kg estimated by the database software Simapro 7.2, shown in Figure 2, attributable to stage craft in the process, particularly in southern Chile.

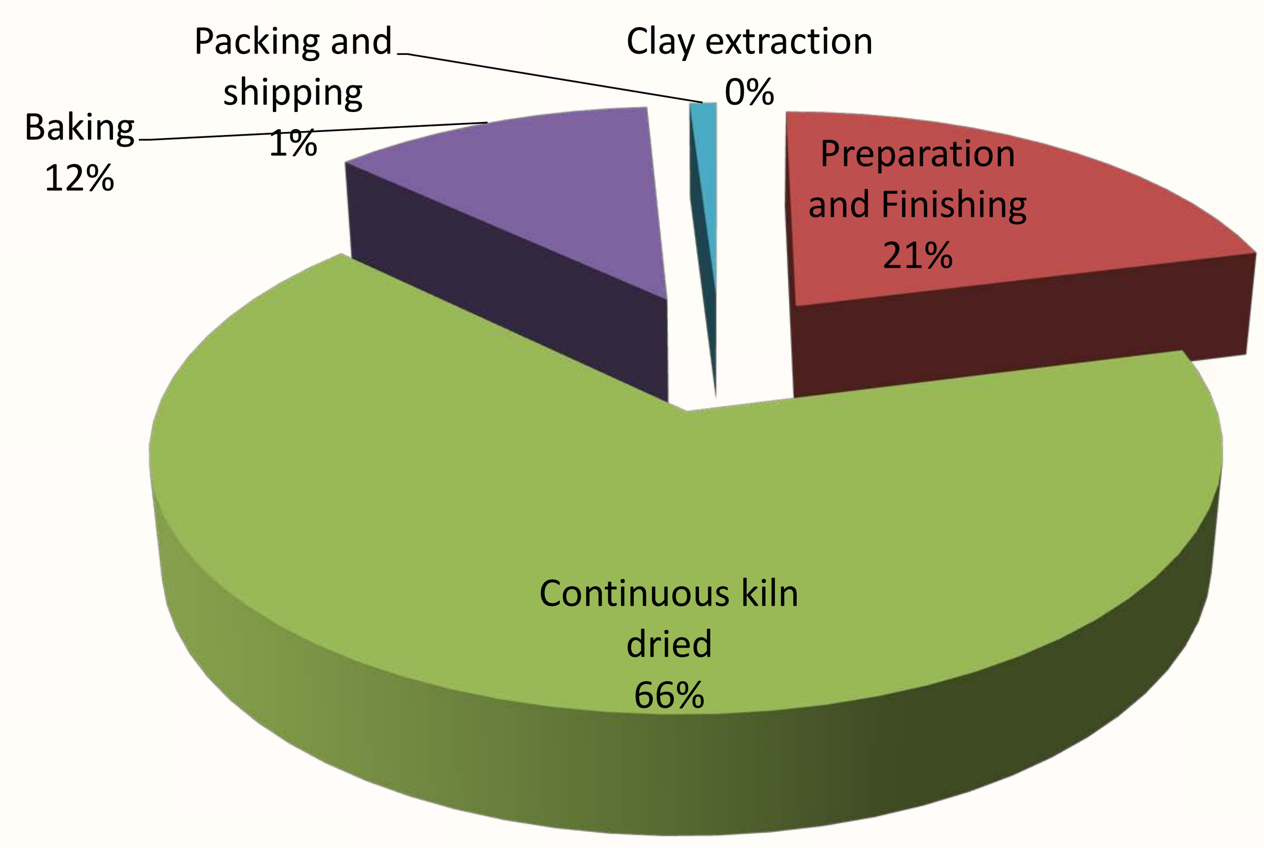

Figure 1. Contribution of brick Life Cycle Stages to the Cumulative Energy Demand.

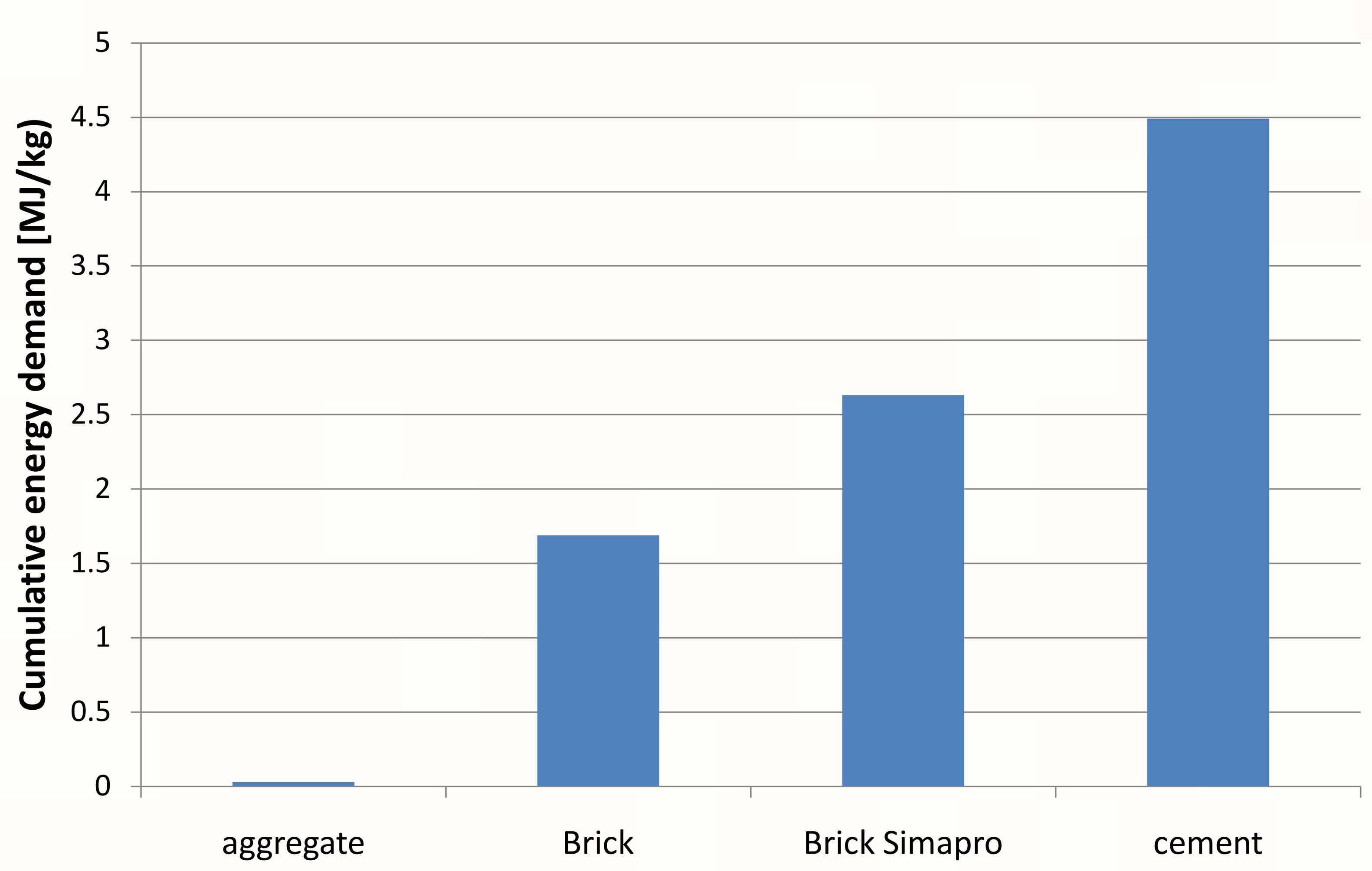

Figure 2 Comparison in cumulative energy demand in the production of one kilogram of material

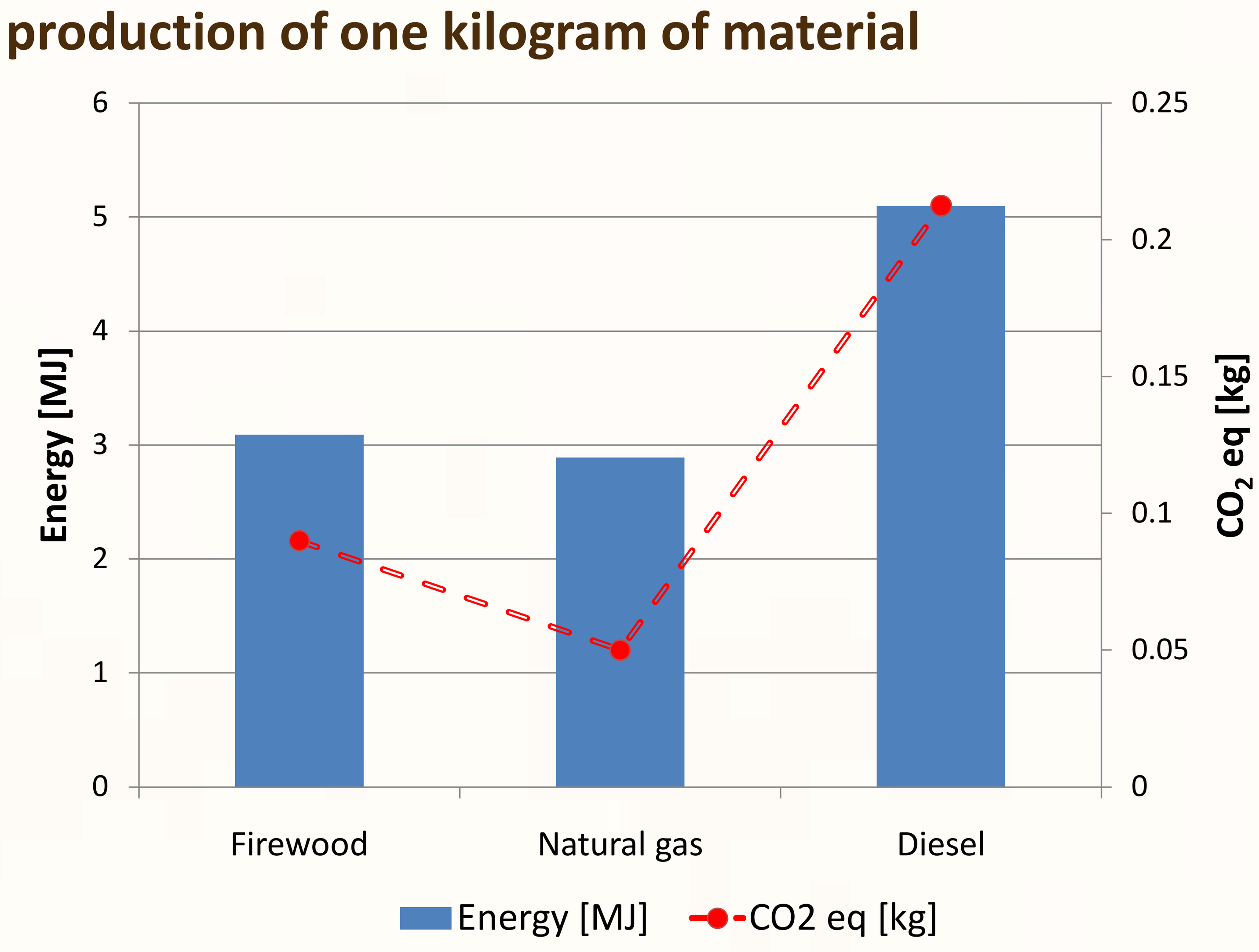

Figure 3 Energy and CO_2 emission fuel for drying process

The figure 3 shows the natural gas as the best option from an energy standpoint, but from the economic point of view the wood still has a much lower cost.

PEMEX PETROQUIMICA · CADIS · Life Cycle Initiative · INSTITUTO DE INGENIERÍA UNAM

Estimation of Carbon Footprint and Cumulative Energy Demand of aggregate through LCA

Edmundo Muñoz[1,2], Alberto Gonzáles[3] & Juan Pablo Cárdenas[1,3]

[1]Doctorado en Ingeniería, [2]Instituto del Medio Ambiente, [3]Departamento de Ingeniería en Obras Civiles, Universidad de La Frontera, Casilla 54-D, Temuco, Chile.
edmunoz@ufro.cl, phone: 56-45-325492, fax: 56-45-325053

Abstract
Using Life Cycle Assessment (LCA), cumulative energy demand and carbon footprint was evaluated of extraction and processing of aggregate in the Region of La Araucanía in Chile. Aggregate plant, located about 10 km from Temuco, Chile, has an area of approximately 11,000 m^2, producing more than 130,000 m^3 of material per year. The processing plant is located about 2 km away from the river where is the raw material extraction. The stages correspond to, extraction and transfer of materials integral to the truck, transport and storage to the processing plant, crushing and stockpiling of products. Using the software Simapro 7.2 was estimated accumulated energy demand in 43.6 MJ/m^3 and the carbon footprint in 2.7 kg CO2 eq/m^3 of aggregate produced, identified transportation as the stage of most sensitivity over the impact categories evaluated.

Keywords: Aggregate, LCA, building, cumulative energy demand, carbon footprint

Introduction
Historically, the construction industry requires a high consumption of materials and energy, which consequently generates large amounts of emissions to the environment. The construction sector mobilizes 10% of the global economy and is estimated to consume 40% of the energy produced worldwide [6].
The aggregate are all stone materials, sand, gravel and crushed stone, of variable size from deposits or quarries and are used in construction and civil engineering. They are hard, stable and inert in the cements, and they are used in the manufacture of mortar and concrete, asphalt mixtures and other applications. Gonzales (2010), in terms of the request of cement and asphalt, estimated at about 25 million m^3 of aggregate consumption in Chile in 2009. Natural sources of aggregate in Chile are both unconsolidated sedimentary deposits, as consolidated deposits, or rocks, which are located throughout the country. The main types of sedimentary deposits exploited relate to: alluvial fans, alluvial fans, fluvial deposits, deposits of marine terraces and lacustrine deposits [1]. The sedimentary deposits are the main source of aggregates in Chile providing 80% of the national total [3].
Process of extraction and production of arid.
The aggregate plant, located about 10 km from Temuco, Chile, has an area of approximately 11,000 m^2 facility, producing over 130,000 m^3 of material per year. The processing plant is located about 2 km away from the river where is the raw material extraction. The stages correspond to, extraction and transfer of materials integral to the truck, transport and storage to the processing plant, crushing and stockpiling of products.

Life cycle assessment methodology
Goal and scope
The aim of this study was to determine the accumulated energy demand and carbon footprint of the process of extraction and production of aggregate Therefore, function is defined as the aggregate's production (gravel, pebble and sand), established as a functional unit producing 1 m^3 of aggregate ready for marketing.

Life cycle inventory
Life cycle inventory (LCI) involves the compilation of calculation data and procedures for quantifying inputs and outputs of a defined system [5]. In this study, life cycle inventory data was mainly obtained by means of in-situ data collection, data bases, scientific and technological literature, and equipment operational manuals.

Inventory data life cycle stages of extraction and production are presented in Table 1. The Figures 1 and 2 show images of the integral material extraction process and the aggregate production plant, respectively.

Figure 1. Extraction and loading process of integral material

Figure 2. Plant of process of aggregate's production

For the evaluation of environmental impacts associated to electricity use, data from the Central Interconnected System of Chile was considered between January 2003 and June 2008. This is the main electricity system of Chile, supplying electricity to more than 90% of the country`s population. Chilean average data of electricity generation origin are distributed in 59.4% hydraulic, 15.3% natural gas, 13.6% coal, 9.9% diesel and 1,8% other non-conventional sources [2]. For identifying environmental aspects associated to electricity use, the data base from BUWAL (Swiss Environmental Protection Agency) [7] from SimaPro 7.2 library was used and partially modified incorporating Chilean national electricity production data.

Impact assessment

Impact assessment is a technical, quantitative and/or qualitative process to characterize and assess the effects of the environmental burdens identified in the inventory [5]. The impact assessment was performed using software SimaPro 7.2, selecting the methodology of the IPCC 2007 to estimate the kg CO_2 eq (100 years) and cumulative energy demand method (MJ).

Table 1. Summary data of life cycle inventory

Input	**Yield/ capacity**	**consumption/ distance**
Excavator	173 m^3/h	0.3 L/m^3
Track 1	12 m^3	2.5 km
Front loader	115 m^3/h	0.14 L/m^3
Track 2	12 m^3	0.1 km
Track 3	12 m^3	0.2 km
Output	**Production (m^3/mes)**	**Energy (kWh/mes)**
Base crushed	11,438	11,211
Gravel	2,147	26,971
pebble	1,654	
Sand	3,615	

Impact assessment

Impact assessment is a technical, quantitative and/or qualitative process to characterize and assess the effects of the environmental burdens identified in the inventory [5]. The impact assessment was performed using software SimaPro 7.2, selecting the methodology of the IPCC 2007 to estimate the kg CO_2 eq (100 years) and cumulative energy demand method (MJ).

Results and discussion

Cumulative energy demand

Cumulative energy demand was estimated in 43.6 MJ/m^3 of aggregates produced, identifying the processing plant, the phase that consumes more energy, equivalent to 42% of the total. At this stage, the use of front loader for loading and feeding the crushing process, is the most energy demand by 66%. The electricity used in the process, only provided with 23% of the cumulative energy demand. A noteworthy aspect of this analysis is the high rate that provides transport of the material to the cumulative energy demand (27%), considering that the transport distance is only 2.5 km. For this reason we performed a sensitivity analysis, which is presented in Figure 4. This analysis showed the influence of transport distance on the cumulative energy demand, identified distance as a critical variable and highly influential on the energy demand.

Carbon footprint

Was estimated carbon footprint of 2.7 kg CO_2 eq/m^3 aggregate, identifying the processing plant, as the stage that contributes greater burden on the impact category, with 52%, as shown in Figure 3. In addition, is observed in this figure that the transportation of aggregate from the quarry area to the ground (2.5 km) contributes with 30% of GHG emissions. As in the previous analysis, base on a sensitivity analysis evaluated the influence of transport on the carbon footprint of aggregates, establishing a strong relation between distance and GHG generation (Figure 3)

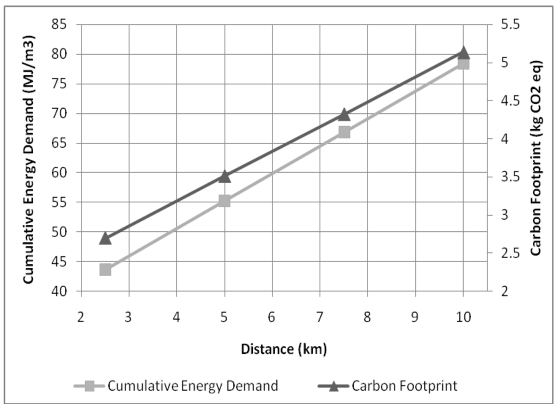

Figure 3. Influence of transport distance on the cumulative energy demand and carbon footprint of aggregates

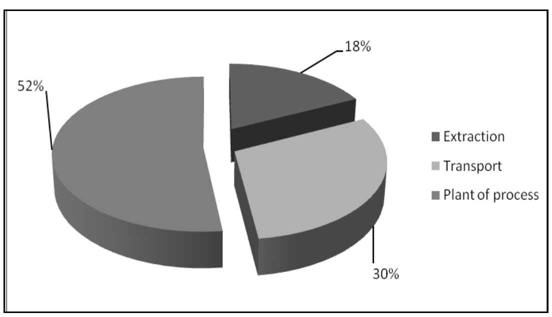

Figure 4. Contribution of life cycle stages of the aggregate to the carbon footprint

Analyzing the aggregate production process, this contributes 1.4 kg CO_2 eq/m^3 aggregates, shown in Figure 5 that using the front loader for the transfer of integral material and crushed base to crusher plant is one that contributes greater amount of emissions with 63%. For its part, the electricity is responsible for 31% of GHG emissions

Conclusions

In general, it was determined that the cumulative energy demand and carbon footprint of aggregates is low compared to other building products. This is mainly due to low energy requirement and inputs used in the production process, and the low transport distances from the extraction area to the processing plant. For this reason, both the cumulative energy demand and carbon footprint, are highly sensitive to changes in the transport distance of the integral material

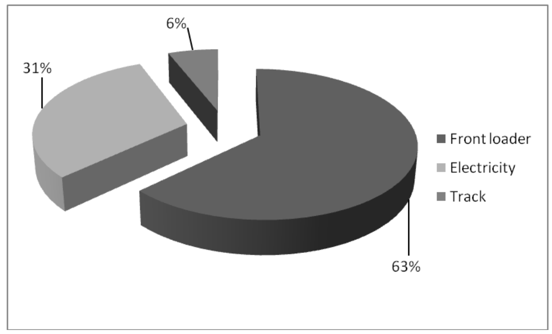

Figure 5. Contribution to the carbon footprint of the aggregate processing plant.

Reference

[1] Adasme, C. (2002). Consideraciones ambientales y de uso del territorio relacionadas con actividades extractivas de áridos. Simposio Internacional de Geología Ambiental para Planificación del Uso del Territorio. Puerto Varas, Chile.

[2] CNE, (2008). Generación bruta SING - SIC. Comisión Nacional de Energía. Santiago, Chile.

[3] Gajardo, A. (2002). Rocas y Minerales Industriales de Chile. Servicio Nacional de Geología y Minería. Santiago, Chile. No. 58, 181 p.

[4] Gonzales, A. (2010). Evaluación del Proceso de Extracción y Procesamiento de Áridos Mediante Análisis de Ciclo de Vida. Trabajo de Título de Ingeniería en Construcción, Universidad de La Frontera. Temuco, Chile

[5] ISO 14040 (2006) Environmental management - Life cycle assessment - Principles and framework. International Organization for Standardization, Geneva, Switzerland.

[6] Lippiatt B. (1998). Building for Environmental an Economic Sustainability (BEES). World Buildings Congress, Construction and the Environment. Proccedings, Gävle, 8 pp.

[7] Spriensma, R. (2004) SimaPro Database Manual, The BUWAL 250 library, PRé Consultants, Amersfoort, The Netherlands.

Operational and Embodied Energy in three houses

Abstract
As environmental issues continue to become increasingly significant, buildings become more energy efficient and the energy needs for their operation decreases. Thus, the energy required for construction and consequently, for the material production, is getting of greater importance.
This research shows a simplified life cycle analysis study of operational and embodied energy of three new houses with similar surface areas, commercial price and internal conditions of occupation, but different materials. These houses are located in Temuco, Chile. To obtain operational energy, computational models were carried out with Design Builder software, with information of the house from thermography and infiltration essays. For the embodied energy were used two databases, Inventory of Carbon & Energy (ICE), 2008, University of Bath, Inglaterra and New Zealand Building materials embodied energy coefficients database. Volume II – Coefficients, 1998, Victoria University of Wellington.
Houses total energy projection at 50 years lifespan was estimated in an average result of 409000 kWh, where embodied energy varies between 4-10% approximately of the total energy, and 65% in average of this embodied energy is contained in the house structure.

Keywords: Construction materials environmental assessment, Embodied energy, Operational building energy, Sustainable construction

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Introduction
Buildings' construction has a major determining role on the environment. It is a major consumer of land and raw materials and generates a great amount of waste. It is also a significant user of non renewable energy and an emitter of greenhouse gases and other gaseous wastes [7].
The building sector contributes largely in the global environmental load of human activities: for instance, around 40% of the total energy consumption in Europe corresponds to this sector. According to data from the Worldwatch Institute, the construction of buildings consumes 40% of the stone, sand and gravel, 25% of the timber and 16% of the water used annually in the world [3]. The building and construction sector (i.e. including production and transport of building materials) in OECD countries consumes from 25% to 40% of the total energy used (as much as 50% in some countries) [4].
Because global materials such as cement, aluminium, concrete and PVC are used, the energy costs and environmental impact increasing daily. Naturally, one solution is come back to building sector begin, local materials use with low energy costs and low environmental impact.
On the other hand, several studies have shown that operational energy accounts for the main amount of total energy use in dwellings during an assumed service life of 50 years and it is approximately 85–95% of the total energy use [9]. It also represents a major target for improvement, and is generally addressed by most environmental policies. There is a clear interaction between all the stages of a building's life: for example, if less is invested in the construction phase (e.g. using poor insulation), the investment needed for use and maintenance will increase. So the question is: is it better to invest in construction rather than in use and maintenance? The application of a global methodology such as LCA will allow us to answer this question, since this methodology can assess the global environmental impact during the life span of a building [2].
However, there are many methodologies proposed in papers with aims to overcome the existing prejudices of architects and engineers about LCA complexity, the difficulties in

understanding and applying the results and the loose link with the energy certification applications. In Chile, the LCA methodology applied on building sector it is a new subject and our work it is focused in incorporate embodied energy concept still.

Methodology

Goal and scope

The aim of this study was to compare different dwellings available on the building market today in the city of Temuco, Chile, according to their embodied and occupational energy at 50 years lifespan compared in total energy and standardized by square meters.

Emboided Energy

Due to lack of inventory in Chile and that the methodology of life cycle analysis appliedto the construction area is still incipient, the analysis was simplified to the calculation of energy in the construction phase as a result of the energy in each material used in the dwelling through two databases: Inventory of Carbon & Energy (ICE), 2008, University of Bath, England and New Zealand Building Embodied Energy Coefficients materials database. Volume II Coefficients, 1998, Victoria University of Wellington. Moreover occupational energy was calculated as necessary to maintain thermal comfort and lighting in the home, designed to fifty years. This study aims to generate a first approximation to the energy issue, a concept not addressed by the construction companies who are incorporating new energy efficiency criteria but only focused on the stage of Occupancy. This form is also meant to see the importance of considering all lifecycle stages of housing construction to move towards a sustainable and certifiable.

Impact assessment

Determination of CO_2 eq emissions.

The emission of CO_2 eq was determined separately in the two life cycle stages. For the first stage the equivalent CO_2 eq associated with the energy content was determined and for the second stage, the emission of CO_2 eq from the stage of occupation associated with the fuel employed.

Obtaining the equivalent CO_2 eq was similar to obtaining the energy. The database used for the determination of CO_2 eq equivalent has the values of CO_2 eq emissions in Kg of CO_2 eq per unit of material. Unlike the energy determination in this case the determination of CO_2 equivalent is done with a single database from the Inventory of Carbon & Energy (ICE), 2008, University of Bath, England. This study is based on data generated from the energy, making changes to emission factors from England, related to emissions from fuel used in the process, which is only a first approximation and does not necessarily represent the reality of Chile. The emission of from the occupation phase was generated from the thermal simulation software DesignBuilder®. The calculation of CO_2 eq was associated with energy consumption of HVAC (heating and cooling) and electricity for lighting calculated by the software. Thus, the software identified a factor for each fuel, which contains the amount of CO_2 eq emitted per unit of energy consumed (kg CO_2 eq/kWh), so this factor by multiplying the energy consumption of housing delivers annual CO_2 eq emissions. The factors presented by the software for energy consumption in Chile were:

» Electricity : *0,685 kg* CO_2 eq*/kWh*

» Diesel : *0,273 kg* CO_2 eq*/kWh*

» LPG y NG : *0,195 kg* CO_2 eq*/kWh*

Results and discussion

Comparing the results for each dwelling is observed that emboided energy represents between 4-10% of total energy, which is explained by the low level of requirements still present in the regulations of Chile, with occupational energy ranges between 137-167 kWh/m^2/year.

Houses total energy projection was estimated in an average result of 409000 kWh, where embodied energy varies between 4-10% approximately of the total energy. This is shown in figure 1.

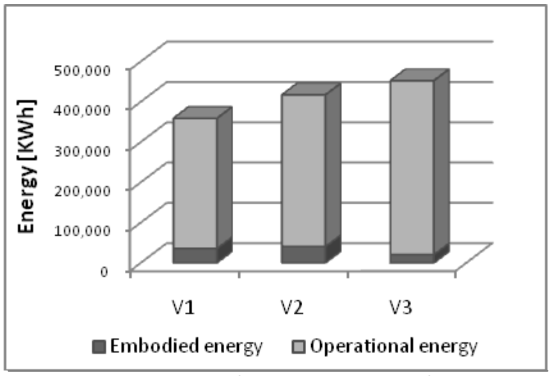


Fig 1 Energy per house (lifespan = 50 years)

As for the normalized operational energy demand, it is observed in figure 2 along with the reference of standard passive house. The figure 2 shows the difference of the standard in Chile with the passive house standard, about 120 kWh/m^2/year.

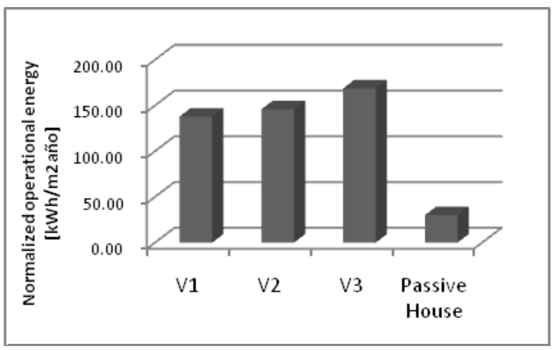


Fig 2 Normalized operational energy compared to passive house standard

In figure 3 is observed that 65% of embodied energy is contained in the house structure. This also observed in figure 4 where the greatest contribution is structural materials as concrete and bricklaying.

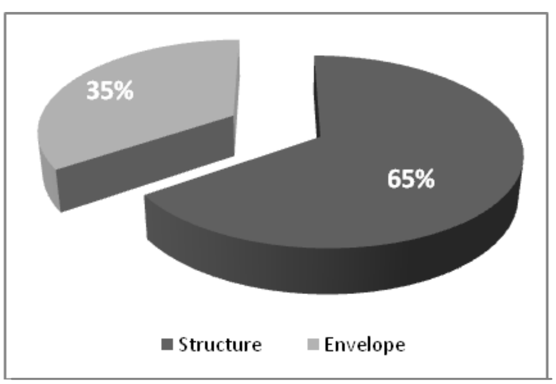


Fig 3 Contribution of constructive stages in total embodied energy

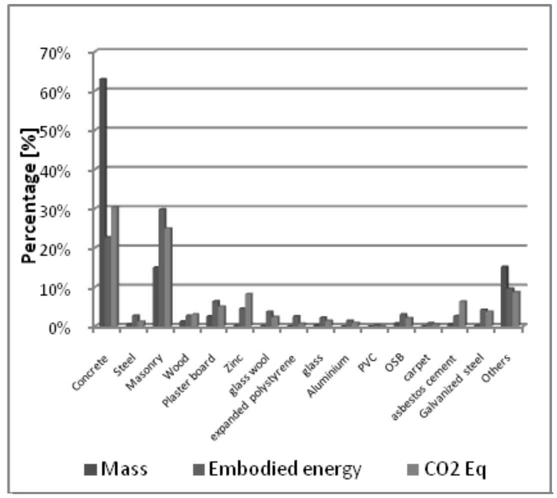


Fig 4 Contribution of materials in total embodied energy.

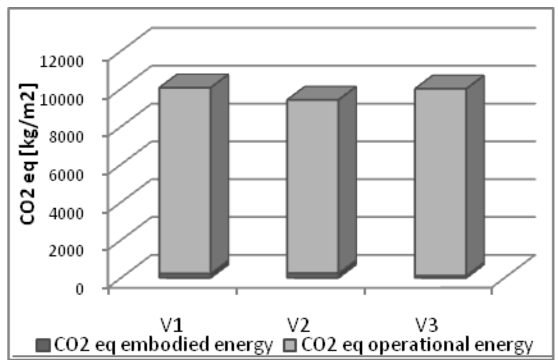


Fig 5 CO_2 eq associated to embodied energy. (lifespan = 50 years)

Figure 5 shows the importance of operational stage in relation to CO_2 eq emission in actual regulations context.

Conclusion

Embodied energy represents between 4-10% approximately of the total energy. This is a low percentage due to high operational demand of housing in Chile.

Reference

[1] Alcom A., Wood P., (1998), "New Zealand building materials embodied energy coefficients database", Centre for building performance research, New Zealand.

[2] Aranda A, Scarpellini S, Zabalza I. (2009) Life cycle assessment in buildings : State-of-the-art and simplified LCA methodology as a complement for building certification. Building and Environment.;44:2510-2520.

[3] Arena AP, de Rosa C. Life cycle assessment of energy and environmental implications of the implementation of conservation technologies in school buildings in
Mendoza–Argentina. Build Environ 2003;38:359–68.

[4] Asif M, Muneer T, Kelley R. (2007) Life cycle assessment: a case study of a dwelling home in Scotland. Build Environ;42:1391–4.

[5] Dimoudi A., Tompa C., (2008), "Energy and environmental indicators related to construction of office buildings", Elsevier, Grecia.

[6] Fuentes F, (2010) Energía contenida y energía ocupacional en viviendas de Temuco, Trabajo de Título de Ingeniería en Construcción, Universidad de La Frontera. Temuco, Chile

[7] Hammond G., Jones C., (2008), "Inventory of carbon & energy (ICE)", University of Bath, United Kingdom.

[8] Kospomoulos P. (2004) Environmental design. 2nd ed. Thessaloniki, Greece [In Greek]: University Studio Press.

[9] Thormark C. (2006) The effect of material choice on the total energy need and recycling potential of a building. Build Environ;41(8):1019–26.

Environmental impact of rainwater harvesting integration in new construction compared with renovated buildings.
Application to urban planning for emerging neighbourhoods in Bogotá.

Angrill, Sara[1]; Morales, Tito[1,2]; Cerón, Ileana[1]; Gabarrell, Xavier[1,3]; Josa, Alejandro[4,5]; Rieradevall, Joan[1,3]

[1]SosteniPrA (ICTA-IRTA-Inèdit), Institute of Environmental Science and Technology (ICTA), School of Engineering (EE), Universitat Autònoma de Barcelona (UAB), Campus of the UAB, Bellaterra (Cerdanyola del Vallès), 08193 Barcelona, Catalonia, Spain.
[2]Facultad de Ciencias Ambientales, Universidad Tecnológica de Pereira (UTP), Colombia.
[3]Department of Chemical Engineering, School of Engineering (EE), Universitat Autònoma de Barcelona (UAB), Campus of the UAB, Bellaterra (Cerdanyola del Vallès), 08193 Barcelona, Catalonia, Spain.
[4]Department of Geotechnical Engineering and Geosciences, School of Civil Engineering (ETSECCPB), Technical University of Catalonia – Barcelona Tech (UPC, Campus Nord), C/ Jordi Girona 1-3, Building D2, 08034 Barcelona, Catalonia, Spain.
[5]Institute of Sustainability (IS.UPC), Technical University of Catalonia-BarcelonaTech, Campus Nord, Building VX. Pl. Eusebi Güell, 6, 08034 Barcelona, Catalonia, Spain
E-mail contact: Sara.Angrill@uab.cat Tel.: (+34)935813760 Fax: (+34)935868008

ABSTRACT
Rainwater harvesting (RWH) presents many environmental, social and economic benefits and it is emerging as a key strategy in order to cope with water scarcity in urban areas. The aim of this research is to analyse the eco-efficiency of several RWH scenarios applied to the development of future Colombian urban districts and to compare the environmental benefits of implementing them in the design of newly constructed neighbourhoods or, conversely, in future renovation building works.

Four scenarios were defined considering several scales of the infrastructures and the tank locations for both construction strategies, newly constructed buildings (N) and renovated buildings (R): Below-roof tank (N1), distributed-over-roof tank (N2), underground tank (R1) and block tank (R2). In order to evaluate the eco-efficiency of these options, the necessary RW catchment, storage and distribution subsystems have been designed taking into account the average rainfall of Bogotá city, the area of the harvesting surfaces and a constant water demand for laundry. Subsequently, they have been environmentally assessed through a Life Cycle Assessment (LCA).

The results evaluate the environmental performance of each scenario and indicate which is the most environmentally-friendly option for implementing RWH systems in future Colombian housing projects. The possibility of incorporating a well-distributed tank over the roof instead of setting up an underground one in an existing building (often the only option in retrofit actions) can reduce its environmental impact up to 4.4 times, thus enabling significant environmental savings in CO_2 emissions. These results allow guiding sustainable urban planning and design by integrating environmental criteria in decision-making processes.

Topic: Building and construction
Keywords: Colombian urban planning, Rainwater, Water demand, Environmental impact.

1. Introduction

The development of new neighbourhoods in Colombia is a priority as there is a high housing deficit, especially for the most disadvantaged social sectors. While 140,000 dwellings are being built on average, 285,000 new households are being formed. Nowadays the deficit is up to 1,500,000 homes [1] so the current government (2010-2014) has proposed the creation of 1,000,000 households over its administration period [2].

On the other hand, Colombia is a country blessed with water wealth as the real offer exceeds 20,000 m^3/person·year [3]. The theoretical water availability in this country is estimated in 45,408 m^3/person·year, standing between 4.5 and 6 times the world average for developed countries (10,637m^3) and for developing countries (7,580m^3), respectively [4].

In this context the use of rainwater (RW) is currently a marginal issue only exploited by people with poor access to water supply. This motivates the need to establish sustainable approaches of RW management in cities in order to achieve a greater stability of the supplying systems in urban areas. Besides, the use of RW on a large scale is perceived as an adaptation strategy to climate change against the reduction of water availability. Future predictions foresee water supply problems in urban areas in the coming years.

Despite the few existing experiences regarding the use of RW, its potential for the development of the new districts proposed is evident. However, it is necessary to develop comparative studies to estimate with high confidence the viability of implementing and using RWH systems from an environmental, economic and social point of view.

2. Goal and scope

2.1 Objectives

The aim is to quantify, by means of LCA, the potential environmental impact of different constructive solutions for RWH in Colombian emerging neighbourhoods. For this purpose we performed a scenario comparison between integrating these systems in the design of newly constructed buildings and adding them in future renovation building works, with the restrictions that the latter option presents.

The functional unit (FU) has been defined as the collection, storage and supply of 1 m^3 of RW provided per person and year to be used as non-potable water for a constant demand of laundry.

2.2 Description of the system under study

The system consists of a high-density urban block of 100x100m^2 with 10 residential five-storey buildings of 24 apartments (700m^2/floor) (Figure 1). The average density of people per household has been estimated on 3.8 people per household.

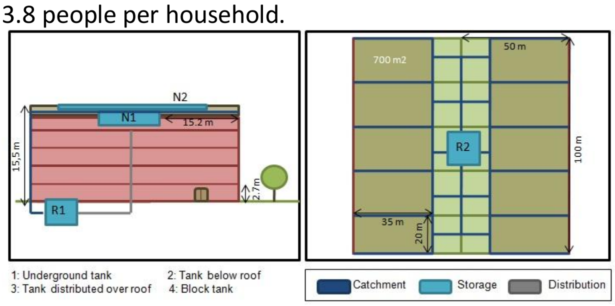


Figure 1 - Characteristics of the study area.

Infrastructures

A total of four scenarios have been defined in terms of the scale of the infrastructure and the location of the tank (Figure 1) for each construction strategy. Two scenarios are related to the integration of RWH systems in the design of newly constructed buildings (N) and the other two concern its implementation in future renovated buildings (R) as it is presented in Table 1.

Table 1 - Definition and characteristics of the scenarios according to the tank scale and location for each construction strategy (N and R).

	Scenarios			
	N1	**N2**	**R1**	**R2**
Tank scale	Building	Building	Building	Block
location	Below roof	Distrib. over roof	Underground	Underground

Each of them integrates the infrastructures for RWH as part of a direct-feed system, divided in 3 subsystems: catchment, storage and distribution. The difference lies in the fact that in new construction there is a chance to place the tank over the roof, as the building pillars can be reinforced on time, reducing environmental impacts and costs. Conversely, this strategy cannot be applied to existing buildings and the best solution is to construct an underground tank.

Definition of subsystems

- *Catchment:* The uptake of water is necessary in all scenarios except the one with the tank distributed all over the roof (N2). It is carried out through galvanized steel gutters placed on the roof of the buildings and polypropylene downpipes (Figure 1). RW is collected from the roofs, which are flat and have a runoff coefficient of 90%.
- *Storage:* The storage subsystem consists of a RW tank, which varies depending on its location and scale (Figure 1, Table 1). The concrete used in this analysis has a characteristic compressive strength of 20-25MPa, used in the construction of the tank and the elements of structural reinforcement. The reinforcement is the requirement of extra material in the structure of the building to withstand the weight of the tank (and water), and therefore necessary in scenarios with tank over and below the roof (N1, N2).
- *Distribution:* The distribution consists on a stainless steel submergible pump (2.2kW) –only in underground tank scenarios (R1, R2)-, and the polypropylene supplying pipes. Scenarios that present a tank located over or below the roof (N1, N2) do not require pump (distribution system has enough pressure to supply water by gravity) (Figure 1).

Reference flows

- *Water demand:* The facilities of RWH have been devised to supply the maximum water demand for each home laundry, quantified in 25m^3/apartment·year over the whole life of the system (it represents 15.5% of the domestic demand). This consumption is based on the eco-efficiency requirements necessary for the acquisition of A+ ecolabel in washing machines.
- *Rainfall data:* The study based its calculations on the average rainfall of Bogotá city, approximately 714mm per year [5].

2.3 Methodology

Environmental calculation tools

The LCA methodology considers the entire life cycle of the RWH infrastructures for each scenario. However, the impact of the recycling process of materials at the end of its life cycle is outside the boundaries of the system, as there is much uncertainty in the recycling process 50 years hence.

The data for materials and the sizing of the infrastructures have been obtained based on conventional hydraulic dimensioning of the building and by structural calculations, performed with a standard program for structures (Cypecad v.2010 [6]).

Only the classification and characterization stages [7] have been considered. The method 2001 Baseline v2.04 CML has been used [8] and the impact categories selected are: Abiotic depletion potential (ADP, 1 kg Sbeq.), Acidification potential (AP, kg SO_2eq.), Eutrophication potential (EP, kg PO_4^{3-}eq.) Global warming potential (GWP, kg CO_2eq.), Human toxicity potential (HTP, kg 1,4-DBeq.) Ozone layer depletion potential (ODP kg CFC-11eq.) and Photochemical ozone creation potential (POCP, kg C_2H_4eq.). The ecoinvent 2.0 database [9] has been used, associated to the software SimaPro7.2.0 [10]. In determining the environmental impacts of concrete, EcoConcrete LCA has been used [11], which contains better quality inventory data from European producers. These data can be extrapolated to the Colombian context as the technology used in the cement fabrication industry is worldwide uniform.

Life cycle stages

The life span of the RW storage tank, pipes and pumps is of 50, 25 and 15 years, respectively [12]. The size of the tank has been determined with the aid of RainCycle [13]. The construction phase takes into account the energy costs related to the construction of the infrastructures. Besides, standard losses of 5% of the total construction materials have been set. The transport stage includes both material transportation (estimated in 30km) and waste transport to local manager (50km). The use stage is present in the distribution subsystem in those scenarios with pumping needs (R1, R2), and provides the necessary power consumption (expressed in kWh).

3. Results

3.1 Impact assessment of systems

Figure 2 shows the relative contribution of each strategy to the total environmental impacts (values are indexed using the most impacting scenario as baseline). The results suggest that new construction strategies (N1, N2) are much better in environmental terms than the renovation of buildings (R1, R2). It can be observed that N2 (scenario with tank distributed over the roof) shows the lowest environmental impacts in most categories except for ODP, in which it is the greater contributor. Conversely, R1 (renovation strategy at building scale with underground tank) shows the most significant negative impacts (in six categories out of seven).

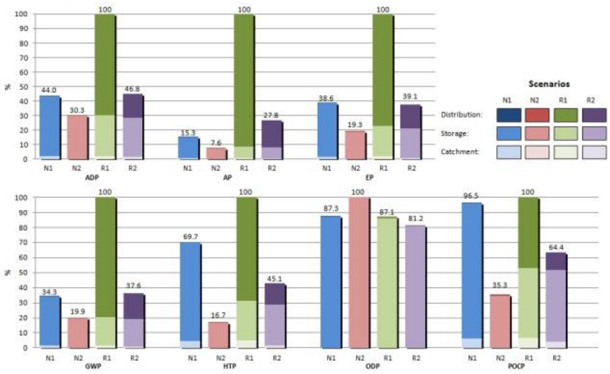


Figure 2 - Proportion of total environmental impacts and contribution of the subsystems in new construction (N) and building renovation (R) strategies.

3.1.1 Impacts of the subsystems

For the new construction strategies (N1, N2) and the renovation scenario at block scale (R2), the greatest impacts are associated with the storage subsystem (Figure 2), representing between 30% and 99% of the total value. On the contrary, in the renovation scenario at building scale (R1) the distribution subsystem is the main contributor with more than 47% of the total impacts. The exception is the impact category of ODP (storage is always the most impacting subsystem).

3.1.2 Impacts of the stages

Table 2 presents the absolute values obtained from the characterization of each stage and the relative contribution of the five life cycle stages proposed. The obtained results show the materials phase as the most important factor in the construction of scenarios N1 and N2, with more than 85% of the total impacts (Table 2). Furthermore, the use stage in the renovation scenario R1 can be attributed to the major environmental impacts in five of the seven categories analyzed. The exceptions are ODP and POCP (materials are the main contributors).

Table 2 - Results of the environmental impacts per FU and contribution of the life cycle stages.

	% Life cycle stages	ADP	AP	EP	GWP	HTP	ODP	POCP
		kg Sbeq	kg SO2eq	kg PO4---eq	kg CO2eq	kg 1,4-DBeq	kg CFC-11eq	kg C2H4eq
N1	Materials (%)	89,98	91,71	93,48	95,58	97,38	99,81	95,81
	Construction (%)	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Transportation (%)	1,72	2,17	2,55	2,52	0,78	0,04	1,47
	Use (%)	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Deconstruction (%)	8,29	6,12	3,96	1,90	1,84	0,16	2,72
	Absolute value (kg)	**1,19E-02**	**4,14E-03**	**6,25E-04**	**1,10E+00**	**7,89E-01**	**1,22E-05**	**2,61E-04**
N2	Materials (%)	92,27	87,66	85,75	87,33	92,04	99,90	91,63
	Construction (%)	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Transportation (%)	3,61	5,94	7,00	6,31	3,85	0,05	4,13
	Use (%)	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Deconstruction (%)	0,57	0,57	0,36	0,15	0,36	0,01	0,35
	Absolute value (kg)	**8,51E-03**	**2,19E-03**	**3,35E-04**	**6,82E-01**	**1,96E-01**	**1,40E-05**	**9,94E-05**
R1	Materials (%)	28,97	9,43	22,14	20,53	30,94	98,73	51,94
	Construction (%)	2,11	0,54	0,88	0,38	0,74	0,09	1,52
	Transportation (%)	0,76	0,34	1,00	0,87	0,56	0,04	1,60
	Use (%)	67,69	89,56	75,77	78,14	67,59	1,12	44,60
	Deconstruction (%)	0,48	0,12	0,20	0,09	0,17	0,02	0,35
	Absolute value (kg)	**2,71E-02**	**2,71E-02**	**1,62E-03**	**3,22E+00**	**1,13E+00**	**1,22E-05**	**2,70E-04**
R4	Materials (%)	62,07	30,97	54,90	54,39	66,03	99,56	79,71
	Construction (%)	5,43	2,35	2,73	1,21	1,98	0,12	2,84
	Transportation (%)	1,60	1,21	2,54	2,29	1,25	0,04	2,57
	Use (%)	29,00	64,66	38,87	41,68	30,05	0,24	13,88
	Deconstruction (%)	1,89	0,82	0,95	0,42	0,69	0,04	0,99
	Absolute value (kg)	**1,27E-02**	**7,52E-03**	**6,31E-04**	**1,21E+00**	**5,11E-01**	**1,14E-05**	**1,74E-04**

4. Discussion

4.1 Impact assessment

The environmental performance associated to the utilization of RW in newly constructed buildings by means of the installation of a tank distributed over the roof (N2) is much better than the other strategies, in particular than the implementation of RWH in renovated buildings. This scenario, although having the highest impact in the category of ODP due to the storage subsystem, can reduce its environmental impacts between 64.3% and 92.4% in comparison with the worst scenario (R1) (Figure 2). However, in the category of ODP all scenarios show a contribution over 80%, as a consequence of the building's materials load. The environmental benefits of scenario N2 are mainly attributed to the lack of a harvesting subsystem, the absence of pumping during use stage and a lower volume of materials in the construction of the storage subsystem.

The scenario with the greatest impact is R1, which belongs to the renovation strategy scenarios. This constructive option shows greater contributions to the total impact in most of the categories analysed (except

ODP), related to the distribution subsystem (Figure 2) during the use stage (Table 2). Scenario R1 doubles the contributions of the other scenarios in most categories except for HTP and POCP. These impacts result from the energy consumption of the pump that supplies water in high-density buildings.

For scenarios N1, N2 and R2 the higher impacts are generally associated with the storage subsystem, due to the tank materials and the reinforcement of the structure (concrete and steel) (Table 2). These impacts, more relevant in scenario N1, are justified by the existence of a structural reinforcement in the construction of the building necessary to offset the weight of the tank located on the roof on a pillar.

4.2. Application of results

By not integrating management policies, RW potential environmental impacts are generated by each of the neighbourhoods built. On average 29,300 new homes per year [1] are built in Bogotá city and we estimate that 732,500 m^3 of water could be supplied by the RW systems, which becomes a factor to estimate the total environmental cost of each one of the categories analysed.

This analysis should also be done for other Colombian urban areas with more favourable RW profiles. If we consider the ones with populations of more than 250,000 inhabitants, there would be an average potential RW supply of between 793 and 2,258 $L/m^2 \cdot year$ within a range of 77 to 230 days with rain per year. This rainfall profile may result in greater volumes of water and therefore smaller tank sizes, which favours the reduction of the environmental impacts calculated and the potential economic costs.

5. Conclusions

This study focuses on the Colombian building sector, characterized by a strong urban projection in the coming four years, although can be generalized to other areas in a similar context. In this sense, the use of endogenous resources such as local RW is not only one of the possible solutions to water management and supply but also a strategy to adapt to the repercussions of climate change. From the results of the LCA comparison it has been observed that the best environmental choice is to implement RWH devices previously when the buildings are being designed rather than in future renovation building works. Besides, the location of the tank over the roof cover with a design that redistributes proportionally its weight on the structure of the building has less environmental impacts than the other scenarios analysed, and possibly lower building costs.

The incorporation of the most favourable constructive option in the design and screening of new residential areas may provide significant environmental savings in CO_2 emissions (GWP). The possibility of incorporating a well-distributed tank over the roof instead of setting up an underground one in an existing building (often the only option in retrofit actions) can reduce its environmental impact up to 4.4 times.

7. References

[1] Departamento Administrativo Nacional de Estadísticas [National Administrative Department of Statistics] –DANE-Colombia. 2005. Sistema de consulta, Censo ampliado 2005 [Query system, Census 2005]. In <http//www.dane.gov.com>. Accessed June 2010.

[2] Urbana. Revista de la Construcción Sostenible. 2010. Cámara Colombiana de la Construcción (Camacol) Edición #0046, Colombia.

[3] Instituto de Hidrología, Meteorología y Estudios Ambientales IDEAM-Colombia. 2000. Estudio Nacional del Agua. 256p.

[4] World Resources Institute (WRI) in collaboration with United Nations Development Programme, United Nations Environment Programme, and World Bank. 2008. World Resources 2008: Roots of Resilience-Growing the Wealth of the Poor. Washington, DC: WRI.

[5] Instituto de Hidrología, Meteorología y Estudios Ambientales, IDEAM-Colombia. (2008). Informe anual sobre el estado de ambiente y los recursos naturales renovables en Colombia. Estudio nacional del agua. Relaciones de demanda de agua y oferta hídrica.

[6] CYPE. 2010. Programa informático CYPECAD - Módulo utilizado CYPECAD 2010.g CYPE Ingenieros, S.A., Alicante (http://www.cype.es/).

[7] ISO 14042. 2000. Environmental Management –life cycle assessment- life cyle impact assessment. International Organisation for Standardisation ISO. International Standard. 14042. Geneva, Switzerland.

[8] Guinée JB (ed.), Gorrée M, Heijungs R, Huppes G, Kleijn R, de Koning A, van Oers L, Wegener Sleeswijk A, Suh S, Udo de Haes HA, de Bruijn H, van Duin R, Huijbregts MAJ, Lindeijer E, Roorda AAH, Weidema BP. 2001. Life cycle assessment: an operational guide to the ISO standards. Parts 1 and 2. Ministry of Housing, Spatial Planning and Environment (VROM) and Centre of Environmental Science (CML), Den Haag and Leiden, The Netherlands (Guinée JB, final editor).

[9] ecoinvent. 2009. Swiss Centre for Life Cycle Inventories. Ecoinvent database v3.0. Technical report. http://www.ecoinvent.ch/. Accessed 12 May 2010.

[10] PRé Consultants. 2010. SimaPro 7.2.0. Amersfoort, the Netherlands: PRé Consultants.

[11] CEMBUREAU, BIBM, EFCA, ERMCO, EUROFER, UEPG. 2003. EcoConcrete software tool. CEMBUREAU, Brussels.

[12] Roebuck RM, Oltean-Dumbrava C, Tait S. 2010. Whole life cost performance of domestic RWH systems in the United Kingdom. Water and Envir. J. ISSN 1747-6585.

[13] Roebuck RM and Ashley RM. 2006. Predicting the hydraulic and life-cycle cost performance of RWH systems using a computer based modeling tool. Proceeding of the 4th International Conference on Water Sensitive Urban Design, Apr. 2-7, Melbourne, Australia, pp: 699-706.

Sustainability assessment within the residential building sector: A case study based on life cycle assessment applied in a developed (Spain) and a developing country (Colombia)

Ortiz Oscar [1], Sonnemann Guido [2], Castells Francesc [3]

[1] **University of Pamplona, Faculty of Engineering and Architecture. Km 1 Vía Bucaramanga, Pamplona N de S, Colombia.**

[2] **University of Rovira I Virgili. Environmental and Analysis Management Group (AGA). Visiting senior research fellow.**

[3] **University of Rovira I Virgili, Environmental and Analysis Management Group (AGA). Department of Chemical Engineering. Av. Països Catalans 26, 43007, Tarragona, Spain.**

Corresponding author: oscarortiz@unipamplona.edu.co, Email address: francesc.castells@urv.cat (F. Castells), Guido.Sonnemann@unep.org (G. Sonnemann).

ABSTRACT

In order to overcome the increasing concern of today's resource depletion, environmental considerations and to address sustainability indicators, the environmental tool of Life Cycle Assessment (LCA) has been used. To illustrate this, a case study has been carried out based on the application to two buildings, one located in Barcelona, Spain and one situated in Pamplona, Colombia. In both case studies, we assessed the construction, use and end-of-life phases. Then, the main objective of this paper is to provide initiatives based on LCA for residential dwellings to reduce environmental impacts and assist stakeholders in improving customer patterns during the dwelling life cycle.

The findings of this work state that the appropriate combination of building materials, improvement in behaviours and patterns of cultural consumption, and the application of government codes would enhance decision-making in the construction industry. The difference in consumption in Colombia and Spanish dwellings is not only due to the variation in results for bio-climatic differences but also because of the consumption habits in each country. It can be seen that the importance of consumption habits of citizens and the need to decouple socio-economic development from energy consumption. There is a crucial necessity to provide satisfaction to basic needs and comfort requirements of population with reasonable and sustainable energy consumption.

Key Words: Colombia, Life Cycle Assessment, Spain, Sustainable construction.

1. INTRODUCTION

Economical and socially, in 2001 the construction sector represented 10% of global Gross Domestic Product (GDP) with an annual output of USD 3.000 billion, of which 30% was in Europe, 23% in developing countries, 22% in the United States, 21% in Japan, and 4% in the rest of the developed word [1]. Furthermore, the European Commission (2006) stated that 11.8 million operatives are directly employed in the sector in Europe and that is Europe's largest industrial employer, accounting for 7% of total employment and 28% of industrial employment in the EU-15. About 910 billion euros were invested in construction in 2003, representing 10% of the GDP [2]. Environmentally, taking into account its entire lifespan, the built environment is responsible in each country for 25 to 40% of total energy use, 30 to 40% of solid waste generation and 30 to 40% of Global Greenhouse Gas (GHG) emissions [3].

Some initiatives for tackling adverse environmental impacts have been taken. To accomplish it, diverse technical and conceptual approaches must be applied. In particular, our interest has been on Life Cycle Assessment as a means to quantify the amount of natural resources consumed and identify the associated environmental impacts in order to provide sustainability indicators and create goals preventing adverse environmental impacts, consequently enhancing quality of life and allowing people to live in a healthy environment and improve socio-economic aspects.

This work is then concerned from a quantitative life cycle perspective to measure sustainability within the residential building sector based on the application of LCA tool.

Life Cycle Assessment (LCA) is an environmental management tool to evaluate impacts throughout the life cycle. The usefulness of LCA tool has been applied within the residential building sector in two countries: one in a developed country (Spain) and one in a developing country (not emerging Colombia).

2. METHODOLOGY

The analysis is divided into the following life cycle phases:

Construction evaluates the fabrication of building materials and the energy used by the building machinery. This phase also includes the transport of the raw materials from the factory to the building site and also the internal waste management with the transport of the wastes generated at the building site to their final destination.

Use includes the operation and maintenance activities.

Operation covers the full service life for HVAC: Heating, Ventilation and Air Conditioning, and other activities such as illumination, domestic hot water (DHW), electrical appliances and cooking.

Maintenance and refurbishment has been calculated including activities such as repainting, PVC siding, kitchen and bathroom cabinet replacement, re-roofing and changing windows. This phase includes also the transport.

End-of-life evaluates the energy consumed by the machinery used during the demolition; and also considers the amount of wastes generated during the dismantling of the original construction materials, including their transport to the final treatment waste.

Three scenarios: landfilling, recycling and incineration, representing the possible options of waste management have been considered.

Landfilling includes the dump infrastructure, the use of land and the effect of the landfilled waste (leachate). Construction wastes that are to be landfilled are special wastes disposed of in underground deposits or controlled landfills, inert wastes are disposed of in inert material landfills and non-special wastes are disposed of in landfills or sanitary landfills.

Recycling takes into account the plant infrastructure, recycling process, and products obtained and wastes generated. This scenario considers the sorting and recycling processes and their transport and, the material saved as a result of recycling. In this scenario all recyclable wastes are sent to a recycling plant, non-recyclable wastes are sent to an incineration plant and non-recyclable or non-incinerable wastes are sent to landfill. This scenario gives positive and negative values. Positive values mean emissions to the environment whereas negative values represent a benefit corresponding to the fact that these recovered materials would actually displace virgin materials.

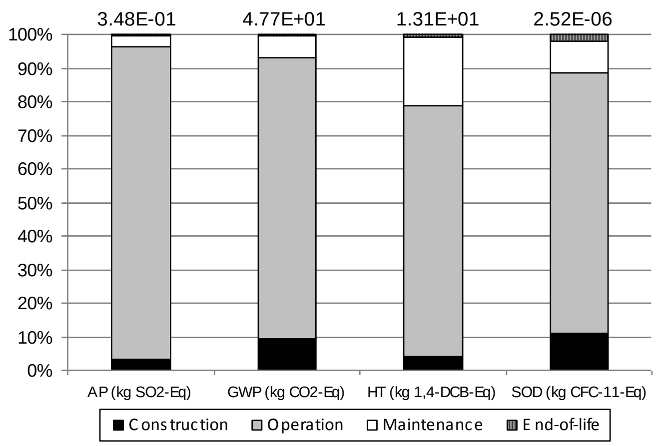
Incineration covers the plant infrastructure, the incineration process, the electricity generated and the disposal of ashes. Electrical energy recovery (calculated from calorific value data) and the amount of residual ashes (which are disposed by landfill) are also considered. Besides, this scenario includes the additional process of transporting the slag and residues of the incineration process to landfill. Incineration generates significant power and thermal energy because of the high calorific value of the construction materials wastes, thus placing the incineration process in credit in terms of its environmental impact. Here negative values represent a credit obtained from the power and thermal energy recovery generated by burning the highly calorific construction material wastes. In this scenario, incinerable wastes are disposed of at an incineration plant and non-incinerable wastes are disposed of in landfill.

3. RESULTS

3.1 **Sustainability assessment results for the application of the Mediterranean home.**

Figure 1 shows how the life cycle environmental impact is distributed over four categories: acidification potential (AP), global warming potential (GWP), human toxicity (HT) and stratospheric ozone depletion (SOD). As can be seen in the figure 1, the time phase with the highest environmental impact is the operation phase; approximately 77-93% of the life cycle's total, except for the human toxicity impact, of which the operation accounts for approximately 75% and the maintenance and refurbishing activities contributed up to 20%. Regarding the environmental issue of SOD, there was a total emission of 2.52E-06 kg CFC-11-Eq m^{-2} y^{-1} during the 50 years occupation, of which about 11% was during the construction phase (external and internal walls represented 54%) and the use phase accounts for 87% and 2% was during the end-of-life due to the construction waste of stone with 97% (concrete 61%, brick 32%, and roof tile and ceramic tiles 7%) of the total stone waste.

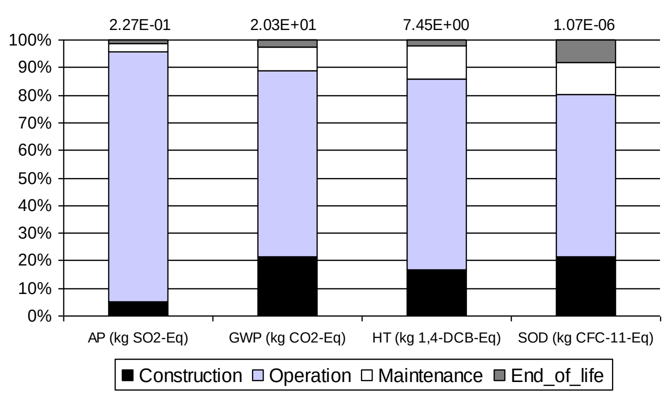
Figure 1: Environmental impacts distribution during the Mediterranean full building life cycle.



3.2 Sustainability assessment results for the application of the Colombian home.

The highest environmental impacts during the Colombian dwelling's life cycle took place during the use, while construction was about 9-31%, transportation and maintenance combined only account for less than 10% of the life cycle impacts. Figure 2 shows the environmental impact results presented for the dwelling life cycle studied.

Figure 2: Environmental impact results during the full building life cycle (Colombian home).



3.3 General results

Data availability: The process of obtaining data in Colombia was a laborious one due to the lack and widely dispersed of the data, therefore it was necessary to draw up estimates, while the development of data collection in a developed country (Spain) was straight forward process because of the national database available.

Building materials: the present work has shown that the combination of building materials can lead to reduced environmental impacts. There is a widespread desire to reduce CO_2 emissions, therefore decisions need to be made with rigorous and appropriate environmental goals set out by the government. This work evaluated and analyzed adverse environmental impacts during the construction, use and end-of-life phases. LCA has been used in decision-making when applying the environmental management principle of "choose it right first" without compromising the quality of a construction project. Hence, this allowed us to see and evaluate environmental burdens based on combinations of different building materials. The adequate combination of energy supplies leads to reduced environmental impacts. The use of efficient energies such as natural gas clearly reduces the environmental impacts during the operation phase. Regarding electrical appliances, the most recent methodologies which incorporate information about environmental aspects, embodied energy and efficiency are necessary for minimizing environmental impacts. Decision-making regarding any environmental impact depends on global and local environmental quality goals and also on environmental threats identified in research and development by governments. Governments need to apply policies and construction codes that lead to improved quality of life for citizens because these same citizens want assurances that an investment in a dwelling will pay for itself over an acceptable time period. In other words, cost is an important issue for the market in facilitating the best economic and ecological value for society, customers and users.

Energy: the origin of the energy source used in each Country plays an important role to minimize adverse environmental impacts, as was demonstrated by the environmental impacts of its use in Colombia where 78% of the electricity came from hydroelectric plants whereas in Spain it is more mixed, 50% coming from fossil fuel combustion. Then, there is a widespread necessity to preserve the environment from the use of fossil fuels (oil and coal) and also to promote the use of renewable energies. Nevertheless, even electricity usage data was based on modelling, data was checked with electricity bills and results it can be concluded that it is not understand that in Colombia where electricity is generated from hydroelectric and there is a charge of € 0.086 cents per kilowatt-hour, when in Spain the cost is € 0.1125 cents per kilowatt-hour and in some Latin American regions such as Venezuela, Ecuador, Peru and Brazil the energy is cheaper than in Colombia and thus Colombia lose competitiveness of green markets.

Waste: In Spain, the waste management phase represents less than 1% of the environmental impact of the total full building life cycle. However, when building wastes are not recycled the amount of waste generated at the building site is higher than urban waste generated by other means. Therefore, architects, contractors, designers and engineers should be proactive and consider sustainability criteria that help decision making at the planning and design stage that allows decisions to be made at the draft stage on the choice of materials and constructive solutions according to techniques during the construction phase. In the incineration scenario attention should mainly focus on plastic and insulation materials because they emit toxic compounds. Paper and cardboard are materials that provide power and thermal energy recovery due to their high calorific value. Recycling plastic and cardboard is important because it reduces the amount of raw materials that have to be sourced. Meanwhile, in Colombia there is a urgent need to foster techniques such as recycling, reusing and recovering materials for optimum waste disposal.

4. CONCLUSIONS AND FUTURE RESEARCH

Life Cycle Assessment was applied to the whole construction process, thus making it possible to improve the sustainability of buildings. For example, a proper design and choice of building materials during the construction phase can improve the energy efficiency during the use phase and the final distribution of buildings' consumption for heating and cooling. Also applying strategies during the operation phase, such as making changes in consumption patterns, would improve consumption for illumination and household equipment in terms of energy and environmental considerations.

Future research will analyze whether the practical LCA guidelines used in the construction industry for single buildings in Spain, strong depending on climate conditions, can be applied in tropical areas. Social and economic indicators the two other parts of sustainability will be considered more in detail because of their major and particular role in developing countries. This is expect to use an optimization model (based on a friendly environment software) that considers variables like thickness of walls, type of window, type of insulation material etc, in order to optimize a model to the correct conditions determined by variables like temperature, direction and wind speed.

Acknowledgments

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REFERENCES

1. European Commission (2006): Construction unit of the European Commission: overview. Information available on line at: http://ec.europa.eu/enterprise/construction/index_en.htm accessed 2006-07-18

2. The building and construction sector: moving towards sustainability. Sustainable Building and Construction Forum: Information available on line at:http://www.uneptie.org/media/review/vol26no2-3/005-098.pdf accessed 2009-04-15.

3. CICA - Confederation of International Contractors' Associations- (2002): Industry as a partner for sustainable development: Construction. ISBN 92-807-2181-X.

4. Ortiz O et al. (2009): Sustainability based on LCM of residential dwellings: A case study in Catalonia. Spain. Building and Environment. Volume 44. Issue 3. March. pages 584 – 594

5. Ortiz O, Francesc C, Sonnemann G (2009): Operational energy in the life cycle of residential dwellings: the experience of Spain and Colombia. Applied Energy. Volume 87, Issue 2, February 2010, Pages 673-680.

Strategies to minimize environmental impact in the construction of an educational building in Catalonia, Spain.

Contreras-Carrillo Juan[1] *, Avellaneda Jaume[1], González Josep-Mª [1], Puyo Joan[1].
[1] Architectural Constructions Department, Universitat Politècnica de Catalunya (UPC),
Av. Diagonal, 649, 7ª planta, 08028, Barcelona, Spain.
***Corresponding autor phone: (+34)633445569; email: juan.carlos.contreras@estudiant.upc.edu**

Abstract

The environmental impact of buildings occurs during all stages of life: from design to demolition, through construction, use and renewal. These impacts resulting from the construction and operation of buildings include emissions of greenhouse gases and other atmospheric emissions.
The aim of this study is to analyze the environmental impact caused by construction materials of an educational building and propose strategies to minimize impact. The indicators to measure are the energy and CO2 emissions.
Once the different structural systems and materials of the building were defined, were made calculations of CO2 emissions, the amount of embodied energy and weight of materials used in construction. Results: After obtaining the results of the current scenario, we proposed modifications and substitutions in the use of some materials used in order to achieve quantitative reductions with lower levels of impact. Three evaluation scenarios were defined. The proposed improvements, despite the low impact of the existing building systems, impacted significantly on reducing emissions and reducing energy by 33% and 44% respectively to replace standard metal recycled metal.

Keywords: LCA, global warming, greenhouse emissions.

Introduction

In the present day, the construction sector´s product is the building itself-a product constituted by organization of a great variety of materials, that, at the same time, are also the product of a diverse set of industrial activities.
Construction inherently consumes the land upon which is located. A consumption that is characterized by the great length of time the construction is in place, the demand for the necessary infrastructure to provide it, and its physical and economical irreversibility that makes it practically impossible to recuperate.(1)
Building plays an important role in consumption of energy (2). As the world's population grows, increasing demand for new buildings in cities. The building is a priority area for reducing energy consumption for the European Union, as it accounts for 40% of total consumption (3).
Building materials requirements grow in that same measure. In the paradigm of sustainability these materials have to produce minor environmental impact because all processes of extraction, transformation, marketing and placement in work to build buildings have an impact. This impact can be read through indicators such as energy and CO_2 emissions (4).
The success of the practice of green building is accentuated with aspects of sustainability also in the planning and design stages. Therefore apply these practices and tools can represent significant savings during construction and operation of projects (5).

The aim of this study is to analyze the environmental impact caused by construction materials of an educational building and propose strategies to minimize impact. The indicators to measure are the energy and CO2 emissions.

Methodology

System study

The study applies to a class type with a surface of 69.1 m km² of a nursery school and primary (CEIP), located in Catalonia, Spain. It is characterized by being built with a system of light industrialization with integrated modules. This constructive system is summarized below in the following denominations: Structure, Facade, Divisions and Details. (See Figure 1).

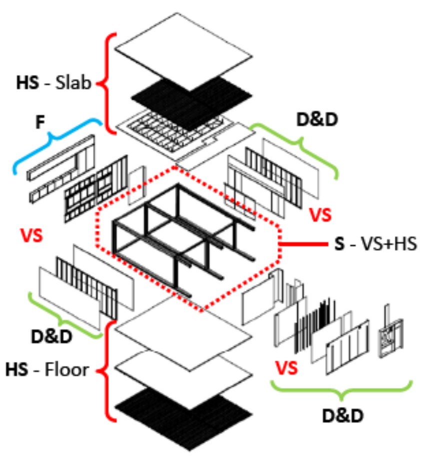


Figure 1. View exploded of study system.

Structure (S): It is divided into Horizontal Structure (HS) composed of two elements, the cover (galvanized steel, concrete, acoustic ceiling) and floor (galvanized steel, concrete, coated) and vertical structure consisting of metal structures.
Facade (F): This consists of a metal structure, insulation, plasterboard, melamine, multiperforated sheet of galvanized steel and aluminum frames.
Divisions and Details (D & D): They consist of metal, insulation, drywall, melamine and aluminum frames.

Tools and environment indicators

Life Cycle Assessment (LCA) is tool used for the quantitative assessment of a material used, energy flows and environment impacts of products. LCA is a technique for assessing various aspects associated with development of a product and its potential impact throughout a product´s life from raw material acquisition, processing, manufacturing, use and finally its disposal (6).
For this study worked only with respect to the characterization of Global Warming Potential (GWP), which analyzes the environmental impacts along the life cycle of materials through the consumption of energy, expressed in megajoules (MJ) or equivalent kilo Watt hour (kWh) and CO2 emissions measured in kg CO2 equivalent. Weight (kg) of material was also taken into account in the quantifications.

Procedure

The calculations were based on the quantities of materials used. Calculations do not include materials relating to hydraulic and sanitary facilities. For environmental impact data was used as a reference the Metabase of the Institute of Construction Technology of Catalonia (ITEC), BEDEC PR / PCT (7,8)

Table 1. Presents a summary of materials date used.

GROUP	MATERIAL	DENSITY	ENERGY	EMISSIONS
ORGANIC	PANEL DM	725 Kg/m^3	13,5 MJ/Kg	0 g CO_2/Kg
	PINEWOOD	450 Kg/m^3	1,3 MJ/Kg	0 g CO_2/Kg
PETROUS	PRECAST CONCRETE	2,340 Kg/m^3	0,66 MJ/Kg	107g CO_2/Kg
	CEMENT MORTAR	1,900 Kg/m^3	1,13 MJ/Kg	204 g CO_2/Kg
	PLASTER	1,300 Kg/m^3	1,13 MJ/Kg	136 g CO_2/Kg
	PLASTERBOARD	850 Kg/m^3	3,12 MJ/Kg	176,5 g CO_2/Kg
	ROCKWOOL	70 Kg/m^3	14 MJ/Kg	80 g CO_2/Kg
	GLASS	2,490 Kg/m3	8 MJ/Kg	569 g CO_2/Kg
METALS	STANDARD STEEL	7,850 Kg/m^3	24 MJ/Kg	1,700 g CO_2/Kg
	RECYCLED STEEL (85%)	7,850 Kg/m^3	11 MJ/Kg	930 g CO_2/Kg
	PERFORATED STEEL PLATE	7,850 Kg/m^3	24 MJ/Kg	1,700 g CO_2/Kg
	GALVANIZED SHEET	7,850 Kg/m^3	24 MJ/Kg	1,700 g CO_2/Kg
	STANDARD ALUMINUM	2,700 Kg/m^3	271 MJ/Kg	22,000 g CO_2/Kg
	RECYCLED ALUMINUM (50%)	2,700 Kg/m^3	182 MJ/Kg	14,000 g CO_2/Kg
SYNTHETIC MATERIALS	EXPANDED POLYSTYRENE	15 Kg/m^3	115 MJ/Kg	468 g CO_2/Kg
	EXTRUDED POLYSTYRENE	25 Kg/m^3	162 MJ/Kg	840 g CO_2/Kg
	PAINT	¬	27'11 MJ/m^2	4 g CO_2/m^2
	ASPHALT PRIMER	1,100 Kg/m^3	5 MJ/Kg	489 g CO_2/Kg
	ELASTOMERIC BITUMEN	1,100 Kg/m^3	5 MJ/Kg	489 g CO_2/Kg
	POLYESTER GEOTEXTILE	910 Kg/m^3	75 MJ/Kg	1,820 g CO_2/Kg

The results are presented on five stages:

Scenario 1. Current state of the building
Scenario 2. The standard metal is replaced by recycled metal
Scenario 3. Alveolar sheet of concrete is replaced by a prefabricated concrete hollow section.
Scenario 4. The vinyl flooring is replaced by cork flooring.
Scenario 5. Apply the proposed scenarios 2, 3 and 4

Results

Table 2 shows the results of the impact of the system under study in its current condition. The purpose of monitoring trends in these graphs is to identify priority areas of intervention for the planning of strategies to reduce the environmental impact of buildings.

Table 2. Summary of results of scenario 1.

System		Total weight kg	weight/surface kg/m2	Total energy MJ	energy/surface MJ/m2	Total CO2 kgCO2eq	CO2/surface kgCO2eq/m2
S	Horizontal S	19,087.60	280.29	111,709.75	1,640.36	8,346.07	122.56
	Vertical S	690.48	10.14	15,899.83	233.48	1,241.51	18.23
	SLAB	148.64	2.18	13,157.74	193.21	1,951.08	28.65
	SUBTOTAL	19,778.08	290.43	127,609.58	1,873.84	9,587.58	140.79
F	F	2,832.74	41.60	43,510.29	640.67	4,017.24	58.99
	SUBTOTAL	2,981.37	43.78	56,668.03	833.88	5,968.32	87.64
D&D	Solid vertical	2,353.55	34.56	48,745.93	715.80	6,636.58	97.45
	Vertical gap	111.86	1.64	976.43	14.34	78.18	1.15
	Horizontal	1,173.09	17.23	25,530.04	374.89	1,983.19	29.12
	SUBTOTAL	3,638.50	53.43	75,252.40	1,105.03	8,697.94	127.72
	TOTAL	26,397.96	387.64	259,530.01	3,812.74	24,253.84	356.15

The structure accounts for 75% of the total weight of the building, 39% of emissions and 49% of the embodied energy.

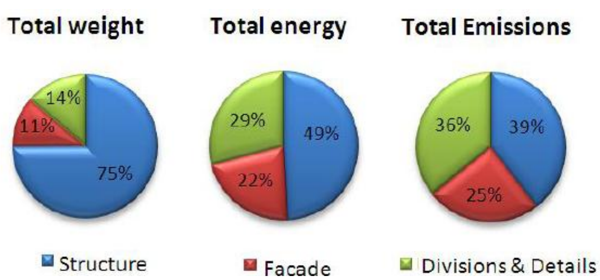


Figure 2. Summary of percents scenario 1.

Table 3 presents a summary of results of study. Scenario 5 has greater weight reduction, energy and emissions.

Table 3. Summary of results all scenarios.

Scenario	Weight kg/m2	Energy MJ/m2	Emissions kgCO2eq/m2
Scenario 1	387.64	3,812.74	356.15
Scenario 2	387.64	2,879.61	290.94
Scenario 3	344.68	3,200.53	310.54
Scenario 4	385.32	3,555.04	334.53
Scenario 5	342.36	2,149.44	238.4

The results of the scenarios proposed to minimize the environmental impact of the current scenario are presented in Figure 3.

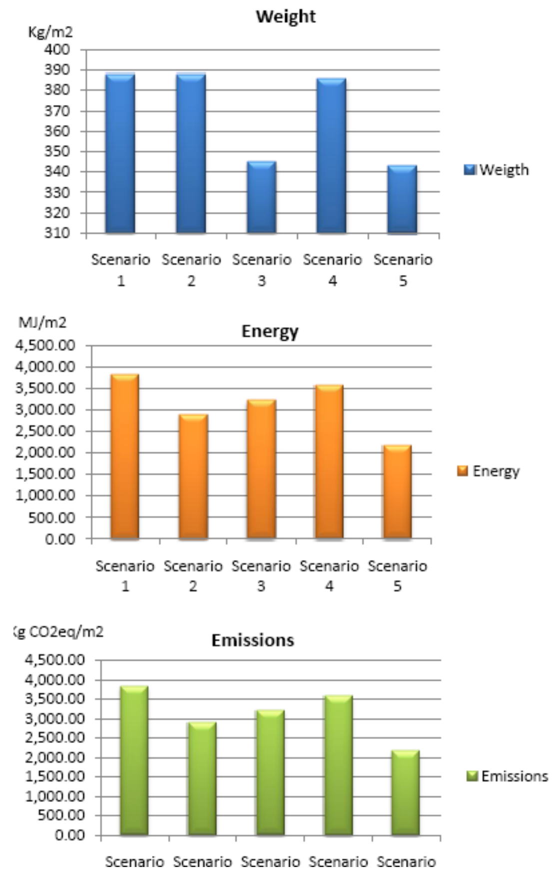


Figure 3. Summary of scenarios proposed.

The greatest reduction in impact was obtained by replacing the standard metal for recycled metal. However with the 3 proposals as a whole is able to reduce energy by 44% and emissions by 33%.

Conclusions

The present study demonstrates that there are significant environmental impact differences in materials and construction techniques of buildings.

The study also demonstrates the efficiency of the LCA tool to implement in stages prior to making decisions about construction materials are concerned.

Although the materials were current and low environmental impact, we obtained a significant reduction in the proposed scenarios.

The materials of greatest impact are the metal. The used in large quantities are produced huge impacts on energy and emissions

References

1.Cuchí A, Wadel G, Rivas P. 2010. Cambio global España 2020/2050. Sector edificación. 01: 45-50

2.Aashish Sharma, Venu Shree. 2010. Life cycle assessment of building. Renewable and Sustainable Energy Reviews. 15: 871-875

3. European Parliament and Council 2010. DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast).

4. Adalbert K. 2001. Life cycle assessment of four multifamily building. International Journal of Low Energy and Sustainable Buildings

5. NIEVA, A.B. y POZO, A.V. (2005). **Guía de construcción sostenible.** Edición: Instituto Sindical de Trabajo, Ambiente y Salud (ISTAS). Ministerio de Medio Ambiente. Madrid, España.

6. ISO, ISO 14040. 1999. Environmental management – life cycle assessment- principles and framework. International Organisation for Standardization

7.ITeC: “Parámetros de sostenibilidad”, p. 96, *Línea del Medio Ambiente y la Construcción*, Barcelona,
2003.

8. Instituto de Tecnología de la Construcción de Cataluña. Disponible en: www.itec.es

Energy and Mining

CILCA 2011
MÉXICO

LCA Biomass Residues Energy Generation
Brazil

Life Cycle Analysis in the selection of energetic sources for isolated communities
Cuba

Production process Life Cycle Analysis (LCA) of the low-density polyethylene (PEBD) in Pemex Petroquimica Cangrejera Complex
Mexico

Life Cycle Inventory of Hydropower Plant of Tucurui
Brazil

Life Cycle Assessment of Petrochemical Industry in Mexico to identify improvement opportunities at the energy efficiency
Mexico

Characterization factors for freshwater ecotoxicity as a decision support tool for the environmental improvement and sanitation of rivers in Mexico
Mexico

Life Cycle Inventory of Electricity Generation in Chile
Chile

LCA for Redesign of Public Luminaires
Brazil

Life Cycle Assessment of two potential energy production systems in degraded soils on the Coast of Hermosillo, Sonora
Mexico

Life Cycle Assessment of Potential Environmental Impacts of the Brazilian Energy Plan - 2030 Brazil

LCA of Biomass Residues for Energy Generation in Brazil

ABSTRACT

Brazil is a great agricultural producer of sugarcane, rice, cassava and soy, to which are associated a proportional amount of residues, namely it is forecasted that Brazil can produce about 451 million agro-industrial residues and that the energy content of this biomass is about 195.2 million GJ/year. This study aims at assessing the environmental impact throughout the life cycle of energy production based on the gasification of biomass residues. Recent studies demonstrate that gasification is the most suitable technological system for processing polidisperse biomass of small dimensions, from sugarcane bagasse and rice peel. The results demonstrate that the potential use of biomass residues energy content presents economic and environmental benefits, through the aggregation of value to such residues and the minimization of the associated impacts.

Topic: LCA: Inventory and Impact Assessment

Keywords: LCI, Sugarcane Waste, Energy, Gasification

1 - Introduction

Brazil is a great agricultural producer of sugarcane, rice, cassava and soy, to which are associated a proportional amount of residues. Beyond lumber and forest residues, these agricultural residues can be used to produce energy through the existing technologies. However, Brazil uses less then half of these residues, specifically are not used more than 200 million tons of agro-industrial residues [1].

In a context of an increasing of many agricultural cultures production, it is forecasted that Brazil can produce about 451 million agro-industrial residues [3], as presented in Figure 1.

The energy content of this biomass is about 195.2 million GJ/year, that could be added to the already established use of sugarcane bagasse for energy supply. This energy can be used for drying these grains, currently supplied by fuel oil. Moreover, Brazil has also the capacity to substitute fuel oil in the farming sector, in the industries of foods and drinks, ceramics and textile [3] and [5].

This study aims at assessing the environmental impact throughout the life cycle of energy production based on the gasification of biomass residues. Gasification is the most suitable technological system for processing polidisperse biomass of small dimensions, from sugarcane bagasse and rice peel [1]. The study compares the production of electricity in diesel engines using as fuel the biomass residues gasification gaseous products, and the results are compared with the usual electricity supply by the Brazilian grid at the agricultural sites.

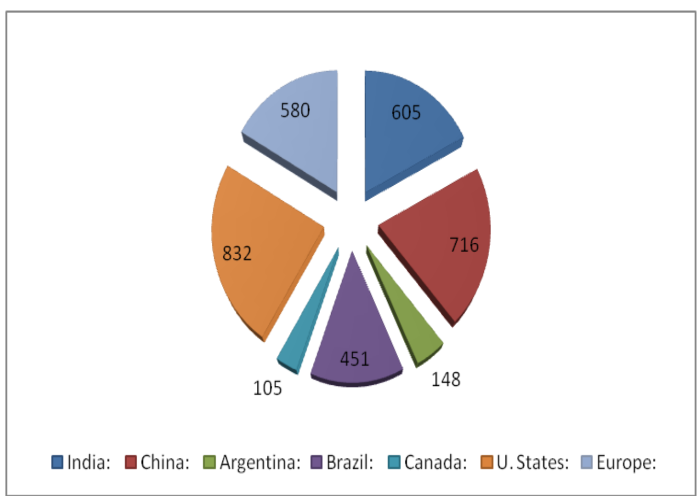


Figure 1 – Technical Potential of Brazilian Agro Waste (Millions of tons) (adapted from [2]).

2 - Discussion

Currently gasification is one of the most used technologies for the transformation of the residual biomass in energy. Biomass gasification is a thermal treatment, where the solid biomass is transformed mainly into a high ratio of gaseous products and small amounts of solid products. Solid biomass suffers thermal decomposition in the temperature range of 873K to 1273K, to form a gaseous phase normally including H_2, CO, Co_2, CH_4, H_2O, and other gaseous hydrocarbons [4].

The gasification of the recycled biomass brings positive impacts to the environment, in which we can highlight the sequestration of carbon from the atmosphere, bringing a neutral ballance of carbon during the process of production of electric energy, contributing for reduction of the greenhouse effect [7]. The use of the residual biomass for generation of energy brings ambiental benefits for the reduction of use of other not-renewable sources. The use of the biomass as fuel could still add value at the agricultural production, through the commercialization of the residues or of exploitation of this energy within the agro-industry units .

Using agricultural residues is possible to extend the renewable fraction of the Brazilian energy matrix, and pushing the development of new energy conversion technologies as the gasification[6].

The study uses GaBi4.4, and ELCD database for the characterization of the analyzed technological model. The processes of production of biomass (sugar cane bagasse and wood residues of native forest exploration, respectively Figures 2 and 3) as well as the inventories of production of electric energy and production of diesel, are based on Brazilian data.

Brazil is the biggest ethanol from sugarcane producer, and 85% of its production is located at the Center South region. Therefore, this study is focused at the Sao Paulo state, since it is the biggest national producer, which results roughly 78millions tons of bagasse during 2007/2008 crop. [1], [5]

This bagasse stands for 30% of the energetic content of the sugarcane [6]. Gasification of the bagasse can be a promising technological path to extract this energy from this biomass waste [7].

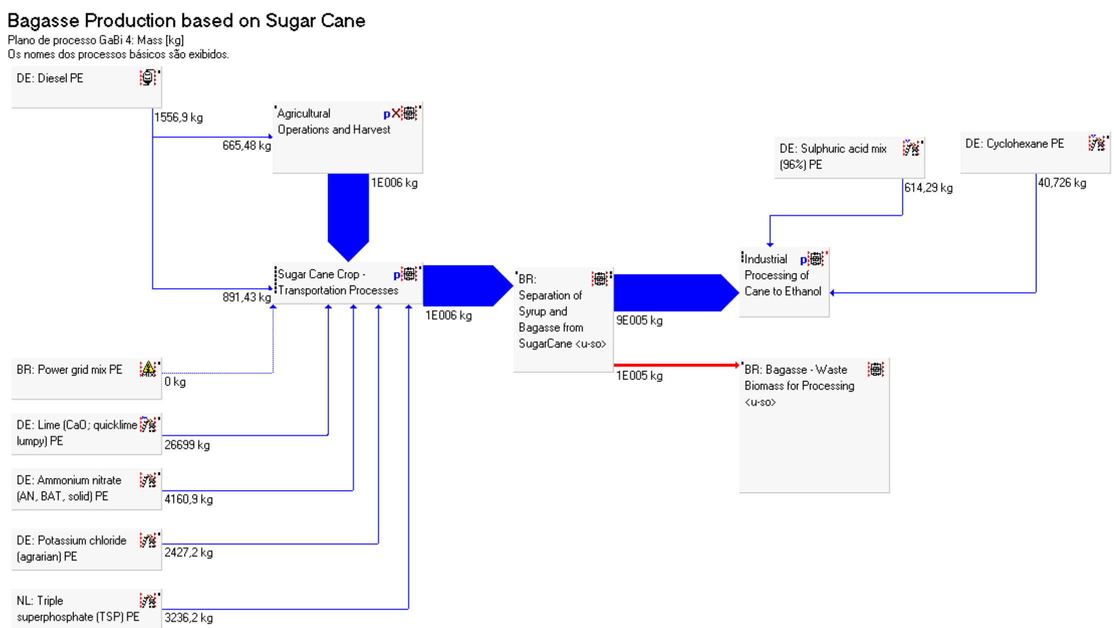


Figure 2 – Fluxograma de processos da produção de carvão vegetal a partir de madeira extraida de floresta nativa (fluxos mássicos) [9]

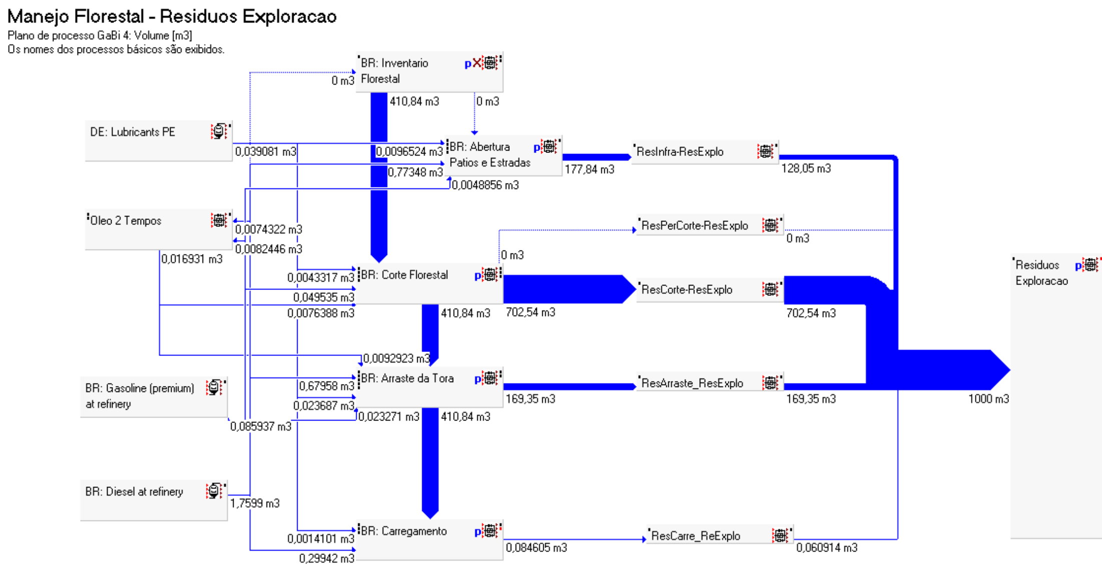


Figure 3 – Fluxograma de processos da produção de carvão vegetal a partir de madeira extraida de floresta nativa (fluxos mássicos) [9]

The results demonstrate that the potential use of biomass residues energy content presents economic and environmental benefits, through the aggregation of value to such residues and the minimization of the associated impacts. At the same time, the activity of collection of agricultural residues can be intensive in man power, with a relevant social impact.

References

1. CORTEZ, L.A.B., *et al.* 2008. Biomassa para energia. Campinas (SP), Brasil: Unicamp. p 19 e 254.

2. BENSTSEN, N. S., FEBLY,C. 2010. Technical potentials of biomass for energy services from current agriculture and forestry in selected countries in Europe, The Americas and Asia. Forest & Landscape Working Papers No. Forest & Landscape Denmark, Frederiksberg. p 9.

3. COELHO, S.T. 2002. Capacity of the Electricity Sector in Brazil and Global Change (In Portuguese). Brazilian Agency of Electrical Energy-ANEEL. Brasília (DF), Brasil.

4. BALAT,M. 2009. Energy Sources Part A-recovery Utilization and Environmental Effects. Chemical Engineering Research Information Center .p. 516.

5. UNICA. 2009. Report on the sugar cane and ethanol production: Center-West and South, 2007/2008 (In Portuguese). São Paulo, Brasil.

6. MAPA. 2008. Report on Sugar Cane Production (In Portuguese). Brazilian Ministry of Agriculture and Supply. Brasil.

7. HASSUANI, S. J., et al .2005. Biomass power generation sugar cane bagasse and trash. Piracicaba PNUD-CTC .Brasil. p.216.

8. GREENPECE. 2004. Positive Energy to Brazil. Generation potential of renewable energy from crops waste (In Portuguese). www.greenpeace.org.br. Access on December 5th 2010.

9. KINTO, O. T. 2002. Biomass enegy from gasification as clean energy supplier (In Portuguese). Scielo.

8. MENDONÇA, R.M. 2007. Carbon Life Cycle Assessment on Soybean oil-based Biodiesel Utilization (In Portuguese). Master Dissertation, Dept. of Mechanical Eng., University of Brasilia.

9. CALDEIRA-PIRES, A., ROUSSET, P., OLIVEIRA, T. 2010. Bilan Carbone de la Chaine de Production de Charbon de Bois-Composante 3/Project Energie e Reforestation en Amazonie. Agencie Française de Development-AFD, France.

10. SABLOWSKI, A. 2008. Material Balance at the Environmental Management of the Charcoal-based Pig Iron Production Chain in Minas Gerais/Brazil (In Portuguese). Ph.D. Thesis, Dept. of Forestry Eng., University of Brasilia.

Title: Life Cycle Analysis in the selection of energetic sources for isolated communities

Author(s) Rosa Domínguez Elena [1] ; Castro Fernandez C. Miguel [2] ; Garzón Soria Carlos Pablo [3] ;Ortíz Clavijo Darwin [3] , Martínez Nodal Pastora de la C. [1],Contrras Moya Ana M.

1 Centro de Estudio de Química Aplicada (CEQA). Facultad de Química - Farmacia. Universidad Central "Marta Abreu" de Las Villas. Cuba Carretera a Camajuní Km. 5. Santa Clara. Cuba. CP: 54830.

2 Centro de Investigaciones y Pruebas Electroenergéticas (CIPEL), Calle 114 No.11901 entre 119 y 127, CUJAE, Marianao 15, CP 19390, Ciudad de la Habana, Cuba.

3 Universidad de Cotopaxi, Ecuador.

E-mail contact: : erosa@uclv.edu.cu

Abstract

The distributed generation (DG) is the electric power generation, to small and medium scale, located the nearest to the load center, with the option of being interconnected with the network for the purchase effects or sale; this scheme allows to take place and to management the energy in the same consumption place. Some productive and service companies and facilities of very high importance, as the hospitals, they use their own systems of electric generation to avoid possible blackouts of the network.

Usually many of these installations use polluting energies as the natural gas or the gasoil to assure electricity, although this type of self-sufficient generation can be based on ecological sources as the biomass, wind, sun or hydrogen.

Usually a technical and economic analysis defines which kind of energy source to use, having in consideration the characteristics of the region from the climatological point of view; normally for this evaluation some software like HIBRID2, HOMER or VIPOR (or at least any preliminary evaluation) is used to do one evaluation of alternative, but they are not kept in mind the environmental aspect. With the increasing environmental operation standards of modern energy conversion systems, the upstream and downstream processes, e.g. fuel supply or power plant and infrastructure production, become increasingly relevant [1] [2].The proposal of this work is carried out this analysis including this aspect, by using Environmental Life Cycle Analysis (LCA) methodology in order to assure this point of view in the final decision that why scheme type or energy source to use for each case.

In the study case it was showed that the best environmental results are obtained when the photovoltaic and wind energy is used.

The wind energy was selected as the best alternative for the community.

Topic: LCA Industrial Application. Energy and mining

Key words: distributed generation, renewable sources, life cycle analysis, environments.

Introduction

Electricity generation in general, is to transform an energy that can be chemical, thermal, mechanical, hydraulic, and solar and wind into electrical energy. In the early years, the electricity industry was characterized by the presence of small generators of electricity generated that used direct current (DC), but as the population was increasing and therefore the big cities, especially in first world countries, it was difficult to transport this current from the center of generation to the place of consumption should be installed so many generating units within cities. The development of systems of alternating current (AC) allowed the development of building more generators capacity and the creation of large generation facilities, and away from load centers, which together with the development of different technologies allowed constructing the power system (EPS) that carry electricity to different points of consumption.

On the other hand today, one of the most difficult problems in the planet is global warming, caused largely by burning fossil fuels like oil and coal, causing emission of toxic gases that affect the environment, in particular altering the atmospheric compositions.

In the world there is a high percentage of people still living in areas where it is difficult to access electricity networks (such as mountain, jungle and others), avoiding thus, be more efficient and competitive in cultural productive and economic issues. In those areas, being far from power grids, has been the need to evaluate alternatives for solving this problem, usually tests are aimed at evaluating different energy sources, including a much wider use of renewable energy sources; these analysis have considered fundamentally technical and economic viewpoint, but without taking into account the environmental issue, or seen this from the point of view more simple: the possible replacement of fossil fuels as energy solution by renewable energy.

Research Methodology

Renewable energy sources have the characteristic of being relatively clean and inexhaustible, but highly dependent on the weather situation in each area for your level of electricity production. Despite these above criteria there is fairly widespread, in fact, any source that is completely clean, because if assessed from the point of view of their life cycle (from birth until death or depletion) all have a certain level of damage to the environment.

To carry out an environmental impact assessment there is no general method, each method refers to specific environmental impacts and none of the methods are fully developed precisely because of the specificity and inability to generalize a particular methodology. The first step in establishing a methodology is to give an idea of the magnitude of impact, with many procedures for environmental impact studies on the environment or any of its factors, the following may be general and other specific or concrete, some qualitative and some operate with large databases and tools more or less sophisticated calculations.

Future development will enable a further reduction of environmental impacts of renewable energy systems. Different factors are responsible for this development, such as progress with respect to technical parameters of energy converters, in particular, improved efficiency; emissions characteristics; increased lifetime, etc.; advances with regard to the production process of energy converters and fuels; and advances with regard to 'external' services originating from conventional energy and transport systems, for instance, improved electricity or process heat supply for system production and ecologically optimized transport systems for fuel transportation. [3]

A tool which allows evaluating this aspect in a way perhaps more complete can be found in the life cycle analysis (LCA).[4] LCA studies the environmental aspects and potential impacts throughout the product life (ie cradle to grave) from raw material acquisition through production, use and disposal. The general categories of environmental issues that require consideration include resource use, human health and ecological consequences.

Results and discussion

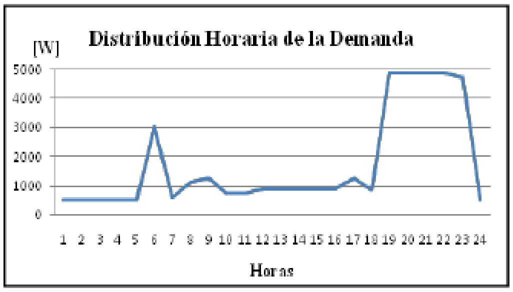
The application of LCA in this study covers only the electricity generation e excluding the construction, infrastructure, transport and distribution phase and for a given community consisting of 30 houses, the equipment present in the community and consumption of electricity demand, were inventoried and obtained the daily electricity demand. Different energy sources that include the use of renewable energy (wind and sun) and non-renewable (diesel) were considered take into account generation schemes with a single source or hybrid schemes (two or more sources of energy).

The first step, before applying the LCA, is to make the design of selected energy systems, as a support tool for this purpose (from the simulation systems) software HOMER is used, the HOMER was developed by the National Renewable Energy Laboratory of the U.S. (NREL) and is a tool that gives users a powerful environment with many variables to get a detailed system analysis as well as allowing simultaneously perform different simulations to compare the result of the different configurations and sizing of components [5].

Demand and energy consumption represent usually needs to satisfy in cases where a solution is sought appropriate energy to the user, is therefore necessary to know the details and characteristics of energy demand in order to provide a solution satisfactory. Figure 2 shows the time distribution of that demand in the community under study.

Figure 2. Hourly distribution of electricity

demand in the community under study.



Based on these conditions is made the scale of each energy sources. The economic and technical analysis of each variant was made and the result showed that from the viewpoint of the initial investment the alternatives wind and hybrid by using wind + diesel generators are more economical than others. But if the comparison is a 20-year horizon, the results vary widely, being the most economical hybrid systems wind + diesel generators and photovoltaic + wind. See table 1

Table 1 Economic Analysis of electricity generation by using different sources

Alternative	Investment cost	Production cost
Photovoltaic (FV)	153 429.14	46 132.64
Emergency generators (EG)	129 048.27	55 275.03
Wind (W)	87 549.70	54 469.48
FV+EG	186 840.92	32 984.24
FV +W	179 300.88	39 730.00
EG +W	80 343.27	24 145.91
FV+W+EG	185 148.00	43 801.25

The functional unit was the production of 41.48 MW-h for all alternatives to generate electricity, can this be changed according to the purpose of study.

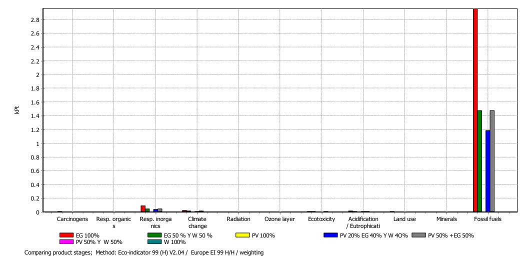
Since inventory is the most complex stage , it was obtained values with highest quality of inputs and outputs for all variants (from actual measurements), which were obtained from the databases of the Wind Energy Association, the Emergency Management Group, both of the UNE, and the company ECOSOL POWER COPEXTEL.

Impact assessment

The impact assessment is carried out with the aid of the software SimaPro 7.2, developed by Pré Consultants. The methodology used was the Eco indicator 99.

The Figure 3 shows the impacts categories of electricity generation of all energetic sources considered in the study. The alternatives where the emergency generator is used have relevant impact in fossil fuel category being considerably major when the emergency generator is used alone.

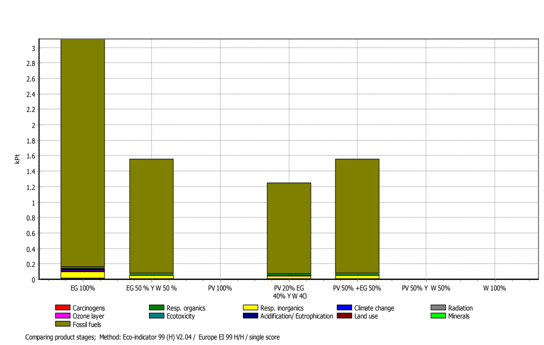
Figure 2. Environmental profile of alternatives



In the assessment of these technologies has a key role diesel consumption, also affects other categories with less significant value such as carcinogenesis, the breath of inorganic and climate change, mainly due to emissions of gases into the atmosphere from the combustion of diesel used in electricity generation. The use of photovoltaic system and the combination with others sources have influence in land use category, however the photovoltaic sources don't have impact considerable in any impact categories.

In figure 3 the total score of different alternatives is showed for the function unit.

Figure 3 Total score of electricity generation alternatives.



The mayor impact is obtained when the electricity is generated with emergency generator and in all alternative where it is used the total impact is appreciable, being less when the tree sources are combined.

For this reason the alternative selected was the wind electricity considering economic and environmental issues.

Conclusions

The combination of economic and environmental impact by using Life Cycle Assessment allow to select the best alternative for generating electricity in the communities isolated from the system.

It is necessary to improve the inventories for system generator with the incorporation of infrastructure data.

Acknowledgements

The authors wish to be thankful to the directions of Eolic energy and emergency generation of the Electrical Union, as well as to company ECOSOL Energy, the data contributed for the conformation of the inventory, thus they can thank for to the sponsors and other collaborators.

References

[1] Pehnt M. (2003) Assessing future energy and transport systems: the case of fuel cells. Part 1: methodological aspects.Int J LCA;6:283–9.

[2] PehntM. (2003) Assessing future energy and transport systems: the case of fuel cells. Part 2: environmental performance. Int J LCA;6:365–78.

[3] Pehnt M. (2006) Dynamic life cycle assessment (LCA) of renewable energy technologies Energy 31 (2006) 55–71

[4]. NC ISO 14 044.2009. Gestión Ambiental. Análisis del Ciclo de Vida. Requisitos y directrices.

[5].http://www.monografias.com/trabajos/ener giasalter/energ iasalter.shtml, Febrero de 2010.

Production process Life Cycle Analysis (LCA) of the low-density polyethylene (PEBD) in Pemex Petroquimica Cangrejera Complex.

Candelario Mario[1]; Morales Miguel[2] and Herrera Gloria[3]

[1, 2,3] Pemex Petroquimica, Jacarandas 100, Colonia Rancho Alegre I, Coatzacoalcos, Veracruz 96558, Mexico
mario.miguel.candelario@pemex.com

Topic: LCA Industrial applications Petroleum - Petrochemical
Keywords: LDPE, LCA, Pemex Petroquimica.

ABSTRACT

Introduction

Estimated use of Low Density Polyethylene in Mexico in 2007 and 2008 was approximately 480,000 tons and 450,000 tons, respectively. 70% on average is imported from Exxon, Dow, Equistar and Chevron. The trends indicate that in the USA and Europe have no substantial consumption increases because do not exceed 15% per annum; unlike the regions of India, Asia and South America that have much higher consumption up to 500% [2].

Pemex Petroquimica as leader in Mexico recognizes the risks that currently exist in the market of plastics; from environmental trends. Mexico issued prospect of environmental legislation that is stricter regarding the use of plastics in some applications as the polyethylene bags. Currently, there have been initiatives to generate environmental regulations aimed at the prohibition of giving and using bags not biodegradable material in self-service stores. Some of these have been stricter, that also proposes penalties and even arrest for those who violate this provision. There are also proposals to establish a program of substitution of plastics.

This work is part of the measures taken by Pemex Petroquimica as a producer of Low Density Polyethylene (PEBD) for the assessment of environmental impacts of their products, with a focus on life cycle assessment, which might be useful to undertake actions for minimization of impacts to help maintain its competitiveness and presence in the market.

Methods

Process description
The low density polyethylene (PEBD) produced in the Cangrejera Petrochemical Complex, is raw material for numerous clients in the production of plastic bags and other products. Low density polyethylene plant was licensed by I.C.I. (Imperial Chemical Industries), detailed engineering in charge of the company Sin-Chem (Union Carves Ltd.) with three trains of production with capacity of 240,000 tons/year. Operation begins between 1984 and 1986. In March 2005 concluded the expansion of the plant with a total capacity of 315,000 tons/year.

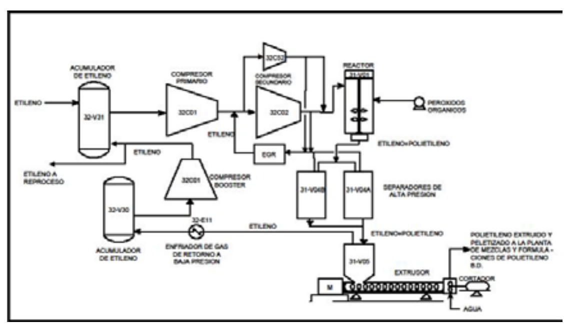


Figure 1 – Simplified process diagram of PEBD Plant.

The process is basically four stages: Step 1. Preparation - ethylene gas is compressed from 18.0 kg/cm^2 up to approximately 1300 kg/cm^2. Step 2. Chemical reaction - is carried out the reaction of polymerization of ethylene under high pressure in a vertical reactor equipped with agitation, by adding organic peroxide. Step 3. Ethylene - polyethylene separation - ethylene remnant is separated of polyethylene product. It also separates light polymer. Recovered ethylene called recirculation ethylene is sent to the suction of the secondary compressor; and Step 4. Extrusion and cut - the product is extruded, pelletized, and sending to plant mixtures and formulations of low density polyethylene, using a hydraulic system transport to be dried, sorted and packaged (Fig 1).

System limits

LCA methodology was used as a tool for assessing environmental impacts following the provisions of the standards ISO 14040 and ISO 14044 with the following aspects: functional unit: production of 1 ton of PEBD. Purpose and scope: assess impacts and compare the production of 1 ton of PEBD in year 2010 vs. production of 1 ton of LDPE in Europe (average).

The impacts were evaluated quantitatively considering the method of Eco-indicator 99 and ReCiPe Endpoint V1.03; using categories of global impacts: Impacts on health (Health); Impact on the ecosystem quality (Ecosystems) and Impacts on resources consumption (Resources). In this work was established as system limit, only the production of the PEBD process (Fig 2). Activities undertaken as assigned loads, are those relating exclusively to the process of production of low density polyethylene (PEBD); and in particular were considered as avoided products, used oil sent to recycling and steam generated and used in the same plant.

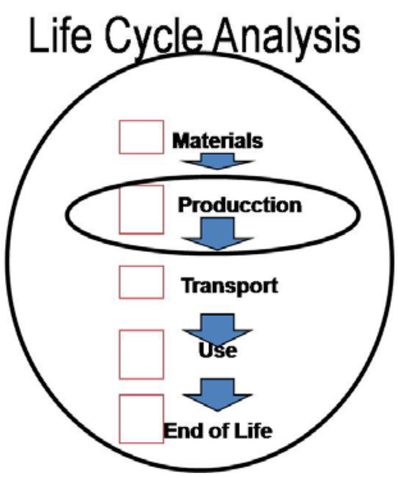


Figure 2 – System Limits for LCA of PEBD.

Inventory used for assessment have a high quality data, because it is feedback directly from the production process, and correspond to low density polyethylene production in the first 4 months of the year 2010 on normal operation of the plant (Fig 3). This is an advantage, because quality of data is usually a limitation of LCA [1]. However, because Pemex petrochemical has no information of the production of some raw materials and inputs, it was necessary to use information on similar processes in which information is available in Europe, using the Ecoinvent database. As a tool for the LCA was used SimaPro Software v 7.1.

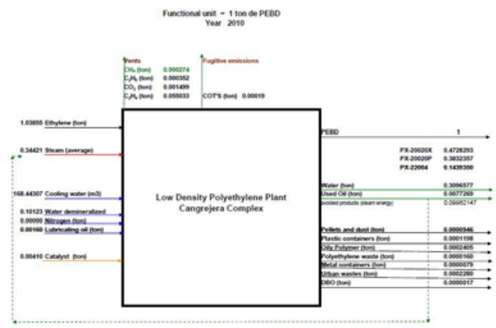


Figure 3 – LCA PEBD production process inventory.

Results and discussion

The results indicate the most important impacts correspond to fossil depletion and climate change mainly as a consequence of using Ethylene as the main raw material and the energy consumption, respectively (Fig 4).

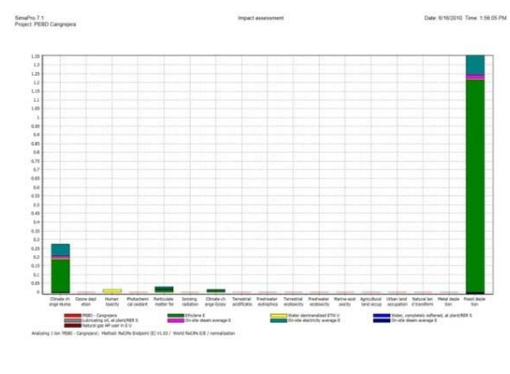


Figure 4 – LCA PEBD Impact assessment.

Obviously those impacts are directly associated to the Resources Category and Human Health (Fig 5)

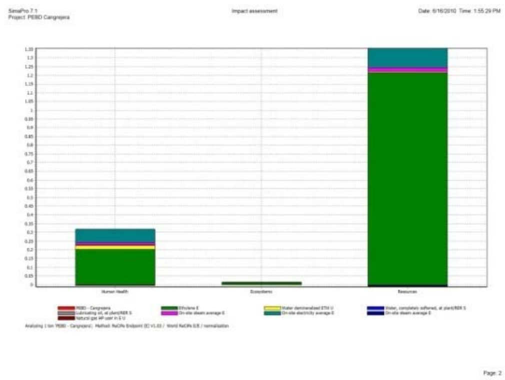


Figure 5 – LCA PEBD assessment per Impact category.

To verify the results, found the global impacts based on single score (Pt) of the process of production of PEBD compared with LDPE Polyethylen-Granulat (average in Europe).

Results by categories of impacts can be seen that the process of Europe has lower impacts on health and quality of ecosystems, and higher on and the consumption of resources (Fig 6).

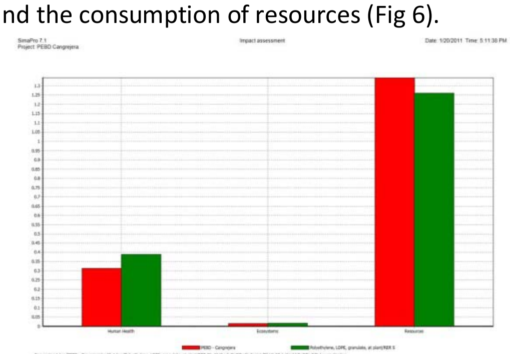


Figure 6 – Comparing Impacts PEBD vs. LDPE* (Europe).

* **Translated name: Polyethylen-Granulat, LDPE, ab Werk Included processes: Aggregated data for all processes from raw material extraction until delivery at plant Remark: Data are from the Eco-profiles of the European plastics industry (APME). Not included are the values reported for: recyclable wastes, amount of air / N2 / O2 consumed, unspecified metal emission to air and to water, mercaptan emission to air, unspecified CFC/HCFC emission to air. The amount of "sulphur (bonded)" is assumed to be included into the amount of raw oil. CAS number: 009002-88-4; Geography: 15 European production sites (A,B,SF,P,NL,S,UK). Technology: polymerization out of ethylene at high pressure and high temperature Time period: time to which data refer. Version: 1.3. Synonyms: LDPE, PE, LD-PE. Energy values: Undefined. Percent representativeness: 47.4. Production volume: 2.3 Mt (1992)**. Source: SimaPro 7.1.

The results show global impacts of the production process of the CPQ. Cangrejera (PEBD) are slightly smaller than the impacts of LDPE (Europe) used for comparing (Fig. 8). From this point of view, the differences are so small that couldn't be considered significant; that means global impacts are similar (Fig. 7).

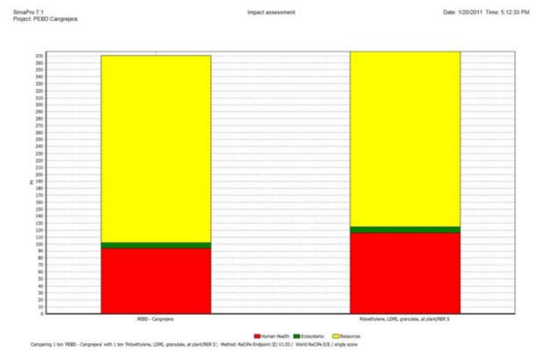


Figure 7 – Comparing Global Impacts PEBD vs. LDPE (Europe).

Regards the emission of greenhouse gasses noted that LDPE production process of the CPQ Cangrejera emissions compared with the corresponding European LDPE are minor, found that emissions to atmosphere measured in ton CO_2e are 2.08 ton/ton against LDPE 2.02 ton/ton of LDPE (Fig.8).

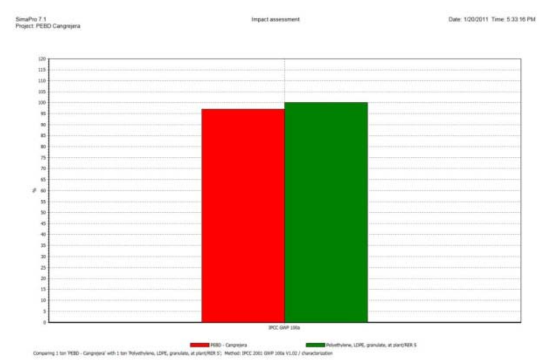


Figure 8 – Comparing CO_2e **emissions PEBD vs. LDPE (Europe).**

Conclusions

The main impacts of the low density polyethylene production process of the CPQ Cangrejera correspond mainly to fossil depletion, because raw (ethylene) and energy used directly from fossil hydrocarbons. This means that actions for the reduction of impacts should focus on the efficiency of the process to reduce raw material consumption and consumption of energy (electric and steam). Derived from the analysis of the impacts resulting from the comparison, estimated differences between production of LDPE and LDPE processes are not significant and can be considered with similar impacts. On emission of greenhouse gases into the air, found that emission to atmosphere measured in ton CO_2e from CPQ Cangrejera is 2.08 ton/ton against 2.02 ton/ton from LDPE, which means a difference of the 2.89% estimated not to be significant; therefore concludes that Pemex petrochemical produce LDPE with emissions of greenhouse effect similar to Europe, processes measured in CO2 equivalent units.

References

1. Chantra T. 2008. Life Cycle Assessment (LCA).Chulalongkorn University. Environmental Research Institute.
2. Pemex Petroquímica.2009. Reporte Técnico 003-2009 – Polímeros Degradables. México. Pemex Petroquímica.
3. Pre Consultants.2009. SimaPro Training - Effective LCA with SimaPro. Netherlands. PreConsultants.

Life Cycle Inventory of Hydropower Plant of Tucurui/Brazil

Afonso Dias

Armando Caldeira-Pires, armandcp@unb.br

University of Brasilia

ABSTRACT

UHE Tucuruí is the biggest Brazilian hydropower plant (8,370 MW)), located in Rio Tocantins, district of Tucuruí, in the Southeast of the State of Pará, in the Amazon region. This work aims at developing the life cycle inventory of UHE Tucuruí, using an attributional approach, and it doesn't include impact assessment. The functional unit is of 1 MWh of electricity, and the technological model includes the construction phase started on 1975, and the use phase with a time scale was of 100 years, taking into account the maintenance and equipment renovation processes in those operations. Otherwise, the decommissioning of the plant was not taken in consideration. During the use phase, it is included the GHG emissions due to flooded biomass decomposition, accordingly on-site measurements.

Topic: LCA: Inventory and Impact Assessment
Keywords: LCI, Hidropower Plant, Attributional

INTRODUCTION

A hydropower plant can be defined as a set of structures and equipment whose purpose is the generation of electric energy through the exploitation of the existing hydro potential in rivers and lakes. In general, the countries that use this type of resource to get energy, on a large scale, possess a great electric potential.

In particular in Brazil, it is distinguished Hydropower Plant of Tucuruí (UHE Tucuruí). It is located in Rio Tocantins, district of Tucuruí, in the Southeast of the State of Pará, in the Amazon region. It is the biggest hydropower plant (8,370 MW) [1] constructed by the Brazilian government. The power plant started to be projected in the year of 1972 [2] within the context of strategic policies aiming at the economic growth of the North region of Brazil. Its first stage was initiated on November 1975[3], and the plant started operation on November 1984 [3], providing 4.240 MW [4]. The second stage was finished on June 2010, with the final capacity of 8370 MW [1].

The main installation includes a large dam with total extension of 11 km [5], a maximum outflow of 110000 $\frac{m^3}{s}$ [6], and its buildings used 6.500.000 cubical meters of concrete [7] and 1,62 tons of iron [7]. UHE Tucuruí reservoir has a total area of 2.430 km^2 and a total volume of water [4] of 45,8 billion cubical meters [4], and it is estimated that 55 million tons of biomass had been submerged in the Tucuruí lake [4]. This plant already generated, since its inauguration, more than 360 million MWh of energy.

This work aims at developing the life cycle inventory of UHE Tucuruí, using an attributional approach. This study doesn't include the impact assessment. The functional unit of 1 MWh of electricity will be used in this work [8]. It includes the construction phase started on 1975, and the use phase with a time scale was of 100 years, **Erro! Fonte de referência não encontrada.**.

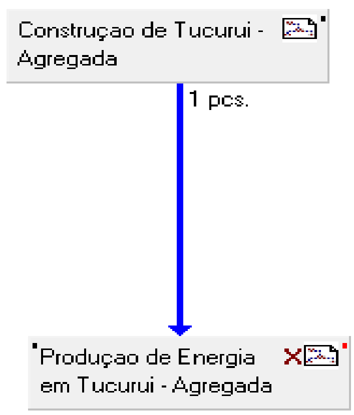


Figure 1- Flowchart of two main UHE **Tucurui**

The power plant modeling included the construction and operation, taking into account the maintenance and equipment exchange processes in the operation. Otherwise, the decommissioning of the plant was not taken in consideration.

These two phases encompass the following processes, as presented by **Erro! Fonte de referência não encontrada.** and Figure 3.

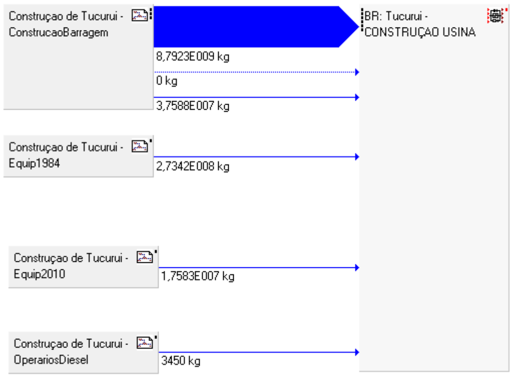


Figure 2 - Flowchart of UHE Tucurui construction phase

The construction phase inventory includes main materials, namely steel, sand and concrete, aluminum, wood, land movements, and fuel to transportation and general machinery. Moreover, it also takes into consideration the fuel needed for workers displacement between their residences to the plant site.

During the use phase, besides the material and fuel used to maintenance operations, it is included the GHG emissions due to flooded biomass decomposition, accordingly on-site measurements performed within the context of the Brazilian GHG Inventory **[4]**.

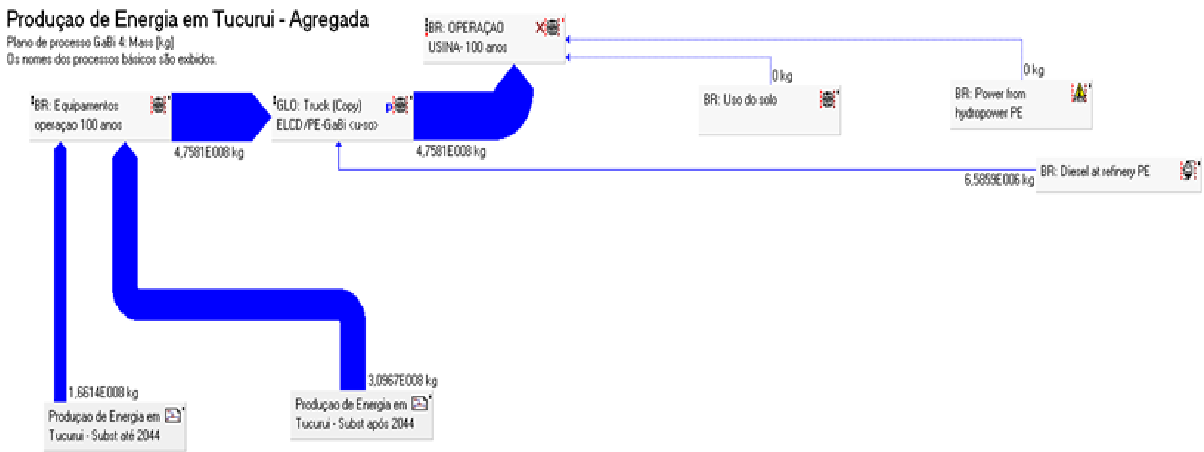


Figure 3 Flowchart of UHE Tucurui operation phases

All data necessary to fulfill these information were acquired from the construction and operation reports prepared by UHE Tucurui manager. Moreover, GHG emissions during operation phase were obtained from specific GHG inventory data from main Brazilian reservoirs.

The work uses GaBi4.4 software**[9]** to assemble all the data, to perform process flow management, and to consolidate the several flowcharts into a single aggregated process, from cradle-to-gate.

On this context, the following activities were performed to develop UHE Tucuruí inventory:

Activity 1 - Preliminary study to identify and to characterize the main components of mass and energy flows of the production of hydropower energy in Brazil, and modeling hydropower generation technologic process data, including most excellent relevant production processes, scope, study objective and limits identification, definition of functional unit. It was used the Brazilian Methodology for LCI development;

Activity 2 – secondary data collection of the main processes and sub-processes within construction and use phases;

Activity 3 - characterization of GHG emissions;

Activity 4 - preparation of final report.

REFERENCES

[1] ELETRONORTE. 2010 http://www.eln.gov.br/opencms/opencms/ Accessed 27 december 2010

[2] ELETRONORTE. 1999. Case studies of the International Dam Comission IMB): Hidropowerplant of Tucuruí (In Portuguese).

[3] ELETRONORTE. 1989. Hidropower planto f Tucurui: Technical reports. p 20 (In Portuguese)

[4] MCT (Brazilian Ministry of Science and Technology). 2006. CO2 and CH4 emissions from the Brazilian hidropower reservoirs. p 26 - 28

[5] ELETRONORTE. 1999. Case studies of the International Dam Comission IMB): Hidropowerplant of Tucuruí (In Portuguese).

[6] ELETRONORTE. 1988. Hidropower planto f Tucurui: Construction reports. Volume 2 p 31. (In Portuguese)

[7] ELETRONORTE. 1988. Hidropower planto f Tucurui: Construction reports. Volume 7 p 57. (In Portuguese)

[8] RIBEIRO, Flávio de Miranda. 2003. LCI of Brazilian Hidropower plant of Itaipu (In Portuguese). Master dissertation, Dept of Chemical Engineering, University of Sao Paulo, p 56.

[9]

Life Cycle Assessment of Petrochemical Industry in Mexico to identify improvement opportunities at the energy efficiency

Morales, Miguel[1], Herrera, Gloria[2], Candelario, Mario[3].
[1]PEMEX-Petroquímica, Jacarandas 100, Colonia Rancho Alegre I, Coatzacoalcos, Veracruz 96558, México.
[2]Phone:+52-921-211-1337.
[3]e-mail: miguel.angel.moralesmo@pemex.com.
[4]e-mail: gloria.carmen.herrera@pemex.com

ABSTRACT
Background, aim and scope

PEMEX Petrochemical is a company that manufactures, markets and distributes Petrochemical products, maximizing its economic value, quality, safety and environmental friendliness. Comprises 7 petrochemical complexes where products are manufactured in three value chains: aromatic, ethylene derivatives, and methane's derived.
This paper presents the Life Cycle Assessment for one of its 7 complexes, its main purpose is to compare the environmental impact during the petrochemicals manufacturing process using a conventional power plant with Rankine cycle vs. the reduced environmental impact gained with cogeneration, and how Cogeneration process reduces the environmental impacts.

Key words
Cogeneration, Rankine cycle, combined cycle.

Methods
As established by the ISO 14040 standard for Environmental Impact Assessment, the software tool used for Life Cycle Assessment (LCA) was SimaPro version 7.1, for environmental impacts evaluation was used the CML-2000 and the IPCC-100a to evaluate the Climate Change factors

INTRODUCTION
PEMEX Petrochemical is a branch of Petroleos Mexicanos that develops markets and distributes petrochemical products to satisfy domestic market needs and represents a cornerstone in the México's industry development.

Four of its Petrochemical complexes are located at Veracruz's south region; its main activity is based on state classified on non-basic petrochemical processes including the next segments:
-Polyethylenes
-Solvents
-Chemicals
-Specialties
The installed capacity of our resorts can cater for 67% of the raw material requirements of the national chemical industry.

DEVELOPMENT
Morelos Petrochemical Complex obtains steam and electric energy from Rankine cycle actually. Steam is generated in five low pressure and four high pressure boilers. Steam from the Low Pressure boilers is fed to process plants. Steam from the High Pressure boilers is fed to three steam turbines to complete condensation to get Electric energy. Condensation process requires to using cooling water from a cooling tower. See figure 1.
Morelos Petrochemical Complex will change its operation mode to obtain Steam and Electric Energy, using Cogeneration, from gas turbines and heat recovery steam generators. Global efficiency will be increased from 69.9% to 83.9%. Cogeneration project includes two gas turbines.

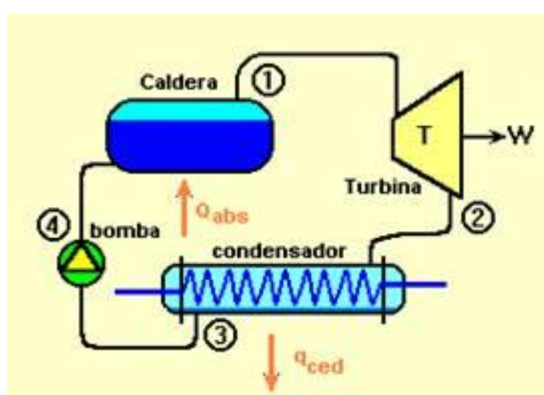


Figure 1. Rankine cycle operates at the Complex, actually.

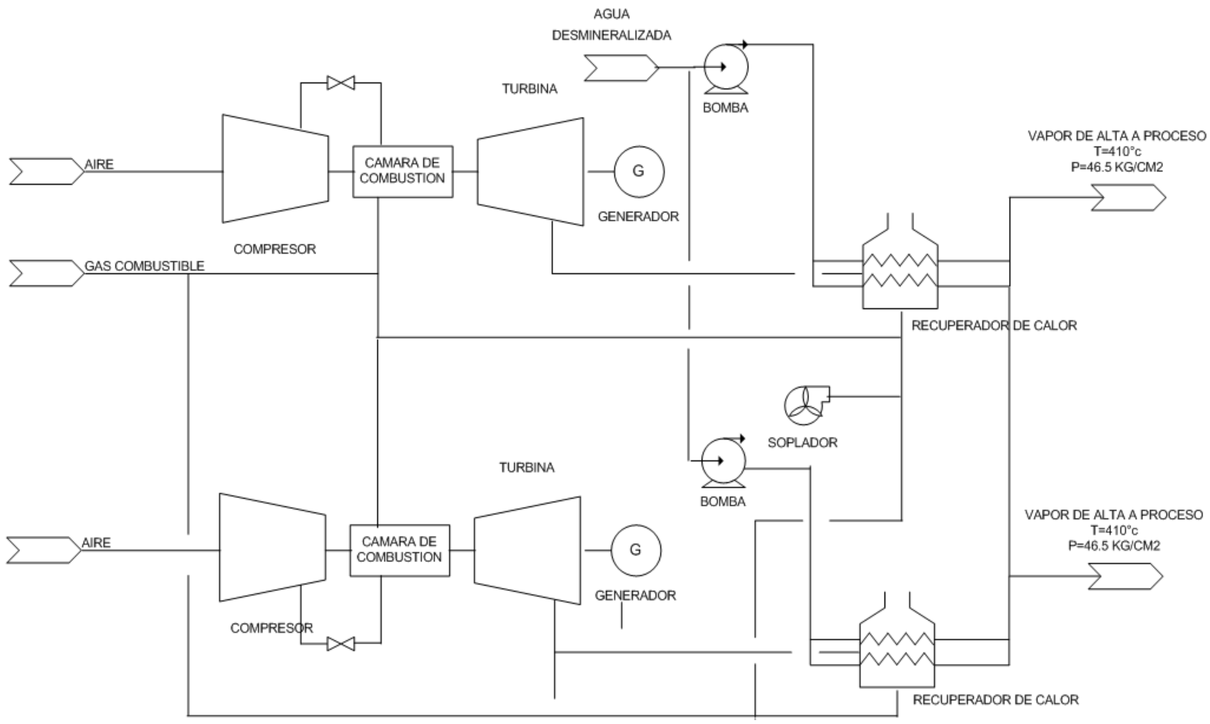


Figure 2. Cogeneration, future scheme to obtain steam and electric energy at the Petrochemical Complex.

In this process fuel gas is fed to gas turbines to generate electric energy and a heat recovery steam generator, each one, recovers energy from turbine exhaust gases to produce steam. See figure 2.

Feedstock consume like boiler feed water, cooling water and fuel gas to boilers will be reduced considerably, avoiding abiotic resources depletion.

A study case of Life Cycle Assessment where compares a coal-fired power plant and a combined cycle generation plant. Scope of its study includes several stages:

- Natural gas production and distribution
- Ammonia Production &Distribution
- Construction & Decommissioning
- Power Plant Operation

Coal is the feedstock used in the highest rated to produced power in the United States. Natural gas in one of the cleanest burning fossil fuels. This combined cycle generation plant to minimize the NOX emission, incorporated selective catalytic with water injection. Ammonia is injected to the catalytic reaction and form nitrogen and water.

The greenhouse gases and global warming potential category of the system is defined as a combination of the following greenhouse gases: CO_2, CH_4 and N_2O. The capacities of CH_4 and N_2O to contribute to the warming of the atmosphere are 21 and 310 times higher than CO_2, respectively, for a 100 years' time frame according to the Intergovernmental Panel on Climate Change (IPCC).

CO2 is the air emission emitted in the largest quantity. Methane is emitted in the next highest quantity, and 74 wt% of the total methane emissions are fugitive emissions from natural gas production and distribution.

The majority Energy consumption, 80%, of the total energy consumed is that contained in the natural gas feedstock. Efficiency plant for natural gas combined-cycle is 48.8% based at the fuel high heat value.

The sensitivity analysis indicated that the largest gains would be achieved by an increase in the power plant efficiency, per kilowatt-h of net electricity, reduces all system stressors (resources, emissions, waste and energy use). This in turn, results in a lower global warming potential and higher energy rations (meaning that more electricity is produced per unit of fossil fuel consumed).

Resources consumption, natural gas is consumed at the highest rate, accounting for nearly 98 wt% of the total resources.

Water emissions, the total amount of water pollutants was found to be small compared to other emissions.

Solid waste, about 94 wt% percent of the total waste for this system comes from the natural gas production and distribution block. Upon further examination, it is evident that most of the waste (65% of the total waste) comes from pipeline transport and that the second largest waste source is natural gas extraction (29% of the total waste).

This case study concludes in a feasible and economical option for reducing the environmental impact of the power industry is to displace electricity from Coal-fired power plants with Natural gas combined-cycle systems. And therefore large amount of waste (ash and flue gas wasted) will be reduced, per kilowatt-h produced. Using natural gas to generate electricity, particularly in higher efficiency combined cycle power systems, can reduce the environmental impact of energy usage in the United States.

Other study case of life cycle assessment about 2-MW rated power wind turbine. Wind power does not produce pollution or emission during operation; it should be considered that there is an environmental impact due to the manufacturing process of the wind turbine and the disposal process at the end of the wind turbine. Study case includes the stages: manufacture, start-up, use and dismantling. The biggest impact can be observed in the rotor, mainly due to the manufacture of the turbine blades, especially, their nonrecycling status. Another result to assess from an environmental point of view is the effect of dismantling and subsequent treatment of waste at the end of the turbine lifetime.

The percentage reduction of environmental impacts of the electricity generation from wind turbine versus the Spanish electrical system, over 92% in all impact categories. Abiotic depletion 98.99%, global warming 98.76%, Ozone layer depletion 96.73%, Human toxicity 89.26%, Freshwater aquatic eco-toxicity 94.06%, photochemical oxidation 99.24%, Acidification 99.28%. Therefore wind turbines electricity produces less environmental impacts than current Spain electrical system.

RESULTS AND CONCLUSIONS

Scope of this Life Cycle Assessment includes Operation stage only; it doesn't include construction and decommissioning, natural and fuel gas distribution stages.

Life cycle assessment realized for current power generation system at the Morelos Petrochemical Complex, where are utilized Boilers to produce steam and steam turbines to generate electric energy, according to study by a recognized institute, process global combined efficiency is over 69.9%.

Cogeneration process using gas turbines and heat recovery steam generators global combined efficiency is over 83.9%. Energy usage with these equipments replace will be an improvement opportunity.

Cogeneration will reduce 5 Midpoint environmental impact categories significantly analyzed for steam, as follows: climatic change 25.6%, photochemical oxidant formation 74.5%, particulate matter formation 86.3% and fossil depletion 5.8%.

Environmental impacts for Petrochemical Products were grouped in 3 great categories, where Cogeneration process reduced, as follows: Human healthy 48.1, ecosystems 42.9 and resources 5.8%. Global environmental impact reduction is 42% for Cogeneration project. (Figure 3).

Greenhouse gases were estimated using a Intergovernmental Panel on Change Climatic model, resulting Cogeneration process will reduce from 1.45 tonCO2eq/ton to 1.060 tonCO2eq/ton of Petrochemical Products, or its equivalents of 27.3% or 789,870 tonCO2eq per year. (Figure 4). Therefore, the Cogeneration is an environmental process friendlier to the environment, due that produces less potential environmental impacts.

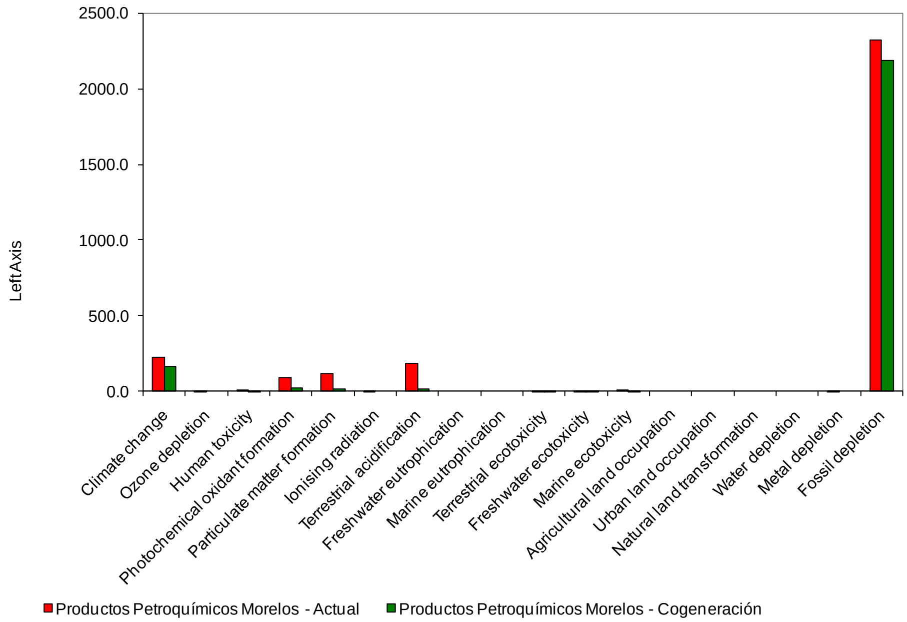


Figure 3. Environmental impact midpoint categories, current Petrochemical Complex versus Petrochemical Complex with Cogeneration.

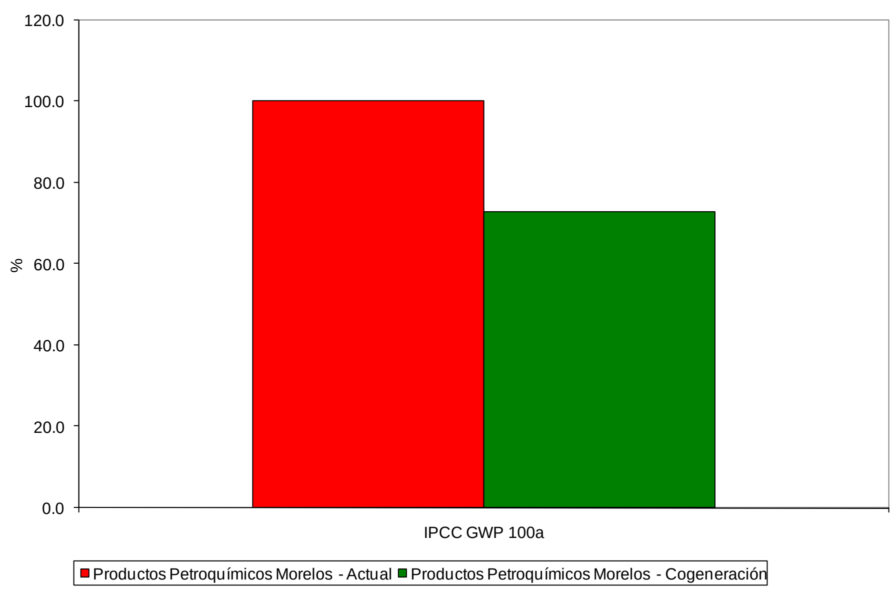


Figure 4. Results of greenhouse gases emissions from the current process versus Cogeneration.

REFERENCES

1. PEMEX Petrochemical. 2006. Technical and economic study "Cogeneration using totally new facilities or existing facilities", México: 57p.
2. PEMEX Petrochemical. 2010. www. http://portal.ad.ptq.pemex.com/Paginas/default.aspx
3. PEMEX Petrochemical. 2010. Energy and material balance, PEMEX Petrochemical Institutional Database.
4. Spath, Pamela; Mann, Margaret. 2000. Life Cycle Assessment of a natural gas combined-cycle power generation system, United States. National Renewable Energy Laboratory. 56p.
5. Martínez, Eduardo; Sanz, Félix; Pellegrini, Stefano; Jiménez, Emilio; Blanco, Julio. 2009. Life-cycle assessment of a 2-MW rated power wind turbine: CML method. Spain. .Department of Electrical Engineering, University of La Rioja. 12p.

Characterization factors for freshwater ecotoxicity as a decision support tool for the environmental improvement and sanitation of rivers in Mexico

Morales-Mora M.A.[1*], Ramos Alonso V.[2], Martinez-Delgadillo S.[3], Rosa-Domínguez E.[4] and Suppen-Reynaga N.[5]

[1] PEMEX-Petroquímica, Jacarandas 100, Colonia Rancho Alegre I, Coatzacoalcos, Veracruz 96558, Mexico. Phone: +52-921-211-1337. E-mail: miguel.angel.moralesmo@pemex.com
[2] Minatitlan Institute of Technology, Environmental Engineering. Boulevar Instituto Tecnológico S/N, Colonia Buena Vista Norte, Minatitlán, Veracruz. Mexico. E-mail: chiky_branch@hotmail.com
[3] Departamento de Ciencias Básicas, Universidad Autónoma Metropolitana-Azcapotzalco, Av. San Pablo 180, Azcapotzalco, Mexico D.F. 02200, Mexico. E-mail: samd@correo.azc.uam.mx
[4] Central University Marta Abreu de Las Villas, Chemistry-Pharmacy Faculty, Camajuaní Road km 5½, Santa Clara, Villa Clara 54830, Cuba. . Phone: +53-4228-1100. E-mail: erosa@uclv.edu.cu
[5] Centro de Análisis de Ciclo de Vida y Diseño Sustentable. Bohemia 2-9, Bosques del Lago, Cuautitlán Izcalli, Estado de México 54766, Mexico. Phone: +52-55-2602-9694. E-mail: nsuppen@centroacv.com.mx

Abstract

The industrial wastewater from more than 65 petrochemical factories and domestic wastewater discharged into the Coatzacoalcos River (SE Mexico) have contaminated its waters and sediments. About 30.7 tons of chemical oxygen demand (COD), 25.3 tons of sulfate, 1.5 tons of nutrients, 0.31 tons of heavy metals and 0.13 tons of toxic organic compounds, mainly polyaromatic hydrocarbons (PAHs), are discharged into its waters daily. Nevertheless, the main tool for water management in Mexico to protect the water supply sources for urban public use, agricultural irrigation, protection of freshwater aquatic life and coastal areas and estuaries, is limited; only 26 inorganic substances and 78 organic compounds are considered in the list of pollutants. In addition, there is a mechanism to establish specific conditions of wastewater discharge from a classification study of local surface water body that only include 17 substances. However, priority pollutants constitute only one part of the large chemical pollution puzzle; there is a diverse group of unregulated pollutants that are discharged by municipal and water industrial wastewater treatment plants.

In this work, the characterization factors (CF) in terms of Comparative Toxic Units (CTU), at local (Coatzacoalcos), county-wide (Mexico) and global (World) scales for emissions into the Coatzacoalcos River from the oil, gas and petrochemical industry were obtained and compared, employing the USEtox™ model. Moreover, a CTUe score type benchmark for freshwater ecotoxicity in Mexico was derived and compared with the wastewater discharge conditions determined by the national authority. From the comparative CF analysis, it was bserved that there was an average difference of four orders of magnitude between global and local scale. CTUe from the emission data of a petrochemical process and CTUe, taking into account the values of water quality limits set to protect freshwater aquatic life in water bodies in the country were calculated. Evaluating the local CF by USEtox model, to obtain it is feasible to predict potential aquatic toxicity, relationship with water quality limits for protection of aquatic life in Mexico.

Topic:

Key word: Coatzacoalcos, Comparative toxic units, characterization factors, freshwater, ecotoxicity, petrochemicals

Introduction

In the port-industrial area of the city of Coatzacoalcos, downstream the Coatzacoalcos river in Veracruz (Southeast Mexico), there are more than 65 petrochemical factories, producing about 15 million tons per year of chemical substances (Toledo, 1988). According to the Mexican National Water Commission (CNA, 2008), about 462 liters/sec of domestic wastewater and 915 liters/sec of wastewater from industry have been discharged into the river downstream in the last years, most of them without treatment. The industrial and domestic wastewater discharges 30.7 tons/day of chemistry chemical oxygen demand (COD), 25.3 tons/day of sulfate, 1.5 tons/day of nutrients, 0.31 tons/day of heavy metals and 0.13 tons/day of toxic organic compounds; mainly polyaromatic hydrocarbons (PAHs). In toxicity units (TU), this corresponds to values between 1 and 3. Toxic organic compounds have been detected in 19 species of commercial fish (De León Rodriguez et al. 1983; Botello, 1986) and the presence of lead in the blood, hair or breast milk in the Coatzacoalcos area human population has been reported by Pérez-Zapata (1983) and INSP (2008).

Nevertheless, the main tool for water management in Mexico to protect the sources of supply for urban public use, agricultural irrigation, protection of freshwater aquatic life and coastal areas and estuaries, is limited to a list of 26 inorganic substances and 78 organic compounds (CNA, 2010). Also, there is a specific mechanism to establish conditions of wastewater discharge from a classification study of local water body (river or lake) that only include 17 substances (CNA, 2008). However, priority pollutants constitute only a part of the large chemical pollution puzzle and there is a diverse group of unregulated pollutants discharged by municipal and industrial wastewater treatment plants.

To reduce the Coatzacoalcos River pollution, the national authority has defined water quality goals to be reached in years 2013 and 2018. Therefore, preventive measures must be taken now, to evaluate and mitigate risks.

Therefore, the used of the an environmental model for characterization of ecotoxicological impacts in Life Cycle Impact Assessment (LCIA) and a good database for organic and inorganic compounds in wastewaters is very important for assessing the fate, exposure and effects of chemicals in the wastewater, which is the main route of emission to the environment (Ternes et al. 2004). In these sense, impact models should be adapted locally, such as the Coatzacoalcos area. The USEtox™ model (Hauschild et al. 2008), can be used for the industry to predict the potential impact of discharges, because this model has the characterization factor (CF) that is substance-specific (expressed per unit emission), specifying the relative hazardousness of each substance (”impact potential”).

The general goal of this study was to analyze the USEtox™ model for the characterization ecotoxicological impacts, and to compare the CF at the local, country-wide, and global scales.

The inventoried substances (halogenated non-aromatics, polycyclic aromatics compounds, and metals) in the effluents from a petrochemical industry near Coatzacoalcos (Table 1) were evaluated, because concentrations of these chemical substances were detected in the Coatzacoalcos river. Also, these substances have been considered priority for LCA studies (Huijbregts et al. 2000).

Table 1. Inventory of the principal substances in the petrochemical industry effluent discharged into the Coatzacoalcos river

Substance	Emissions (kg/day)
1,2 Dichloroethane	5.90E+02
Chloroform (CHCl3)	5.22E+00
Benzene	7.81E-02
Trichloroethylene	1.30E-02
1,2-dichloropropane	7.81E-02
Tetrachloroethylene	1.04E-01
1,3-Dichloropropene	9.77E-03
1,1,2-Trichloroethane	4.82E+00
1,3-Dichloropropane	8.73E-02
Dibromochloromethane	2.34E-02
Naphthalene	1.26E-02
Fluorene	3.78E-04
Phenanthrene	5.21E-04
Fluoranthene	1.69E-04
Pyrene	5.08E-05
1,2 Dichloroethane	5.90E+02

The inventory of these substances was obtained by direct measurements (four samples per day resulting a mixture sampling) from the effluents of industry and municipal wastewater plants (IMTA, 2008), as well as using databases from National Commission Water at the Coatzacoalcos river discharge in 2009 (citar bibliografia de CNA). For each substance, in the human and freshwater toxicity, its CF according to the USEtox^{TM} model was estimated, including the fate factor (FF), exposure factor (XF), effect factor (EF), and the emission rate for each industry, according to equation 1.

Ecotoxicity;

CF= FF*XF*EF; Human toxicity: CF= FF*XF*EF (1)

The fate factor and exposure factor are combined to reflect the intake fraction (iF) of a chemical substance, representing the fraction of the emitted mass to which the human population is exposed, and is defined by equation 2.

iF=FF*XF (2)

In addition, the Human Toxicity Potential (CTUh = cases/kg emission) and Ecotoxicity Potential (CTUe = PAF m^3.day/kg emission^{-1}) were obtained from these data, to stress the comparative nature of the CF. Moreover, the specific method to establish conditions of wastewater discharge from a classification study of local water body for the national authority (CNA, 2008) was evaluated. Eq. (3) shows how scores for each download special condition (DSC) were calculated:

$$DSC_i = \frac{\frac{\boldsymbol{Q_i C_i}}{\sum_{i=1}^{n} \boldsymbol{Q_i C_i}} \text{MDL}}{0.0864 Q_I} \qquad (3)$$

Where:

DSC_i= download special condition for the *i* discharge (mg/L); Q_i= rate flow discharge (L/s); C_i = concentration no restricted pollutants (mg/L), MDL = Maximum discharge limit of the contaminant (kg/day), established in table 7 of the declaration of the Coatzacoalcos river and 0.0864= unit conversion factor.

Result and discussion

In table 2, it is shown the comparison between the aquatic toxicity CF in freshwater, measured as PAF.m^3.day/$kg_{emission}$. The USEtox model considers the fate factor (FF), the exposition factor (XF) and the effect factor, to calculate the ecotoxicological characterization factors. The EF reflects the change in the fraction of species potentially affected (PAF) due to the change in concentration (PAF.m^3.kg). Specifically to analyze the effect of the petrochemical process and its potential impact on a tributary to the river Coatzacoalcos, the CTUe were obtained. In the same table are shown the comparison between the emission CTUe of the petrochemical processes and CTUe, based on the water quality Mexican rules (NWC) in an influent into the Coatzacoalcos River. To estimate the values, it was considered that the flow rate discharged into the river was the same of the petrochemical wastewater.

The CTUe was considered a benchmark because there is no a scale to compare the quality water levels in Mexico, and then it can be used the industry. Also, in the same table 2 are shown the EC50, which were obtained with the USEtox. There are important differences with those values reported by ECOSAR (USEPA 2009). As seen, ECOSAR reported higher EC50 values for 1,3-Dichloropropene y el Tetrachloroethylene, whereas by using USEtox the higher values for the 1,2 Dichloroethane and the Dibromochloromethane were obtained.

Laboratory tests do not always resolve disputes regarding the potential toxicity because the analysis is based on a sample of water that can contain a mixture of substances and various physical and chemical factors that make it impossible to specify the substance causing toxicity. By the USEtox it can be identified the current or potential toxicity, starting from the estimate emissions CTUe generated from a particular production process or wastewater treatment plant.

Thus, by relating the CTUe to water quality limits for use in industry, may in future provide the critical load values based on the assimilative capacity of the river, being that the adverse effects of toxicity have a seasonal dimension, which varies according to the process and period of operation in the oil, gas and petrochemical industry, especially in periods of maintenance and / or entry into operation of the plants and / or production process units (Birkved, 2010).

Table 2. Comparison between the emission CTUe of the petrochemical processes and CTUe based on Mexico's water quality guidelines and EC50 value

Substances	**CTUe** (PAF.m³.day/ $kg_{emission}^{-1}$) the emission petrochemical processes	**Water quality guidelines** [a] **kg/m³**	Emission considering of the water quality guidelines [b]	**CTUe** (PAF.m³.day/ $kg_{emission}^{-1}$) considering water quality guidelines to Teapa stream	**EC50** [c] **USEtox kg/m³**	**EC50** [d] **ECOSAR kg/m³**
1,2 Dichloroethane	9.33E+02	1.2E-03	1.30E+01	2.06E+01	1.55E-01	2.60E-02
Chloroform	2.21E+01	3.00E-05	3.91E-01	1.65E+00	5.77E-02	4.92E-02
Benzene	5.03E-01	5.00E-05	6.51E-01	4.19E+00	3.25E-02	6.11E-02
Trichloroethylene	1.06E-01	1.00E-04	1.30E+00	1.06E+01	2.88E-02	2.52E-01
1,2-dichloropropane	3.57E-01	2.00E-03	2.60E+01	1.19E+02	5.14E-02	1.63E-02
Tetrachloroethylene	6.04E+00	5.00E-04	6.51E+00	3.78E+02	4.29E-03	1.08E-01
1,3-Dichloropropene	1.89E+00	----	----	----	1.17E-03	3.18E-01
1,1,2-Trichloroethane	2.26E+01	2.00E-04	2.60E+00	1.22E+01	5.87E-02	2.70E-02
1,3-Dichloropropane	3.85E-01	----	----	----	5.63E-02	1.46E-02
Dibromochloromethane	2.84E-01	----	----	----	2.61E-02	6.63E-02
Naphthalene	2.44E+00	2.00E-03	2.60E+01	5.03E+03	2.60E-02	4.89E-03
Fluorene	1.49E-01	----	----	----	1.07E-03	1.87E-03
Phenanthrene	1.10E+00	----	----	----	3.04E-04	1.24E-03
Fluoranthene	2.78E+00	----	----	----	7.94E-05	6.04E-04
Pyrene	7.87E+00	----	----	----	7.27E-06	6.04E-04

a = Protection of aquatic life: Fresh water, including wetlands. (National Water Commission)
b = Emission considering the same volume of discharge from petrochemical presses and water quality guidelines
c = Local scale (Coatzacoalcos Area)
d = Global scales (USEPA) Bioindicator: Green algae (96 hours)

Conclusions and recommendations

The USEtox[TM] model can be used to predict potential aquatic toxicity estimating the CTUe, from its relation to the limit values of water quality limits for protection of aquatic life in receiving water bodies where the industry discharges their effluents, or as a control mechanism within a given production process.

Reference

Birkved M (2010) The Basis Getting the inventory right. Seminar USEtox. Graduate School 3R

Botello, A.V. y Páez-Osuna (1986) El problema crucial: la contaminación. En: Serie Medio Ambiente en Coatzacoalcos. Vol. 1. Ed. Centro de Ecodesarrollo. México, D.F.

Comisión Nacional del Agua (2008) Declaratoria de clasificación del Río Coatzacoalcos, sus afluentes (Río Calzadas, Arroyo Gopalapa y Arroyo Teapa) y Laguna Pajaritos. DOF. Miércoles 6 Febrero

Comisión Nacional del Agua (2010) Lineamientos de calidad del agua. In: Ley Federal de Derechos. DOF. 18-11-2010

Deleón-Rodríguez, I., Pérez-zapata A.J (1983) Demostración citoquímica de plomo y hallazgos histológicos relacionados, en peces del rio Coatzacoalcos. Anales de la Esc. Nal. De Ciencias Biológicas. Mex. Vol.27.Num.1-4. 165-174 p.

Hauschild, M.Z. M. Huijbregts, O. Jolliet, M. Macleod, M. Margni, R. Rosenbaum and T. E. McKone (2008) Building a Model Based on Scientific Consensus for Life Cycle Impact Assessment of Chemicals: The Search for Harmony and Parsimony. *Environ. Sci. Technol.*, 42 (19), pp 7032–7037.

Huijbregts M.A.J, U. Thissen, J.B. Guinèe, T. Jager, D. Kalf, D. van de Meent, A.M.J. Ragas, A. Wegener Sleeswijk, L. Reijnders (2000) Priority assessment of toxic substances in life cycle assessment. Part I: Calculation of toxicity potentials for 181 substances with the nested multi-media fate, exposure and effects model USES-LCA. *Chemosphere* 41. 541-573.

Instituto Mexicano de Tecnología del Agua (2008) Estudio para el tratamiento de Aguas Químicas: Caracterización de los Efluentes Acuosos Finales de cada una de las Plantas de Proceso del Complejo Petroquímico Pajaritos (CPP). Informe interno.

ISO (2006a) ISO 14040: 2006 environmental management — life cycle assessment — principles and framework

ISO (2006b) ISO 14044: 2006 environmental management — life cycle assessment — requirements and guidelines

Pérez-Zapata, A., J. Irma Deleon R. y Ma. T. Valenzuela V (1982) La contaminación por plomo en habitantes de Coatzacoalcos, Veracruz. Anales de

la Esc. de Ciencias Biológicas, IPN. Vol. 26, 147-151.
Ternes, T.A., Joss, A., Siegrist, H., 2004. Scrutinizing pharmaceuticals and personal care products in wastewater treatment. Environ. Sci. Technol 38, 392A–399A.
Toledo A. (ed) (1988). Medio ambiente en Coatzacoalcos. CECODES-UV. 88 pp.
USEPA (2009) USER'S guide for the ECOSAR Class Program. Office of Pollution Prevention and Toxics, U.S. *Environmental Protection Agency*. 39 pp.

Life Cycle Inventory of Electricity Generation in Chile

Vega Mabel[1], Zaror Claudio[1], Peña Claudia[2]
[1]University of Concepcion, Concepcion, Chile
[2] Centre for Mining and Metallurgical Research CIMM, Santiago. Chile

University of Concepción PO Box 160-C, Correo 3, Concepción. Chile
mabvega@udec.cl

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Abstract

This paper presents the life cycle inventory of Chilean energy production and transmission. The Northern (SING) and Central (SIC) interconnected networks are included in this study. These grids cover more than 99% of total electricity generation in Chile. Results show that the SING grid features larger loads of emissions to air and water, and greater impact on fossil energy resources, than the SIC network.

Introduction

During the last decade, the Northern and Central electricity generation systems have shown significant changes in the contribution of various primary sources, mainly due to restrictions in the availability of natural gas from neighbouring Argentina. Moreover, the Chilean economy has experienced a fast growth which has also required a proportional increase in electricity generation capacity. This trend is expected to continue over the long term, and new investments in electricity generation capacity are likely to modify even further the current electricity mix.

Given the importance of electricity as a key energy input in all productive processes, sound LCI data on electricity generation and transmission is required. Unfortunately, no such information is currently available

The primary goal of the study was to develop a cradle-to-gate Life Cycle Inventory (LCI) for electricity generation/transmission in Chile, focussing on the Northern and Central networks. Since no other LCI on Chilean electricity generation has been published up to now, the present study is to be regarded as a first approximation, considering such environmentally sensitive issues as the carbon footprint, water usage, fossil fuels consumption, land occupation and air quality aspects associated with Chilean electricity generation. The intended direct audience is expected to be composed of environmental managers, process engineers and LCI practitioners within the Chilean industry, involved in process design and environmental management.

Methodology

The ISO 14040:2006 [1] standard was used as the methodological framework to conduct this LCI study. This study included all significant inputs and outputs related to electricity generation and distribution in the Chilean SING and SIC networks, including major materials and energy inputs, air and water emissions and solid wastes. Data corresponding to 2008 was used to build this LCI, and was set as the reference year.

The first boundary is set at the extraction of primary energy sources, and the end point is drawn at the industrial user gate. Thus, the reference flow was 1 kWh of high voltage electricity (above 66 kV). The life cycle inventory analysis presented in this paper follows a cradle-to-gate approach.

A major constraint in this study was the lack of detailed primary, site specific, environmental and operational data. Indeed, only a limited set of relevant variables were registered in most cases, and secondary sources had to be used to estimate missing data (eg. Environmental Impact Declarations and Assessments, official environmental monitoring reports to local authorities, official energy statistics reports, Centre for Load Delivery memoirs, technical reports, scientific literature, among others). Missing information was completed with data obtained from similar European processes as found in Ecoinvent database.

Results

Table 1 summarises main emissions to air, discharges to water, and consumption of natural resources associated to electricity production at SING and SIC networks for the 2008 average electricity mix.

In general, thermoelectric processes account for the largest fraction of air emissions, whereas hydroelectric generation is responsible for most water usage at the SIC network.

Greenhouse Gases (GHG): Electric generation and distribution at the SING network features a cumulative GHG emission of 1.10 kg CO2 equivalent per kWh, as compared with an overall emission of 0.47 kg CO2 equivalent at the SIC. The difference in GHG emissions reflects the greater contribution of thermoelectric generation at the SING network. Diesel and coal based generation accounted for 93% of CO2 generated in both networks in 2008. Methane and dinitrous oxide contributed less than 3% to the total global warming potential of air emissions in both networks. Other GHG such as SF6, and CFCs did not make a significant contribution to the global warming potential associated with electricity generation in Chile.

Carbon Monoxide (CO): CO loads at SING are slightly higher than at SIC, given the higher contribution of thermoelectric generation in the former. Diesel plants show greater emissions, above the upper level found in the Ecoinvent database for European plants. It must be said that in recent years a large number of natural gas plants had to be operated using diesel as primary fuel. In those plants, the fuel-to-air ratio has been difficult to control leading to greater CO emissions.

Nitrogen Oxides (NOx): NOx emissions at SING totalled 3.5 g/kWh, whereas SIC emissions only amounted to 1.2 g/kWh. Again, coal and diesel power plants are responsible for most NOx emissions in the electricity mixes. Most electrical energy generated at the SING comes from fossil fuels combustion, and those results were expected.

Sulphur Oxides (SO_X): Sulphur oxides are generated from the oxidation of sulphur containing organic compounds in fossil fuels, and from sulphur removal processes in crude oil refineries. LCI results for 2008 show that SO_2 emissions associated with electricity generation and distribution at SING correspond to 6.3 g/kWh, compared with 2.5 g/kWh at SIC. Coal-based power plants contribute with the highest fraction of those emissions, and to a lesser extent emissions from diesel based plants. In both networks, SO_X emissions were determined by the coal sulphur content. In this respect, coal used in Chile features relatively low sulphur contents (mostly below 1% w/w). None of the Chilean thermoelectric plants features in-situ desulphurisation processes, since no SO_2 emission regulations currently exist in Chile.

Particulate Matter: Particulate matter emissions (including PM2.5 and PM10) reported in this LCI reflect the significant contribution of coal-based thermoelectric generation at SING and, to a lesser extend, at SIC.

Discharges to water: Discharges to water at SING network are higher than at SIC, reflecting the greater contribution of thermoelectric generation. Those discharges account for cooling water usage in thermoelectric operations, mainly in coal and diesel based plants. Additionally, there is a significant contribution of dissolved organic matter and nutrients loads from oil refineries during diesel production.

Fossil Fuels: SING features three times greater coal and natural gas consumption than SIC, as a result of the greater contribution of thermoelectric plants. The low efficiency of Chilean coal and diesel plants leads to higher fuel consumption compared with more efficient modern plants.

Water usage: The SING and SIC cooling water consumption amounts to 0.276 and 0.075 m3/kWh, respectively. These values are consistent with the larger contribution of thermoelectric generation in the SING network, since cooling water usage in hydroelectric generation is negligible. Most coal-based plants are located near the sea, close to port facilities; therefore, sea water is used for cooling purposes. On the other hand, a large number of diesel and natural gas power plants are located in the Central valley, and cooling water is obtained from surface and ground sources. In this case, a significant fraction of cooling water is recycled after heat is removed in cooling towers.

Water for electricity generation in the SIC system amounts to nearly 10 m^3/kWh, as compared with less than 0.2 m^3/kWh in the northern network, where the contribution of hydropower to the mix is very small.

Contribution Analysis

In both networks, around 88% of CO2 emissions were generated during the energy conversion process in thermoelectric plants. On the other hand, primary fuel extraction, refining and transport accounted for around 10% of those emissions.

In the case of hydroelectric generation, GHG emissions were associated with infrastructure and anaerobic degradation of organic matter in reservoirs. The contribution of hydroelectric generation to GHG emissions at SIC represented less than 0.5% of total GHG emissions, whereas at SING it was negligible.

Energy conversion at power plants accounted for 76% and 80% CO emissions at SING and SIC, respectively, followed by fuel extraction/refining, and transmission. Diesel based thermoelectric plants were responsible for 80% and 89% of CO emissions at SING and SIC, respectively. On the other hand, natural gas based plants contributed with less than 2% of total CO emissions.

NOx were mostly generated in the energy conversion stage (72-76%), followed by fuel extraction and refining (13-16%).

Coal plants accounted for 76% and 59% NOx emissions, whereas the contribution of diesel plants was 23% and 39% at SING and SIC, respectively.

Conversion processes, mostly from coal-based plants, accounted for 81-87% of total SO2 emissions, followed by fuel extraction and refining (11-16%). Fuel transport contributed with around 5%, mainly due to emissions from maritime transport of coal, crude oil and diesel.

Fuel extraction and refining were responsible for 39-46% of PM emissions, followed by transmission and fuel transport (viz. 22-24%, and 16-20%, respectively).

Diesel based power plants accounted for 46% and 62% of total PM emissions at SING and SIC, respectively, whereas coal based plants contributed with 51% and 25%, respectively.

Over 90% of BOD5 loads were associated with fuel extraction and refining, mostly from Diesel based plants, in both networks.

Between 90 and 97% of fossil fuels depletion could be attributed to fuel extraction and refining.

Most water consumption was attributed to energy conversion processes, with cooling accounting for over 97% of cooling water usage, mostly in coal based power plants Hydroelectric generation accounted for 97% of water-through-turbine usage at SIC.

Finally, climatic factors, such as La Niña phenomena, and global warming, have a strong influence on the SIC mix, since a significant fraction of hydroelectric generation capacity is located within the Bio Bio river basin. Rainfall at the Bio Bio region is extremely sensitive to these atmosphere-ocean interactions, and influences the SIC generation mix. These periodic effects should be carefully monitored in future studies.

Conclusions

This LCI study resulted in a preliminary inventory for electricity generation in Chile, considering the Northern (SING) and Central (SIC) electricity networks.

Results shows that the SING grid, with its total reliance on thermal conversion processes, features large rates of emissions to air and water, and greater impact on fossil energy resources. On the other hand, the SIC grid features a larger proportion of hydroelectric sources, and as a consequence, presents lower levels of emissions to air and water, and less pressure on fossil resources. However, land occupation and water usage is much higher at SIC.

Since thermoelectric generation is responsible for most emissions to air in both SING and SIC networks, results show a high sensitivity to thermal efficiency, and type of fuel.

LCI results reported in this study correspond to the 2008 electricity mixes, and extrapolation to future scenarios requires careful assessment of the particular technological and fuel mixes found in SING and SIC at that particular time.

The lack of awareness on life cycle methodology within Chilean industry was a major constrain in the efforts to obtain reliable operational and environmental data for LCI purposes. Companies collect a minimum set of environmental and process data, with view to satisfying legal requirements, rather than improving their environmental or operational performance.

Finally, this study unveiled important improvement opportunities in the Chilean electricity generation sector. I

In conclusion, this LCI study provides a sound foundation for further improvements, as new site specific data becomes available in the near future, leading to more detailed LCI studies..

Acknowledgements

Authors would like to thank FONDEF project (D06I1060) for their financial support.

References

[1] ISO 14040. 2006. “Environmental management. Life Cycle Assessment. Principles and framework”

TABLE 1 Key environmental burdens of Electricity Mix at SING and SIC Networks. Reference Year : 2008

	kg / kWh EE	
	SING	**SIC**
Atmospheric emissions		
CO_2 fossil	1.08	0.46
CH_4 fossil	$6\ 10^{-4}$	$3\ 10^{-4}$
N_2O	$3\ 10^{-5}$	$2\ 10^{-5}$
SF_6	$3\ 10^{-9}$	$2\ 10^{-9}$
CO	$1.6\ 10^{-3}$	$1.0\ 10^{-3}$
NOx	$3.5\ 10^{-3}$	$1.2\ 10^{-3}$
SO_2	$6.4\ 10^{-3}$	$2.5\ 10^{-3}$
PM_{10}	$9\ 10^{-4}$	$1\ 10^{-4}$
$PM_{2,5}$	$5\ 10^{-5}$	$3\ 10^{-5}$
NMVOC	$2\ 10^{-4}$	$1\ 10^{-4}$
Discharges to water		
DBO_5	$1.5\ 10^{-3}$	$1.1\ 10^{-3}$
COD	$1.6\ 10^{-3}$	$1.1\ 10^{-3}$
Sulphate	$2.8\ 10^{-3}$	$1.2\ 10^{-3}$
Nitrate	$2\ 10^{-6}$	$1\ 10^{-6}$
Phosphate	$1\ 10^{-4}$	$4\ 10^{-5}$
Natural Resources		
Crude oil	0.11	0.08
Coal, in ground	0.31	0.09
Natural Gas	0.03	0.01
Water, cooling	276	75
Water, turbines	172	9,870
Land Transf. (m^2)	$1\ 10^{-3}$	$8\ 10^{-3}$
Land Occup.(m^2y)	0.6	0.4

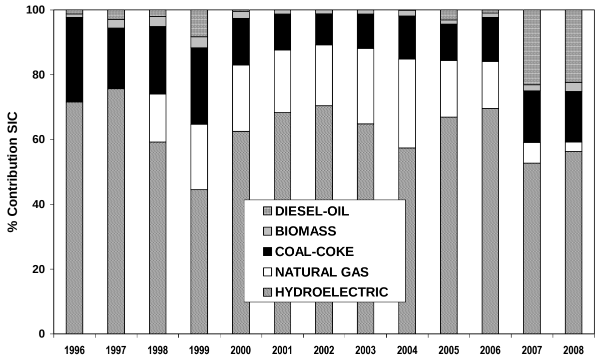

Figure 1: Primary energy sources at SING. 95-08

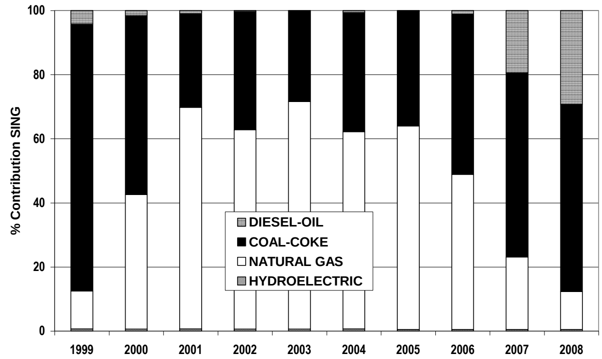

Figure 2: Primary energy sources at SIC. 95-08

LCA for Redesign of Public Luminaires

Sanchez Júnior, Oswaldo

Instituto de Pesquisas Tecnológicas do Estado de São Paulo S. A. – IPT. Centro de Integridade de Estruturas e Equipamentos, Laboratório de Equipamentos Elétricos e Ópticos. Av. Prof. Almeida Prado, 532, Cidade Universitária, São Paulo, CEP 05508-901, São Paulo, Brasil. Fone (+55 11)3767-4588, e-mail: osanchez@ipt.br.

Abstract

The Life Cycle Analysis – LCA was used to support the redesign of public luminaires. A comparative analysis of two products manufactured by different processes (manufacturers) was used to obtain sensitivity and validate the technique. Following recommendations of ISO 14040, the study's scope was defined to ensure that its breadth, depth and degree of detail could attend the established objective. The relevant inputs and outputs to all stages of life were recorded. With the support of software GaBi 4.0, the environmental impacts were obtained from environmental surveys. The functional unit was customized in order to promote a gain in sensitivity when comparing the environmental performance of both products. Then, the products were compared according to the environmental impacts considered. From the strategies prescribed by the ecodesign approach, the main points to be improved in the redesign of products were identified to mitigate the potential environmental impacts associated with its life cycle and to improve their environmental performance. Thus, it was found that the technique of LCA has the potential as a tool for this type of product development.

Topic: Ecodesign.
Keywords: luminaires LCA, products redesigning by LCA; products for lighting ecodesign.

Introduction

There is a serie of efforts at various levels of government to reduce consumption of electricity for public lighting and thereby reduce costs and minimize the need for future supply of energy. However, most initiatives using procedures emphasize the replacement of technology from an analysis focused only on saving energy. Such procedures, in Brazil, are supported by the Brazilian National Agency of Electrical Energy (Aneel) and by the brazilian state-owned electricity company (Eletrobrás), since the criteria used for assessing projects in public programs for efficiency of public lighting installations, encourages this practice.
Considering the scale of public and private investment involved in replacement of Public Lighting – PL technologies, other requirements associated with the manufacture, use and disposal of products could also be used to promote, for example, improved performance for the final user, the decrease of production and maintenance costs (better price), mitigation of environmental impacts from manufacturing, use and disposal of products, among other aspects related to the management of PL systems. Inventories that had this function could also provide relevant information to be used for the redesign of the product, as well as the planning of its production [1].
This study aimed to contribute to fill this gap, from the proposition of using the technique of Life Cycle Assessment - LCA as a support for decisions that take into account the environmental performance of this product family.

Method

Considering all the basic steps for developing a product, the phase of Conceptual Design offers a wide range of opportunities for application of the technique of LCA, considering the following steps: Step 1 (Definition of Object and Scope), Step 2 (Inventory Analysis), Step 3 (Environmental Impact Assessment), Step 4 (Interpretation). The product of the interpretation of results may take the form of conclusions and recommendations for professionals who rely on LCA as a tool to decision-making process [2, 3, 4].

Results

The flowchart in Figure 1 below presents the scope of the analysis phase of luminaires for IP manufacturing, that corresponds to the intrinsic system of each manufacturer (area defined by dashed polygon). The standardized components purchased from other manufacturers, which are essential to integrate the product, although they may be specified and analyzed separately, are not actually subjected to changes that may occur within the productive system. Once you have made your specification and acquisition, it remains to integrate them as required by manufacturing plan. For this flowchart is possible to verify the origin of each component of the product generated.

The other processes present throughout the life cycle of the product were modelled in simplified form, in order to include in the analysis the effects of choices made in its design. The Functional Unit for LCA (defined set of requirements for analysis of the functional performance of the products) was defined as the **"Lighting service of a public road standard with 500 meters long, 10 meters wide with sidewalks of 2 meters in side, luminaires installed at 8 feet above the ground with arm of 4 meters, run for 12 continuous hours daily during the night, for twenty years, with average luminance of 14 lux minimum along the track, with uniformity at least 0.2 (average night traffic of vehicles and heavy nighttime traffic of pedestrian, according to ABNT NBR 5101/92)[5]. "**

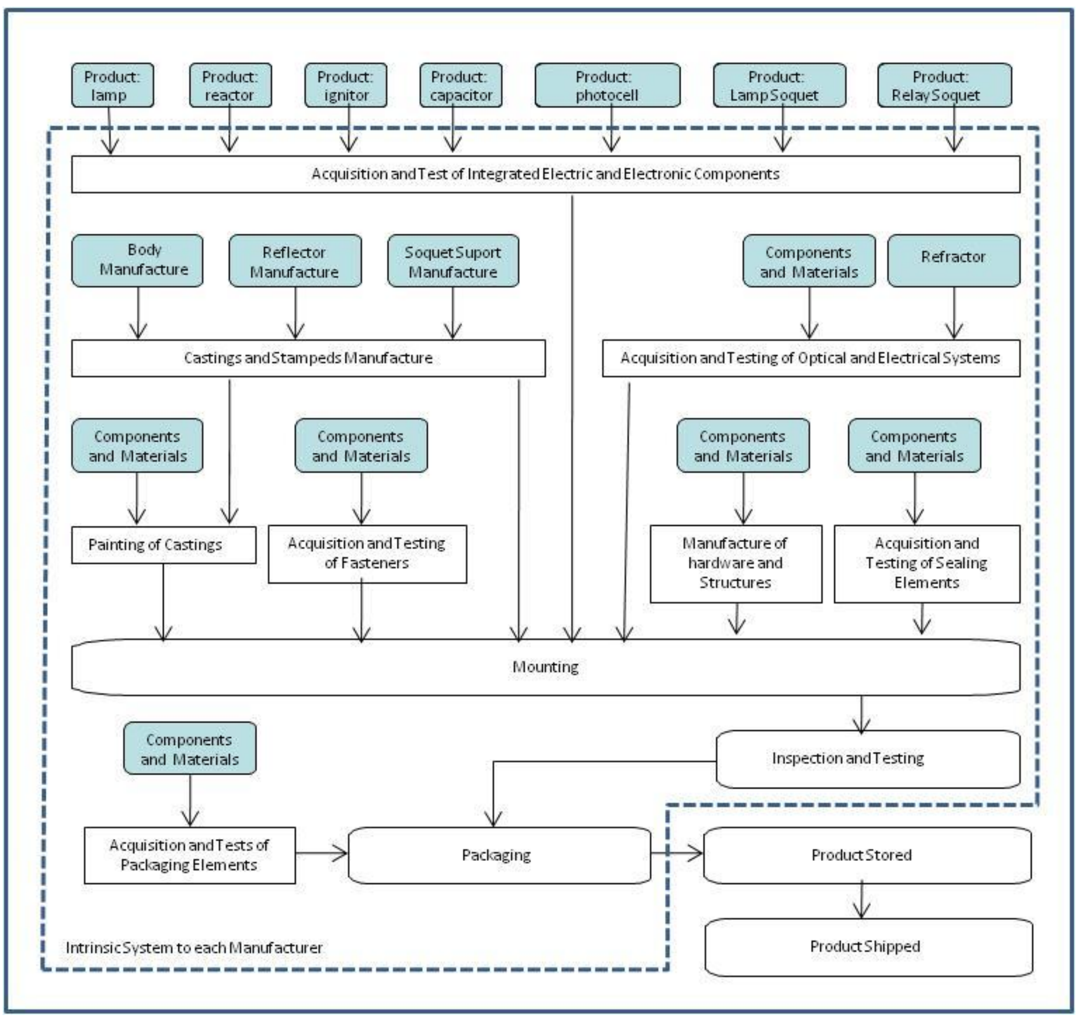

Figure 1 - Flowchart of Public Luminaires Manufacturing Production System. Source: Prepared by author.

The luminaries were disassembled and it was measured the mass of each component, identifying the constituent material. The results are presented in Table 1, where the mass of components and materials of luminaires A and B are presented in a aggregated form by subsystem.

Table 1 – Masses of Luminaires by Subsystems.

Subsystem	**Luminaire A (g)**	**Luminaire B (g)**	**Difference (%)**
I. Fasteners	161,0	110,3	31,5
II. Castings	4.976,0	3.686,9	25,9
III. Hardware and Structures	520,8	342,9	34,2
IV. Electric Connectors Elements	78,4	49,0	37,5
V. Sealing and Heat Dissipation Elements	118,6	77,5	34,7
VI. Painting	78,0	72,8	6,7
VII. Packing Elements	858,0	629,0	26,7
VIII. Optical System Components	1.257,5	683,1	45,7
IX. Integrated Electric and Electronic Components	3.750,4	3.457,0	7,8
Total weight:	11.798,7	9.108,5	22,8

Source: Prepared by author.

To meet the functional unit, it was necessary to simulate a lighting project with the use of each luminaire to be tested. This lighting design was implemented with the tools provided by the manufacturer of each luminaire (specific lighting design software). With this lighting design customized for each luminaire was possible to define the quantity of luminaires required to meet the requirements of the Functional Unit. The most relevant fact is that, by dividing the length of the track to be illuminated by the custom distance between poles (configured for each luminaire according to their photometric characteristic curve) was obtained a constant balancing of masses scheduled for Luminaire A (C = 18.18) and the Luminaire B (C = 14.28) and, consequently, emissions and impacts related to the manufacture of each. Some authors state that the weighted quantity of product needed to meet the requirements of the functional unit should be called "reference flow" since it is associated with a specific product and is used to consider the environmental performance of each[6].

To model the lifecycle of the product, the software used was Gabi 4.0 of PE International, chosen due to the final cost of acquisition, its versatility in the setup process, its scale (allows dismembering generic processes into specific subprocesses) and because of the fact that it contains the brazilian energy matrix in its database. This software allows you to apply and compare some evaluators models of potential environmental impacts widely known such as the Eco-Indicator (EI 99), among others[7]. Figure 2 shows the graph of an analysis carried out, explaining the impacts assessed for each stage of the lifecycle of a luminaire (luminaire A), excluding the highest impact (climate changes), to obtain sensitivity for the other impacts considered by the EI99 method.

Conclusion

The data analysis made in the previous section shows that the technique is effective for the purpose of comparing the environmental performance of two products for the same function and; in the case, luminaries for public lighting.

Despite of the need to establish viable hypotheses for the model of the life cycle of products, such as configuration parameters in the environment that worth supporting software for both products, the comparison is restricted to intrinsic characteristics of products, precisely those scheduled and associated with its design and conception.

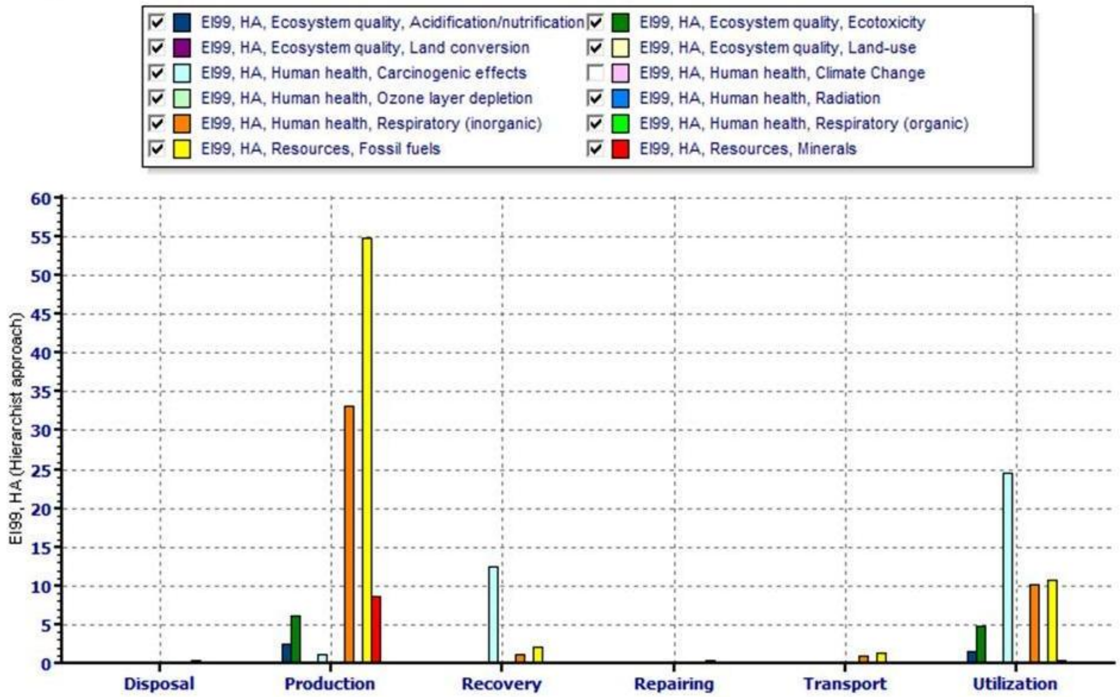

Figure 2 - Impacts generated by the life cycle of the luminaire, measured, normalized and weighted by EI99 method. Source: Prepared by author.

After analyzing the results generated it is possible to draw the following conclusions.

A. With restrictions, the LCA technique is applicable to assessing the environmental performance of public lighting luminaires manufactured in Brazil, if the procedures and parameters to be used for this assessment are established;

B. The technique provides a relatively simple script to identify the main environmental aspects, that cause major environmental impacts related to the manufacture, use (including energy consumption) and disposal of public lighting and, therefore, allows to plan the activities to mitigate them;

Among the limitations, it is understood that the most damaging to the application of the technique in this case was the lack of data on production processes in Brazil. With the emergence of a specific legislation on environmental labelling, there will be difficulties to standardize the analysis because there is insufficient public data of all subprocesses in the factories.

References

[1] Manzini, E. et al. 1998. **O desenvolvimento de produtos sustentáveis**. São Paulo: Edusp.

[2] Associação Brasileira de Normas Técnicas – ABNT. 2004. **Gestão ambiental - Integração de aspectos ambientais no projeto e desenvolvimento do produto,** ABNT NBR ISO 14062. Rio de Janeiro: ABNT.

[3] Associação Brasileira de Normas Técnicas – ABNT. 2009. **Gestão ambiental - Avaliação do ciclo de vida - Princípios e estrutura**, ABNT NBR ISO 14040. Rio de Janeiro: ABNT.

[4] Associação Brasileira de Normas Técnicas – ABNT. 2009. **Gestão ambiental - Avaliação do ciclo de vida - Requisitos e orientações**, ABNT NBR ISO 14044. Rio de Janeiro: ABNT.

[5] Associação Brasileira de Normas Técnicas – ABNT. 1992. **Iluminação pública – procedimento**, ABNT NBR 5101. Rio de Janeiro: ABNT.

[6] Hendrickson, C. T.; Lave, L. B.; Matthews, H. S. 2006. **Environmental life cycle assessment of goods and services – an imput-output approach**. Washington: RFF.

[7] Goekoop, M.; Spriensma, R. 2001. **The Eco-indicator 99 – a damage oriented method for life cycle impact assessment.** Amersfoort: Pré Consultant. Available at: <http://www.pre.nl/eco-indicator99/default.htm>. Accessed: 04 set. 2009.

Life Cycle Assessment of two potential energy production systems in degraded soils on the Coast of Hermosillo, Sonora

Padilla, Set[1]; Girón, Héctor[2]; and Güereca, Leonor[3]

[1,2] Maestría en Ciencias en Desarrollo Sostenible ITESM-CEM; and [3] Instituto de Ingeniería, UNAM

set_padilla@hotmail.com

ABSTRACT

The growing concern about the environmental impact caused by energy consumption has raised a variety of solutions to the problem. Two of them are the production of biofuels and power generation through the capture of solar radiation. The use of agricultural land for biofuel production has raised a series of controversies that have led to propose the use of degraded lands to its production. The coast of Hermosillo meets both degraded soils and high solar radiation, which is why their conditions allow comparison between two systems of energy production by a Life Cycle Assessment. The results are striking: each liter of water consumed during the life cycle of jojoba biofuel production could generate 0.0038MJ, while each liter of water used in steam generation could produce 5.54MJ. The assessments of a series of environmental negative impacts also conclude that the generation of biofuels surpasses those generated by the collection of the solar radiation.

Topic: LCA Industrial Applications. Biofuels, Energy and Mining.

Keywords: biofuels, solar energy, LCA.

INTRODUCTION

Never before, in the history of humanity, has it been so crucial to guarantee that energetic supply be evaluated and managed in function of its environmental impact[1]. (Sims, 2004).

Some initiatives indicate that degraded soils can be used to produce biofuels without detriment to food production. In the Mexican Coast of Hermosillo, Sonora, overexploitation of groundwater and deficient agricultural crops, has turned part of the zone into an unproductive area of 100,000 ha.

However, two questions remain unasked: Is biofuel production the best option to reuse this soil? Which role does the high solar radiation in the area play in energy production?

Using Life Cycle Assessment (LCA) —a worldwide accepted methodology to evaluate environmental impacts and loads in product or process manufacturing— the potential impacts of commercial *Simmondsia chinesis* (jojoba) plantations are evaluated, as well as their oil extraction and refining to get Biofuel, versus a Solar thermal plant with Parabolic Cylinder technology using two different configurations: 50MW and 6-hour thermal storage, and 80MW and no thermal storage combined with other biofuels (rapeseed, soy, and palm oil) produced in other world regions (Eastern Europe, Brazil, and Thailand respectively).

The electric production of these two solar thermal configurations is also evaluated versus the USA energetic mix (2000) due to unavailability of a LCA for the Mexican energetic Mix.

METHODOLOGY

The functional unit is defined as 1 Mega Joule.

The comparison of Solar Thermal Centrals (STC) versus the USA energetic mix has been defined as a 1 MJ_e delivered into the electric power network. The time limit for both systems is 30 years.

Using TEAM 4.0 the following impact categories were evaluated: greenhouse effect (100 years), abiotic resource depletion, stratospheric ozone depletion, human toxicity, aquatic toxicity, terrestrial toxicity, acidification, eutrophication and photo-chemical oxidants, all of them using the CML 2000 methodology.

Tables 1 and 2 show the most relevant variables of both systems. The necessary information to determine the material and services inventory was obtained from the German Aero-spatial Agency, NASA, the SOKRATES[2] project and Universidad de Sonora[3].

Table 1. Hypothetical characteristics of STC with CCP technology on the Coast of Hermosillo, Sonora

Description	80 MW	50 MW	Unit
Mean direct radiation	2,781.3	2,781.3	kWh/m^2,y
Number of CCP	578	685	Units
Solar multiple	SM1	SM2	-
Receiving surface	472,717	559,633	m^2
Full hours	2,580	4,887	h
Load factor	29.45	55.79	%
Lifetime	30	30	y
Energy produced in a year	206,400	244,350	MWh
Energy produced in lifetime	6,192	7,330.5	GWh
Storage capacity	0	6	h
Storage system	-	$NaNO_3$ & KNO_3 (60:40)	-
Solar field efficiency	47.6	47.6	%
Thermal efficiency	35.72	35.72	%
Parasitic load and use	92.33	92.33	%
Net efficiency	15.70	15.70	%
Water consumed	12.20	14.44	hm^3

Table 2. Relevant variable of the production of jojoba methyl ester on the Coast of Hermosillo, Sonora

Description	Quantity	Unit
Calorific value	42.82	MJ/kg
Productivity per hectare	2,000	kg
Pressed oil yield	786	l
Hectares planted	182.50	ha
Plants per hectare	1,250	Plants
Total	228,125	Plants
Rooting survival	80	%
Total survival	85	%
Seedlings to produce	335,478	Seedlings
Number of greenhouses	15	Greenhouses
Plant Capacity to 30 years	10,950	t
Tons processed 30 years	8,960	t
Raw jojoba oil 30 years	3,521.28	t
Methyl ester obtained 30 years	1,825.15	t
Jojoba alcohols 30 years	1.372.99	t
Groundwater consumed 30 years	20,531,250	m^3
Electricity consumed 30 years	10,230,842.6	kWh_e

RESULTS

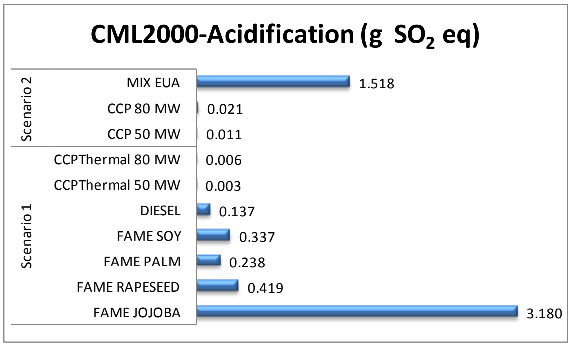

Figure 1. Acidification

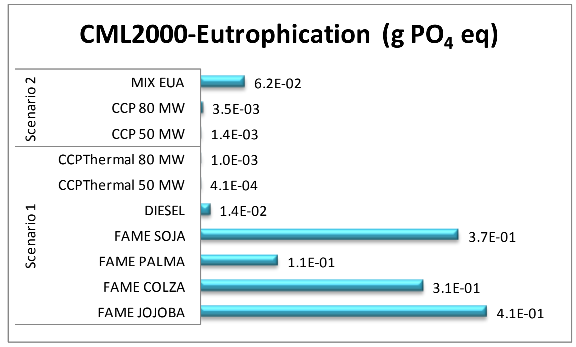

Figure 5. Eutrophication

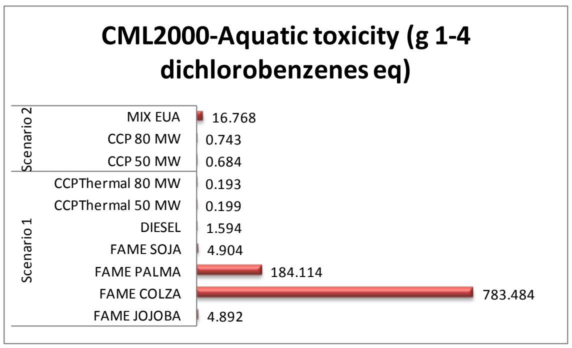

Figure 2. Aquatic toxicity

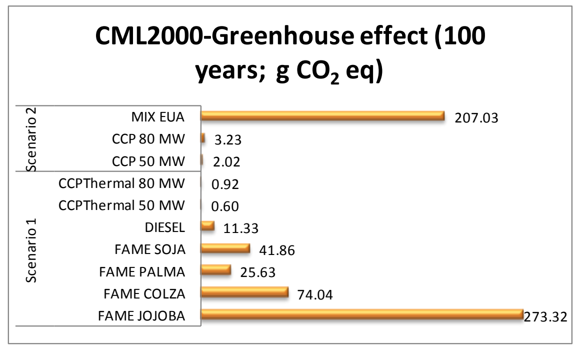

Figure 6. Greenhouse effect (100 years)

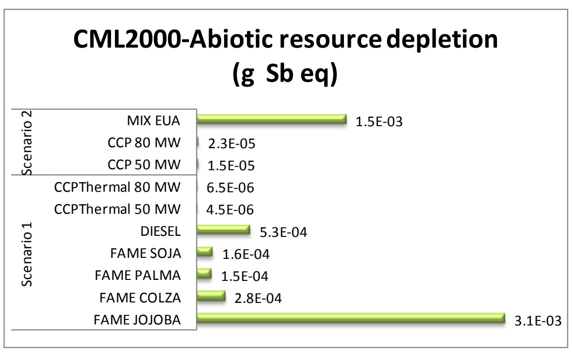

Figure 3. Abiotic resource depletion

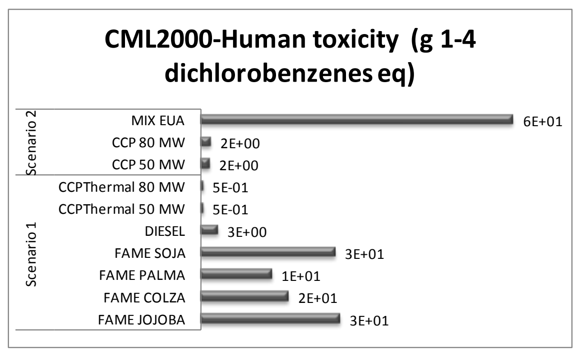

Figure 7. Human toxicity

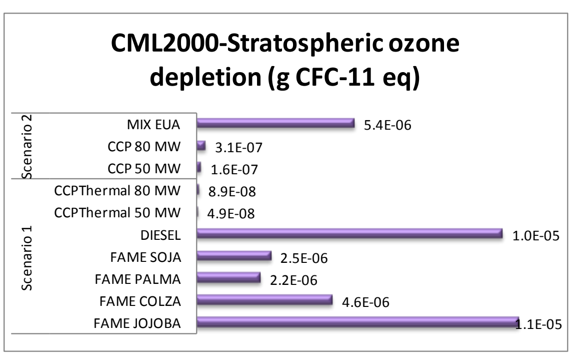

Figure 4. Stratospheric ozone depletion

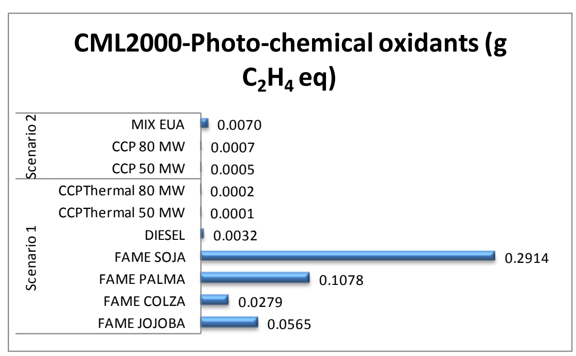

Figure 8. Photo-chemical oxidants

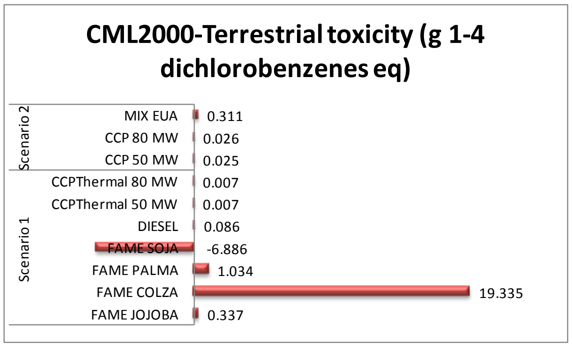

Figure 9. Terrestrial toxicity

INTERPRETATION

These results suggest that jojoba oil production and its subsequent transesterification for biofuel production have significant environmental impacts in comparison with methyl-esters derived from other vegetable oils.

Climatic conditions of the study area make it necessary to build a complementary irrigation system supplied by deep-well groundwater. This model of water extraction would demand a significant amount of electric power reversing the potential environmental benefits that jojoba plantations could offer.

Solar thermal energy production using the evaluated configurations, given the mean direct solar radiation in the area, could achieve a better environmental performance according to the selected categories.

In the second scenario, electric energy production based on radiation intensity through a thermodynamic cycle, could offer a better environmental performance than energy generation based on hydrocarbon combustion. Comparing both configurations, a better performance is achieved in smaller installed capacity configurations that include a thermal storage system.

Comparisons of the results obtained are in line with in the lower range of impacts obtained in other LCA conducted in different regions.

The above mention might be the result of LCA of facilities located in region with a lower mean solar radiation (Europe and Japan[4]).

CONCLUSION

The results obtained by LCA exhibit a low efficiency conversion of solar light into biomass, and the latter into potential energy.

In ideal conditions the 30-year production of jojoba over 6,228 ha. would be necessary to equal the thermal production of one solar camp with 50MW installed capacity and 6-hour thermal storage; or the 30-year production of jojoba in 5261 ha. to equal one 80MW solar thermal plant with no thermal storage.

Moreover, considering the water stress borne by the area aquifers, it is important to point out that each liter of water consumed during the life cycle of jojoba biofuel production, could generate 0.0038MJ, while each liter of water used in steam generation could produce 5.54MJ in both solar configurations

Energy generation through solar concentration systems could significantly diminish the environmental impacts compared to traditional electric generation systems.

REFERENCES

[1] Sims, R. (2004), *Bioenergy Options for a Cleaner Environment*. 1° Ed. Oxford, UK. Elsevier. Pp 1-26.

[2] Viebahn, P. *SOKRATES-Projekt, Solarthermische Kraftwerkestecnologies für den des Erdkima*s, A.P. 2.2.

[3] Castellanos, A. (2009). *Bionergy, Biofuel and Biodiversity in Arid Lands*. DICTUS, USON. Hermosillo, Sonora. Pp 1-29.

[4] Lechón, M. et al (2006). Life Cycle Environmental Impacts of Electricity Production by Solar Thermal Power Plants in Spain. *SolarPACES*. B5-S5.

Life Cycle Assessment of Potential Environmental Impacts of the Brazilian Energy Plan - 2030

ABSTRACT

This article analyses the Brazilian Energy Plan - PNE 2030 proposals, presenting its potential impacts on the environment. It recommends using the LCA - Life Cycle Assessment framework, to properly measure the impact ensuing from changes on the Brazilian energetic matrix profile.

Topic: Sustainable LCA; Energy and Mining
Keywords: Brazilian Energetic Matrix, Potential Environmental Impacts, Nuclear Energy

1. Introduction:

In the last few decades, Brazil has adopted several measures to mitigate the socio-economic and social problems that, although being not focused on environmental concerns, have brought important impacts on this field, with significant reductions in the CO_2 emissions. Moreover, it has also adopted other programs specifically aimed at the CO_2 mitigation, although these are not part of the Annex 01 of the United Nations Framework Convention on Climate Change (UNFCCC), which waives Brazil from these actions, since it is considered to be an emerging country.
Among these measures, the intensified use of the hydro-energetic matrix, and the program on alcohol and biodiesel production, are worth of mentioning [1]. Hydroelectricity and biomass contribute with up to 45% of the total energetic matrix, against a total of 14% in the remainder countries. Therefore, the Brazilian energetic matrix is considered to be “clean”, with reduced emission of greenhouse effect gases, in a context where the energy sector accounts for about 75% of the total CO^2 emissions in the world – the emission pointed out as the main one responsible for the climate changes [2].
The economic development observed in the last few years have led to an increasing demand on the production of energy, signaling the exhaustion of water sources, bringing serious concerns. Studies developed in this area show that the total potential of this segment is of 174 GW, of which 98 GW have already been used, remaining 76 GW mainly concentrated in critical biomes, like the Amazonian and the *Cerrado*. The actual possibility of using this potential is arguable, because of the existence of biological and indigenous reserves in the area, which are protected by legal statutes, additionally to the existence of extensive forest coverage, and the abounding diversity of flora and fauna [3]. One can observe close links between the availability of energy and the Gross Domestic Product – GDP. Within this context, the long-term energetic planning plays a core role, as a way of ensuring the sufficient supply of energy to sustain economic growth. Here one should observe aspects like diversification of sources, search for energy efficiency, and respect to socio-environmental issues, in the light of sustainable development.
In 2007, the Ministry of Mines and Energy (MME) disclosed the National Energy Plan 2030 - PNE 2030, where it discusses the impacts of the demand for economic growth on the energetic matrix. The increasing concern about the emission of greenhouse effect gases urges the discussion about the expected scenarios, since a

change on the Brazilian energetic matrix could have global impacts. Maintaining a “clean” matrix is crucial to place Brazil as a leading nation in the production of CO_2 emission-free renewable energy.
This article approaches the PNE 2030 proposals, presenting some potential impacts on the environment. It recommends using the LCA - Life Cycle Assessment framework, to properly measure the impact ensuing from changes on the Brazilian energetic matrix profile.

2. PNE 2030 – Perspectives to the energy consumption:

The PNE 2030 considers the following values to the average GDP annual growth, from 2003 to 2030: 2.2, 3.2, 4.1 and 5.1%. The total consumption of energy and electric power in 2030 to the maximum and minimum values of the GDP is disclosed below:
Observing Table 1, we can notice that the electric power consumption always increase above the total energetic consumption, and above the reported GDP as well.

Table 01 - Scenario to 2030 – total energetic consumption and of electricity

	Baseline Year 2005	2,2 (*)	5,1 (*)
Total energetic consumption (in 10^6 toe)	165	309	847
Electricity consumption (in TWh)	375	474	1224

(*) GDP average annual growth – 2005 / 2030

Table 2, in turn, shows the link between the GDP growth and energy consumption:

Table 2 - Link GDP/average electricity consumption

GDP average annual growth – 2005 / 2030	2,2	3,2	4,1	5,1
Total energetic consumption (*)	2,5	3,1	3,6	4,3
Electricity consumption (*)	3,5	3,9	4,1	5,1

(*) average annual growth

These results from the larger growth in the services sector, increased participation of higher added value industry, as well as the increased possession of electric household appliances by the population. For planning purposes, the MME assumed the scenario of average GDP growth equivalent to 4.1% a year, which is considered to be the most likely one.

3. PNE 2030 – Perspectives to the electric power production:

According to the PNE 2030, the electric consumption forecasted for 2030 is 225 GW. The existing hydroelectric potential is of 174 GW, and 168 GW are expected to be used until 2030. So, there is a deficit of 61 GW to be coped with by other sources, mainly thermal generation – notably biomass, coal, natural gas and uranium. Figure 1 shows the energetic matrix development. The reduction in the consumption of oil and vegetal coal, as well as the increase in new sources is highlighted:

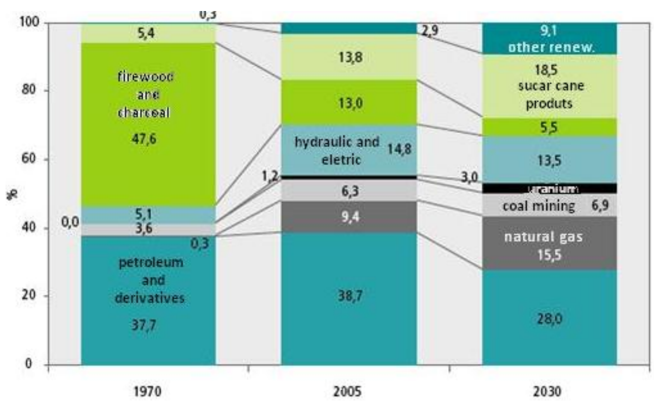

Figure 1 - Structure and development of the Brazilian energetic matrix – from 1970 to 2030.

As regards thermal sources, the nuclear program is restarted with the conclusion of Angra III and the constructing of new power plants at the Southeast and Northeast regions, with impacts on the transmission grid expansion. Up to additional 8 GW are forecasted to the three Angra power plants, meeting 3% of the total demand for electric power. The nuclear program is economically feasible, and the treatment of radioactive debris is dully equated. There are extensive uranium reserves and Brazil masters the cycle of production and ore enrichment.
When it comes to pit coal, the coalfields in the South region house huge volumes of ore adequate for electric power production, with competitive extraction / processing costs from 2015 to 2030. Additional 3.5 GW are expected to the 2.15 GW forecasted for 2015. Based on the

four thermal electric powers currently projected / under construction, which are to work with minimum performance of 35%, the ore currently available allows for the building of, at least, 34 new power plants. Pit coal should account for 6.9% of the total electric power production in 2030 [4].

Regarding natural gas, estimates point out a domestic availability, as of 2030, equivalent to 267 million m^3/day. This raw material is of utmost importance to the chemical industry and to generate industrial heat. Its use for thermal-electric generation brings advantages in the socio-environmental field, constructing time schedule, competitiveness, flexibility and reliability. An 8 GW expansion on the installed basis of the 11,000 MW is expected to 2015/2030. This expansion can develop until it accounts for 15.5% of the total electric power production in 2030, depending on the fuel availability [5].

4. Environmental impacts associated to non-renewable sources of thermal generation:

In 2030, the CO^2 emissions are expected to reach 770 million tons, where oil by-products are mainly responsible for these figures [6].

Here, one should notice the expansion of the iron industry in Brazil, as well as pit coal-fueled thermoelectric power plants, making this energy source account for about 18% of the total CO^2 emissions. The use of pit coal in industrial processes is an important component in the production of greenhouse effect gases, and other residues. However, the use of proper technologies enables an average reduction of 80% of particulates in the atmosphere, and more than 90% of sulphur and nitrogen compounds.

The emissions resulting from the expanded natural gas electric power generation should exceed to 90 million tons of CO^2 in 2030 [7]. Nonetheless, the use of natural gas, when compared to other sources, entails some advantages, reducing the emissions in 20% to 25% in relation to the use of fuel oil, and in 40% to 50% against pit coal. Moreover, the use of proper equipment to burn the gas eliminates the emission of sulphur oxide, soot and particulate materials, while the CO and NOx emissions are fairly well-controlled.

The nuclear energy, in turn, is free from emission of greenhouse effect gases.

5. Discussion:

The electric power production strongly contributes to environmental degradation. Effects can be either local or global, and the quality of air, water, soil and human health can be affected. The greenhouse effect gases generation and air pollution caused by the emission of particulate material are important aspects of this degradation [8].

Brazil has many options to expand the supply of CO^2 emission-free energy. These include the ethanol, biodiesel, use of vegetal oils to produce diesel (H-bio) and electric power generation from renewable sources (co-generation from biomass, wind farms, solar energy), or non-conventional sources (urban residues), additionally to the nuclear energy [7]. Pereira Jr. and his co-workers [9] warn that, if there are restrictions to the extensive use of hydro-energetic reserves, even making intensive use of renewable energies, new alternatives will be required to supplement the energetic need. If the option of supplementation is focused on natural gas, in 2030 the volume of greenhouse effect gases produced could be up to 5 times higher than the total produced by the system in 2005.

The intensive use of hydro-energetic resources makes the matrix strongly dependent on rains and the proper management of reservoirs [10], thus pointing out the need for highly reliable / available sources as a way of keeping an energy flow capable of sustaining the country's development.

6. Recommendation:

The Life Cycle Analysis (LCA) framework is broadly used to assess environmental impacts, besides being a tool recognized worldwide. Using it to assess the energetic matrix's future profile is crucial to guide investments and initiatives of weaker environmental impacts, meeting a social demand for energetic matrixes with less environmental impact. Moreover, a matrix with this characteristic could serve as a tool to affirm the Brazilian policy on environmental preservation before the international forums.

7. References:

[1] Szkloa, Alexandre Salem; Schaeffera, Roberto; Schullera, Marcio Edgar; Chandlerb, William.

2005. **Brazilian energy policies side-effects on CO^2 emissions reduction.** Energy Policy 33:349–364

[2] Manish S.; Pillai, Indu R.; Banerjee, Rangan. 2006. **Sustainability analysis of renewable for climate change mitigation.** Energy for Sustainable Development Vol. X 4:25-36

[3] PNE 2030 "b"– **Brazilian Energy Plan –2030** (In Portuguese)**.** 2007. MME, Ministry of Mines and Energy, Brazil, Cap. Introdução.

[4] PNE 2030 "g" – **Brazilian Energy Plan –2030** (In Portuguese). 2007. MME, Ministry of Mines and Energy, Brazil, Cap VIII.

[5] PNE 2030 "e" – **Brazilian Energy Plan –2030** (In Portuguese). 2007. MME, Ministry of Mines and Energy, Brazil, Cap V.

[6] PNE 2030 "a", "c" – **Brazilian Energy Plan – 2030** (In Portuguese)**.** 2007. MME, Ministry of Mines and Energy, Brazil, Cap. I.

[7] PNE 2030 "d", "f" – **Brazilian Energy Plan – 2030** (In Portuguese)**.** 2007. MME, Ministry of Mines and Energy, Brazil, Cap. III.

[8] Alves, Araujo; Uterbey, Wadaed. 2010. **Environmental degradation costs in electricity generation: The case of the Brazilian electrical matrix.** Energy Policy 38:6204–6214.

[9] Pereira Jr., Amaro Olimpio; Soares, Jeferson Borghetti; Oliveira, Ricardo Gorini; Queiroz, Renato Pinto. 2008. **Energy in Brazil: Towards sustainable development?.** Energy Policy 36:73-78.

[10] Fernandes, E.; Oliveira, J.C.S.; Oliveira, P.R.; Alonso, P.S.R. 2008. **Natural-gas-powered thermoelectricity as a reliability factor in the Brazilian electric sector.** Energy Policy 36:999–1018

Footprinting

CILCA 2011

MÉXICO

Life-cycle costs and benefits of the Car Allowance Rebate System (CARS) program of the U.S
United States

Ecological footprint and environmental sustainability indicators on the campus of Central University “Marta Abreu” de Las Villas, Cuba
Cuba

Carbon and water footprints of vineyards in Mendoza, Argentina
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Brazil

Carbonfootprint for a cracker in Colombia
Colombia

Developing a Network for Environmental Product Declarations and Product Category Rules in the Americas: A Concept Paper
Costa Rica

Carbonfootprint for chocolate in Colombia
Colombia

Life-cycle costs and benefits of the Car Allowance Rebate System (CARS) program of the U.S

Sangwon Suh1 Brian Walseth2

Sangwon Suh[1], University of California, Santa Barbara, United States
Brian Walseth[2] University of Minnesota, United States

The Car Allowance Rebate System (CARS) program of the United States provides \$3,500 - \$4,500 cash incentives for trading in fuel-inefficient vehicles when buying a fuel-efficient vehicle. CARS program aimed at increasing motor vehicle sales and improving the environment. Nearly 680,000 older vehicles were replaced by more fuel-efficient vehicle, and about 3 billion USD has been spent on the program. This paper discusses the life-cycle costs and benefits of the CARS program and the cost-effectiveness of the CARS program as an option that government can exercise to stimulate the economy and to reduce environmental impacts. Detailed make and odometer data for the entire 680,000 vehicles traded-in and the same number of vehicles acquired through the program were retrieved and analyzed using the most detailed life-cycle assessment data available. The impact of job creation was analyzed using US input-output table of 2002. The results show that the CARS program reduced 7.8 million ton of CO_2e as a result of spending 3 billion dollar (Fig 1). This means that marginal cost of GHG abatement through CARS program amounts to \$382/ton CO_2e, while recent market price of CER is around \$10/ton. CARS program is found to increase PM10, PM2.5 and SOx emissions due to the large quantity of these emissions during the manufacturing phase (Fig 2). Furthermore, it is found that the CARS program provided relatively marginal effect on stimulating the U.S. economy using federal taxpayer dollars. The top sales brand under the CARS program was Toyota marking about 1/5 of the total sales. Sales of Honda and Nissan were also significant. While part of these vehicles is manufactured in the U.S., it is also the case that significant part of the vehicles produced by the U.S. automakers are manufactured abroad. Using detailed data on vehicle part origin, we estimate that only 39% of the \$3 billion or \$1.16 billion will remain in the U.S. Therefore, stimulation of U.S. economy through CARS program is ineffective due to large portion of supply-chain residing outside the U.S.

Ecological footprint and environmental sustainability indicators on the campus of Central University "Marta Abreu" de Las Villas, Cuba.

Leiva Jorge[1], Rodríguez Ivan[1], Martínez Pastora[2], Quintana Candido[3].
[1]Chemical Engineering Department. Central University "Marta Abreu"of Las Villas. Road to Camajuaní Km 5.5. Santa Clara, c/p 54830, Villa Clara, Cuba.
[2]Applied Chemistry Center, Central University "Marta Abreu"of Las Villas. Road to Camajuaní Km 5.5. Santa Clara, c/p 54830, Villa Clara, Cuba.
[3] Energy Department. Central University "Marta Abreu"of Las Villas. Road to Camajuaní Km 5.5. Santa Clara, c/p 54830, Villa Clara, Cuba.
***corresponding author: jorgelm@uclv.edu.cu**
Telf: (53) (422)-81164 Fax: (53) (422)-81608

ABSTRACT
In the paper a study of the main systems of sustainability indicators is realized: Commission of Sustainable Development of the United Nations, Organization for the Cooperation and economic Development (OECD), Statistical Office of the European Communities. (EUROSTAT), Scientific Committee on Problems of the Environment (SCOPE), Division of statistics of the UN, (UNSD), and others initiatives. [1]. In order to optimize efforts and time in the pick up of the data and the information processing a screening of all the variables including in the different systems was defined an Index of Relative importance, by means of this index is possible to define the environmental variables most significant on global scale. The main indicators are defined to evaluate in each one of the environmental variables, this is based on the environmental diagnosis of the region that will be evaluate. For the mathematical processing the professional software Mesarovic Globesigth has been used, the software has been donated by the Chair of sustainability of UNESCO in Catalonia, [2].
In the paper the calculation of the ecological footprint of the Central University "Marta Abreu" of Las Villas is realized, the used methodology is the proposal by Lopez Alvarez N. of the University of Santiago de Compostela. The environmental indicators proposed and the footprint are elements for the system of environmental management in our university.
The method is being applied in the campus of the Central University "Marta Abreu" of Las Villas, but it can be extrapolated to other regions and organizations of our country and region. In summary the method permit to evaluate the environmental sustainability on local scale and serves as instrument in the decision making at different levels, allows to evaluate a territory or organization environmentally, as well as the projects of this type which they are carried out in the region and constitutes an element more in the environmental education of all the social actors. The systems of indicators obtained by this method are in correspondence with the main indicators that are reported in our National System of Environmental Indicators.
Topic:
Key Words: Ecological Footprint, Environmental indicators.

INTRODUCTION
For several years the preoccupation exists to determine the negative impacts caused by the man to the nature to satisfy its needs, despite the creation of effective mechanisms to approach the thematic is novel, the first attempts date the nineties year of the past century. One of the pioneers in realizing warnings on the impacts caused by the man to the nature was SCOPE, Scientific Committee on Problems of the Environment of International Council of Scientific Unions). [3]. Different international organizations have established thematic basic for the evaluation of the degree of sustainability in different regions, countries or other scenes, but it is necessary to consider that the indicators reflect politician status, the government form, the culture and idiosyncrasy of the peoples, for that reason the design of a system of indicators must be subject to the established tendencies on international scale but considering the specific characteristics of each region where they will applied.
A sustainability indicators system cannot be extrapolated from a region to another without realizing the adjustments and necessary valuations in order to adapt them at new scenes. [1,4,2].
It's our objectives to design a sustainability indicators system that allow evaluating the environmental performance of the Cuba regions. In this paper the design a sustainability indicators system for the Central University "Marta Abreu" of La Villas serves like an instrument that can be extrapolated to other institutions of our country. Besides adapting a methodology for

calculating the ecological footprint in the Central University "Marta Abreu" of Las Villas.

Sustainable development

The sustainable development does not concentrate exclusively in the environmental questions. In more general terms, the policies of sustainable development affect three areas: economic, environmental and social. In support to this, several texts of the United Nations, including the final document of the World-wide Summit of 2005, talk about the three components of the sustainable development, that are the economic development, the social development and the protection of the environment, as "interdependent pillars that reinforce mutually".

Of more than 300 existing definitions of Sustainable Development, the most used are the enunciated in the Brundtland Report. According to this definition, the Sustainable Development is “the development that satisfies the needs with the present generation without jeopardizing the capacity of the future generations to satisfy its own needs”. (World-wide Commission of the Environment and the Development. 1988).

Indicators

The indicating concept comes from the Latin verb *indicare*, that it means to indicate, to show to a thing with indications and signals. And applied to viability, it is the parameter that provides information on the state of the relation society-nature.

The OECD considers that an indicator is a parameter, or derived value from other parameters, directed to provide information and to describe to the state of a phenomenon with a meaning addition greater than directly associated to its own value. As well, this organism defines the concept of index like a set added or average of parameters or indicators.

In agreement with the previous thing and according to the document “Indicating environmental. A proposal for Spain”: “an environmental indicator is, therefore, a variable that socially has been equipped with a meaning addition to the derivative of its own scientific configuration, with the purpose of to reflect of synthetic form a social preoccupation with respect to the environment and to coherently insert it in the process of decision making”

Thus, an environmental indicator becomes an indicator of sustainability with the addition of the factors of time, limits and objectives. Really, a sustainability indicator could be applied of simple form to concrete dimensions of the sustainable development, for example the economic sustainability, or to be applied to the ecological integral sustainability, that is to say, agglutinating so much component, as social and economic. In this last case, we will be speaking of indicators of integral sustainability.

Ecological footprint

In 1995, W. Rees and Ms. Wackernagel introduced the concept of ecological footprint, concept defined as “the surface of productive territory ecologically necessary to generate the resources used and to assimilate the residues produced by a defined population, with a certain standard of life” [5]. The footprint is a tool of ecological quantification that uses land areas like unit of measurement. By means of this indicator it is observed that the space that occupies the slumses goes beyond its geographic territory.

The ecological footprint is distinguished by its great pedagogical potential and of pursuit of the activity of any organization. This indicator allows comparing the consumption of a certain sector of population with the limited ecological earth productivity.

The ecological track evaluates a certain model of life. It express in hectares by person in one year, representing the planet surface necessary to assimilate the impact of the activities of the analyzed model of life. The footprint of a population is determined by its number of members, the volume of consumption and the intensity in the use of the resources to provide it with goods and services.

2. MAIN SUSTAINABILITY INDICATORS SYSTEMS ON WORLD-WIDE SCALE.

Next the most excellent initiatives on international scale for the design and system application of environmental indicators of sustainability appear. The results corroborate the criteria of Rayen Quiroga [1], specialist of the CEPAL and leader in the Latin America and the Caribbean region in the thematic of sustainability indicators.

I. Commission of Sustainable Development of the United Nations. (CDS).
II. International for Center Tropical Agriculture, World Bank and Program of the United Nations for the Environment. (CIAT-BM-PNUMA)
III. European agency on Environment. (EEA, 2000).
IV. Organization for the Cooperation and economic Development (the OECD)
V. Scientific Committee on Problems of the Environment. (SCOPE)
VI. Statistical Office of the European Communities. (EUROSTAT)
VII. Division of statistics of the UN, (UNSD)
VIII. Institute Worldwatch “Vital Signs”
IX. World Resources Institute.

2.1. *Proposal of sustainability indicators for Cuba.*

For the analysis of the indicators to consider the mentioned most excellent initiatives studied previously, but they adapted based on the diagnoses available as well as by the local, regional and national strategy environmental of the Republic of Cuba [4].

From the methodological and practical point of view the sustainability indicators can be differentiated in four great sub-groups, these are:

1. Social indicators.
2. Institutional indicators.
3. Economic indicators.
4. Environmental indicators.

The methodological support of the system of indicators proposed will evaluate only the environmental indicators, the rest of the indicators: social, institutional and economic they are considered like essential basic premises for the application of the system, this consideration is based on the following elements:

- They would not contribute to significant differences when evaluating them in different spaces or time in the context from Cuba.
- They guarantee a suitable level of fulfillment, which supposes a decent standard of life.

2.2. *Environmental indicators*

In order to know thematic that but frequently is used to measure the performance environmental the defined most excellent initiatives were reviewed previously. Thematic exist altogether 30 that indifferently are used in one or the other sustainability indicators system. In Table 1 are reported the environmental variables that more frequently are included in the environmental indicators systems.

Table 1.Example of environmental variables reported in the different analyzed systems.

Variables	Name	Variables	Name
X1	Atmosphere and climatic change	X16	Fishing
X2	Earth	X17	House Human
X3	The oceans, seas and coast	X18	Health
X4	Water	X19	Noises
X5	Biodiversity	X20	Scenes
X6	Handling and generation of residues	X21	Urban atmosphere
X7	Use of the energy	X22	Eutrophication
X8	Population	X23	Acidification
X9	Economic development	X24	Exhaustion of the resources
X10	Social development	X25	Natural disasters
X11	Food and agriculture	X26	Environment
X12	Forests and mangrove swamps	X27	Wars and conflicts
X13	Industry and materials	X28	Communication and transport
X14	Information and participation	X29	Gender and development
X15	Chemical	X30	Institution and governability

The evaluation of the environmental performance of a country, region or organization must be precise but must as well become by a fast methodological procedure and easy understanding, for that reason it was precise to realize a screening of all the variables including in the different systems.

3. RESULTS AND DISCUSSION

3.1. Procedure for the screening of the variables. Methodology for the calculation of the relative importance of the variables.

1. Repetition of the variable (R), in the different analyzed systems.

   R = (n /N),

   Where: n is the number of times that appear the variable in the different systems and N is the total number of analyzed systems, (9).

2. Relative extension of the variable (ER), in the different analyzed systems.

   - Calculate the fraction of applicability, (FA), number of countries that systematically apply each set of indicators divided by the total number of reported countries, (according UN).

   FA = np /nt

   Where:

   np is the number of countries that apply of systematic form each system of indicators and, nt is the total number of reported countries, 238.

   - To calculation the relative extension of the variable, (ER).

   ER = Σ FA

   Where Σ FA means sum of all the fractions of applicability where appears the variable.

   The value of the relative extension of the variable is standardized for better understanding and interpretations of the results.

3. Index of Relative importance of the variable. (IR).

   IR = (R+ER) /2. (Value between 0 and1).

3.2. Application of the procedure for the screening of the variables

The procedure for the screening of the variables was realized in spreadsheets in Excel. The following table is a summary of the screening of the variables.

Table 2. Environmental variables that present the majors values of relative importance indices.

Variables	**Name**	**Relative importance indices**
X1	Atmosphere and climatic change	1.0000
X2	Earth	0.7203
X4	Water	0.7929
X5	Biodiversity	0.6416
X6	Handling and generation of residues	0.6969
X7	Use of the energy	0.5615

3.3. Procedure of identification of the environmental indicators.

Each one of the six selected environmental variables includes a determined number of indicators, and then it is necessary to define the indicators that really are significant in variable happiness. If we realized a simple aggregation of indicators the result will not be satisfactory, since the damages and significant impacts caused to the environment that jeopardize the future development of the region or organization not visualize with the necessary clarity.

Until this point the elements in the design of the system of indicators can be applied in any region or organization of our country. The own elements of each region, municipality, company or another organizational form are contemplated in the methodological proposal next.

The propose methodology is the following:

1. To review by each environmental variable the damages and impacts that appear reported in the environmental diagnoses.
2. To establish the corresponding indicators based on the previous point.
3. To order the indicators based on the established frame of presentation. (The frame of presentation Pressure, State, Answer is recommended).
4. To analyze the correspondence of the indicator with the proposal of national indicators.
5. To include, exceptionally, some indicator that does not adjust to the environmental variables defined by the Relative importance Index.

3.4. Application of the methodology. Case of study Central University "Marta Abreu" of Las Villas.

Table 3. Pressure, state and answer Indicators for each one of the selected environmental variables in the Central University "Marta Abreu" of Las Villas.

Variable: atmosphere and climatic change		
Pressure Indicator	State Indicator	Answer Indicator
• Emission of SOx (t/year). • Emission of COx (t/year). • Emission of NOx (t/years). • Emissions of Particulate Matter (t/year).	• Concentration of SOx (ppm) • Concentration of NOx (ppm) • Concentration of COx (ppm) • Concentration of Particulate Matter (mg/m^3).	• Spending on reducing air pollution. • % of Fixed Sources with Control system of Emissions • Norms and Laws of Emission (y/n)
Variable: Earth		
Pressure Indicator	State Indicator	Answer Indicator
• Areas of teaching, residential and university extension (ha / ha total)	• % of green areas and gardening	• Program of territorial ordering (y/n) • .Expenses improvement of green areas and gardening
Variable: Potable water		
Pressure Indicator	State Indicator	Answer Indicator
• Annual per person Water consumption (m^3/per person).	• Quality of Waters (according to Cuban Norm)	• Cost in improvements of the treatment, conduction and

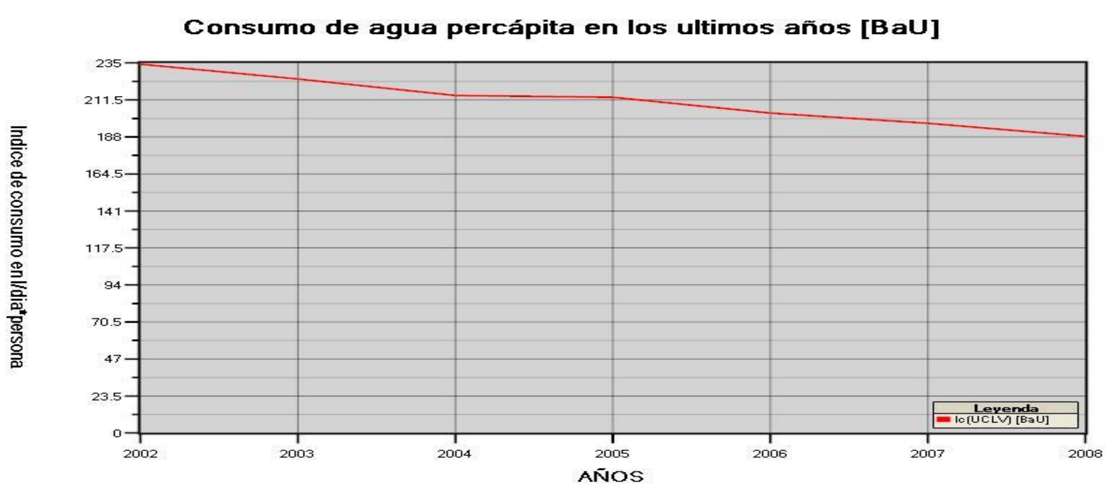
• Pouring non Treated (m^3/per person)		efficient use of the water system • Cost in the diminution of contamination by liquid residuals
Variable: : Biodiversity		
Pressure Indicator	State Indicator	Answer Indicator
• Annual loss of Natural Areas (ha)	• Natural Areas (%) • Species in Danger (% total) • Rate of Extinction of Species (%) • % of Endemic Species	• % of the Protected Territory (%). • Inventories of Biodiversity (y/n). • Resources Inverted in Investigation and protection of the Biodiversity. ($).
Variable: Generation and handling of Residues		
Pressure Indicator	State Indicator	Answer Indicator
• Generation of Dangerous Residues (kg/per person) • Generation of Municipal Residues per capita (kg /per person.)	• Service of Harvesting of Residues according to Cuban Norm (y/n).	• % Residues Recyclings • % of Municipal and Dangerous Residues Ready Correctly • Cost in the diminution of contamination by solid Residues
Variable: Use of Energy		
Pressure Indicator	State Indicator	Answer Indicator
• Per person electrical power consumption (kW. /per person) • Consumed tons of petroleum. (TPE/per person)	• Relation of Renewable Energy and non Renewable Energy consumption (%)	• Potential of bioenergy (MW.)

3.5. *Software Mesarovic Globesight*.

The software was donated by the Sustainability Chair of UNESCO in Catalonia, the same can be used for the processing of the data and the graphic presentation of the results of all the environmental variables, as well as of all the environmental indicators conform them.

As an illustration the results obtained with environmental indicators of the variable Water appear.

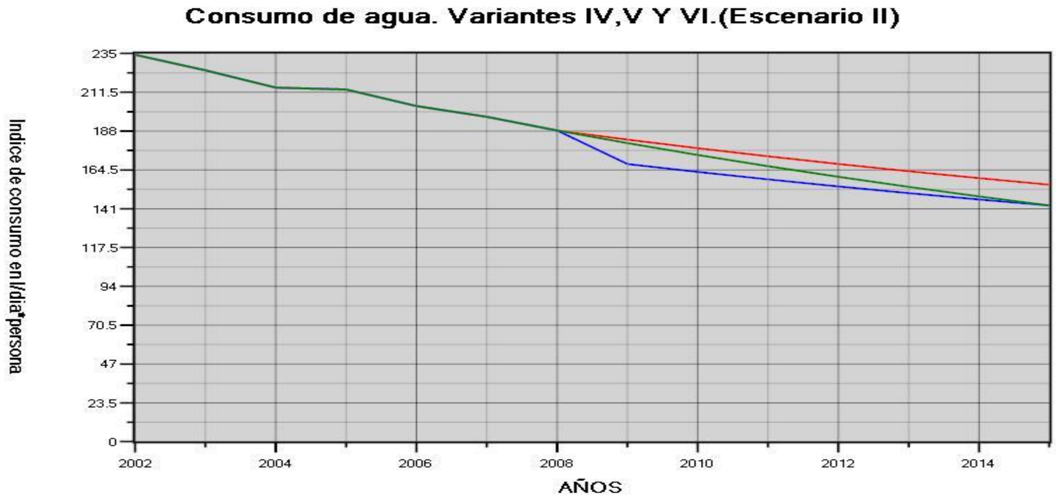
In graph 1 appears the specific water consumption in the last years in the Central University 'Marta Abreu" of Las Villas. This diagram and the following have been obtained from the Mesarovic Globesight.



Graph 1. Real water consumption per person in the Central University "Marta Abreu"of Las Villas in the last years.

Within the possibilities of used software it is the creation of future scenes, as an illustration, we will recreate scene II, with a perspective until year 2015.

This scene II estimates that the number of people in the university continues, until the 2015, with the tendency of growth of the last years, in this scene exist three variants, the variant IV estimated that investments were not realized in the distribution and consumption systems water, the diminution of the index, in this case, only obeys to the increase of the number of person, does not exist a real reduction of the consumption water, nor exists guarantee of satisfaction of all the needs. The variant V considers investments capital where the problems of distribution and water consumption are solved in the course of one year, and the variant VI, considers, him execution staggered of investments until the 2015, that guarantees in that year a per person ideal water consumption. The graph 2 with the variants of scene II appears next.



Graph 2. Tendency in the per person water consumption in the Central University“Marta Abreu” of Las Villas according to scene II.

The graph 2, tendency in the per person water consumption in the Central University” Marta Abreu” of Las Villas according to scene II, considers an increase maintained of the number of people in the University, similar to the experimented during the past years, according to this tendency in 2015 will exist in the university 10414 people and the index of water consumption will be of 143,0 l/day*per person. These prognoses give a valuable referred information to consumptions, necessity of equipment, availability of resources, among others action that help to the integral sustainability.

3.6. Methodology for calculating the ecological footprint in the Central University "Marta Abreu" of Las Villas.

After a bibliographical revision it was decided to use the Methodology for the calculation of the ecological footprint in universities, his author is Lopez Alvarez N. of the Office of Sustainable Development, University of Santiago de Compostela in Spain. [6]. From the point of view of the environmental impact, a university can be considered like a system integrated within its surroundings, with entrances associated to the consumption of natural resources: water, materials (construction of buildings), paper and fuels (electrical energy, calorific energy, mobility) and exits (production of residues). The impact associated to the consumption of natural resources and the production of residues determines from the CO_2 emissions regarding each consumption or type of produced remainder. These emissions later will be translated to surface of forest necessary to assimilate them.

For the calculation of the CO_2 emissions, emission factors are used, obtained of diverse sources, are prioritized the local emission factors, in case these do not exist are used accepted factors internationally. In some cases the emissions are obtained multiplying the consumptions by the emission factors. This happens for the following consumptions: water, consumptions associated to the construction of buildings, electrical energy, calorific energy, consumption of associated fossil fuel to the co-generation, consumption of paper and production of residues. To this amount of forest the occupied space by the university buildings will be added directly also.

The average carbon fixation for a Cuban forest land, that is accumulated in biomass (lives and dead) and ground (vegetal earth and mineral ground), is considered in 5.06 ton CO_2/ha/year, [7], in Results of the estimation of carbon capture in Cuba between years 1989-1997, presented in the Symposium the International measurement and monitoring of the carbon capture in forest ecosystems 18 to the 20 of October of 2001, Valdivia Chile.

From the amount of CO_2 emitted to the atmosphere, dividing by the capacity of fixation of the forest mass, the forest surface is obtained.

The propose methodology by Lopez Alvarez does not contemplate the food consumption, these services assume independent organizations in the universities where development the methodology, in our case is necessary to contemplate it by the weight that it has in the calculation of the ecological footprint of our university. The ecological footprint is calculated applying the following formula:

$$Footprint\left[\frac{ha}{year}\right] = \frac{\text{Emissions}(t\ CO2)}{\left[\frac{\frac{t\ CO2}{ha}}{year}\right]} + \text{Campus area}\left[\frac{ha}{year}\right]$$

3.7. Calculation of CO2 emissions

In the case of having data of consumptions the emission factor is applied directly and CO_2 emissions are obtained, as it is in the following formula, where **um** indicates the unit in which each consumption is computed:

Emissions (kg CO_2) = consumption (um) *Factor of emission (kg CO_2/um)

At the time of determining the emission factors priority to the local factors against the global ones can be given, following the criteria established by Rees and Wackernagel. In some cases the emission factors, as they are in the consulted sources, are not expressed in the same units that the consumptions to which they must be applied; reason why a later transformation is necessary, considering different equivalences between units.

Once the emission factors are known and it is had the consumption data, it is only necessary to multiply by the corresponding emission factor to know the emissions associate. In the case of the construction of buildings one considers that the life utility of the same is of 50 years, since it is the time that esteem that passes without it is necessary to realize works of preparation of sufficient spread like modifying the factor value.

3.7.1. Water consumption

According to data taken from the energy site of the university (http://paec.uclv.edu.cu/) and based on the water flows handled by the plant water-treatment the efficiency index of the system expressed in Kwh/m^3 is of 0.00761. In order to know the amount required fuel in equivalent tons of petroleum (Tep) the conversion factor used, Fc, specific consumption in final use, reported in information of the Ministry of Economy and planning, Fc = 0.352. Tep= Fc* (consumption electrical energy)

Tep = 0,352 * 4,5 = 1.584

In order to obtain the amount of CO_2 released to the atmosphere with the burning fire of this fuel we used the index of 3 CO_2 t by each consumed equivalent tons of petroleum.

t. CO_2 emissions = 1,584 * 3 = 4,752 t

The electrical power consumptions in the plant water-treatment plant were taken from the site: http://paec.uclv.edu.cu/

3.7.2. Buildings construction

In order to know the annual emissions it considers that the life utility of the buildings is of 50 years, since it is the time that esteem that passes without it is necessary to realize works of preparation of sufficient spread like modifying the value of the factor.

According to Report MIES [8], the CO_2 generation of the buildings, with the previous considerations is of the order of 475 kg of CO_2/m^2 in the new constructions and of 104 kg of CO_2/m^2 in the renovations, this for a life utility of 50 years since it has been explained previously. Therefore the index used annually will be:

Annual index of emissions (kg of CO_2/m^2) = 475/50 = 9,5

CO_2 emissions = (kg of CO2/m^2) * (m^2 constructed surface)

CO_2 emissions = (9.5) * (72979)

CO_2 emissions = 693300.5Kg. = 693,3 t

3.7.3. Electrical energy

Will be similar to the previous section, to know the amount required fuel in Tep is used the factor of conversion, Fc, specific consumption in final use, reported in information of the Ministry of Economy and planning.

Fc = 0.352.

Tep= Fc* (consumption electrical energy)

Tep= 0,352 * (3943.23)

Tpe = 1388.01696

In order to obtain the amount of CO_2 Released to the atmosphere with the burning fire of this fuel we used the index of 3 t of CO_2 by each equivalent tons of petroleum consumed.

CO_2 emissions = 1388.01696* 3 = 4164,05 t

The electrical power consumptions in university (2008) were taken from the site: http://paec.uclv.edu.cu/

3.7.4. Mobility

In order to evaluate the CO_2 emissions due to means of transport employed by the students and professors considered the amounts of fuels used annually by the University, since its use is exclusive of the educational activities, research and of Extension University own of the institution. The used fuels, diesel and gasoline, are convert to tons of equivalent petroleum (tpe), finally to obtain the amount of CO_2 released to the atmosphere with the burning fire of this fuel we used the index of 3 t of CO_2 by each consumed equivalent tons of petroleum.

Diesel Consumption (in tpe) =122.085

Gasoline consumption (in tpe) =114.168

Total consumption (in tpe) = 236.765

CO_2 emissions = 236.765* 3 = 710,295 t

3.7.5. Steam generation

In order to evaluate the CO_2 emissions due to the steam generation considered the amounts of fuels (fuel oil) used annually by the University in the generation boilers, the steam is used largely for the baking of foods. The used fuel is taken to Tpe; finally to obtain the amount of CO_2 released to the atmosphere with the burning fire of this fuel we used the index of 3 t of CO_2 by each consumed equivalent tons of petroleum.

Fuel consumption oil (in tpe) =165.229

CO_2 emissions = 165,229 * 3 = 495,687 t

3.7.6. Consumption of paper

The consumption of paper during the year 2008, according to data provided by the department of investments of the Central University "Marta Abreu" of Las Villas, was of 12,2883 t. The index of CO_2 generation by amount of produced paper is of 1,84 kg CO_2 /kg paper, this index is recommended by Lopez Alvarez N. in the elaboration of the Methodology for the calculation of the ecological footprint in universities. [6].

CO_2 emissions =12288.3 * 1,84 = 22610,472 kg = 22,610 t.

3.7.7. Food consumption.

For this paragraph all the foods consumptions of the university during a year were accounting, the data were provided by the subdivision of feeding of the economic department of the Central Universities "Marta Abreu" of Las Villas. In this case the indicator has been calculated basically based on the yields by hectares of the cultures or the productivity of water-bearing, considering the local conditions. The conserve products or those they require of previous elaboration it have considered based on the energy intensity factor for their elaboration.

In total for the production of food and absorption of carbon generated in industrial processes related to food requires a total area of 559.74000 ha

3.7.8. Generation of Residues.

The generation of residues in the Central University "Marta Abreu" of Las Villas in 2008 was of 659113,4 kg. The emission factor in kg of CO_2/Kg of domestic residues considered is of 0,61 [9].

CO_2 emissions = 659113,4 * 0.61= 402059,174 kg = 402,059 t.

Summary CO_2 emissions

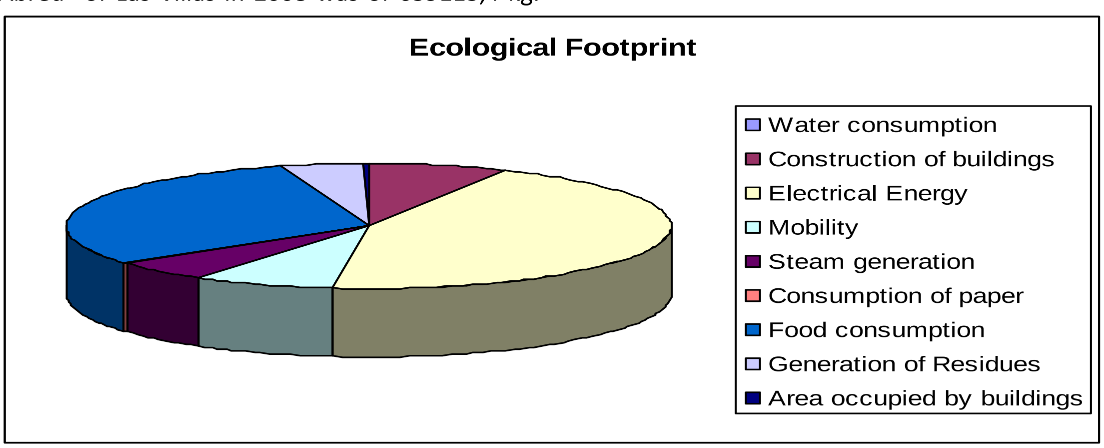
The CO_2 emissions in the Central University of Las Villas in year 2008 appear reported in the following table.

Table 4. Summary of CO_2 emissions and area required for absorption

Category	**Emissions CO_2 (ton/year)**	**Required area (ha)**
Water consumption	**4.752**	**0.93913**
Construction of buildings	**693.300**	**137.01600**
Electrical energy	**4164.050**	**822.93500**
Mobility	**710.295**	**140.37500**
Steam generation	**495.687**	**97.96190**
Paper Consumption	**22.610**	**4.46838**
Food Consumption*	___	**559.74000**
Generation of Residues	**402.059**	**79.45830**
Area occupied directly by buildings	___	**7.29790**
Total	**6492.753**	**1850.19**

*This indicator has been calculated directly based on the yields by hectares.

In 2008, the ecological footprint of the Central University "Marta Abreu" of Las Villas was 0.21516 hectares per person. Below is illustrated in graph 3.



Graph 3. Ecological footprint in the Central University Marta Abreu of Las Villas in 2008.

4.0. CONCLUSIONS

1. Exist different international initiatives referred to sustainability indicators, reflecting each the ways and styles of life, as well as the interests and objectives of their authors.
2. An Indicator of Relative importance has been defined that allows selecting the more environmental representative variables.
3. A procedure for the selection of the environmental indicators has been defined for including in the different selected variables.
4. The Mesarivic Globesigth Software is a valuable tool that allows to graphically process and to present the environmental results of indicators and variables, at the same time allows the construction of future scenes.
5. A methodology has been adapted to our conditions that allows to the calculation of the ecological footprint in institutions of superior education of Cuba.
6. The Ecological footprint in the Central University 'Marta Abreu' of Las Villas in 2008 was 0,21516 ha per person.

5. REFERENCES.

[1]. Quiroga M Rayen. (2001). Indicadores de sostenibilidad ambiental y de desarrollo sostenible: estado del arte y perspectivas. División de medio ambiente y asentamientos humanos. Series manuales # 16. CEPAL, ECLAC, Naciones Unidas, Santiago de Chile, ISBN 92-1-321911-3 pp. 117.

[2]. Sureda, B. (2002). Hacia la valoración de la sostenibilidad de una región teniendo en cuenta su capacidad de carga y sus aspectos sociales, según los diferentes criterios de sostenibilidad. En VI Congreso Nacional de Medio Ambiente. Madrid: Fundación CONAMA.

[3]. SCOPE (2000): Environmental indicators, a systematic approach to measuring and reporting on the environment in the context of sustainable develoment in, indicators of sustainable develoment for decision-making, Eds. N. Gouzee, B. Billharrz, Federal Planning Office,Bruselas: 1-25

[4]. Leiva Mas J. (2007). Selección de variables para la evaluación del desarrollo sostenible a escala local. Memorias tercer Simposio Internacional de Química. Santa clara, Cuba5 -8 de Junio (2007), ISBN 978-959-250-337-3.

[5]. Wackernagel, M.; Rees, W. (2001). Nuestra huella ecológica: Reduciendo el impacto humano sobre la tierra. Ediciones LOM. Santiago de Chile.

[6]. López Álvarez N. (2009). Metodología para el Cálculo de la huella ecológica en universidades. Universidad de Santiago de Compostela. Oficina de Desarrollo Sostenible. 6

[7]. Manso R. (2001). Resultado de la estimación de la captura de carbón en Cuba entre los años 1989 y 1997. Simposio internacional de medición y monitoreo de la captura de en ecosistemas forestales. 19 al 20 de octubre 2001. Valdivia Chile.

[8]. Cuchí, A., López, I. (1999). Informe MIES. Una aproximació a l'impacte ambiental de l'Escola d'Arquitectura del Vallès. Bases per a una política ambiental a l'ETSAV, Universidad Politécnica de Cataluña con el apoyo del Departamento de Medio Ambiente de la Generalitat de Cataluña.

[9]. Iregui, G.; Marañón, E. (2008). Proposta de índices de conversión de residuos para la huella ecológica. Universidad de Oviedo.

[10]. Domenech, J. L. (2004). La huella ecológica empresarial: el caso del puerto de Gijón. Actas del VII Congreso Nacional de Medio Ambiente. 22-26 Nov., 2004. Madrid. CD-ROM: 8 pp.

[11]. E. Carreras, JJ Felipe, B. Sureda, N. Tollin.(2006) Composite Indicators: A methodology proporsalfor alternative design. I International Conference on Sustainability Measurement and Modelling. Terrassa, España, 16-17 de noviembre 2006. ISBN 84-96736-36-7.

[12]. IVMA. Estrategia Ambiental de la Universidad Central "Marta Abreu" de las Villas. Instituto virtual de medio Ambiente. Universidad Central "Marta Abreu" de las Villas. 2008.

[13]. López Álvarez, N; López Rodríguez, R; Taboada Fernández, J. L. (2008). Impacto ambiental en centros da USC; Coordinación do Plan de Desenvolvemento Sostible da Universidade de Santiago de Compostela e Consellería de Medio Ambiente da Xunta de Galicia,

[14]. Mesarovic, M D., McGinnis, D.L., and West, D.A., *Cybernetics of Global Change: Human Dimension and Managing of Complexity*, MOST Policy Paper 3, UNESCO, Paris, 1999.

Carbon and water foorprints of vineyards in Mendoza, Argentina.

Civit, Bárbara[1,2] Curadelli, Silvia[1] and Arena, Pablo[1,2]
[1]Universidad Tecnológica Nacional Facultad Regional Mendoza – Cnel. Rodríguez 273 (5500) Mendoza, Argentina - ++54 261 5243001
[2]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
bcivit@frm.utn.edu.ar

Abstract

Key words: wine industry, environmental impacts, carbon footprint, water footprint

Topic: LCA Management Trends – Carbon and water footprints

Introduction

Argentina is the world's fifth largest wine producer and more than 70% of the vintages are located in Mendoza province. Local winemakers have conquered markets of demanding consumers for whom sustainability is more and more relevant. So, it is important for wineries to calculate indicators such as carbon footprint (CF) not only to increase the sales but also to keep them. On the other hand, as Mendoza is located in an arid region, the use and consumption of water is crucial.

This study presents the calculation of carbon and water footprint (WF) for grape cultivation in Mendoza, Argentina.

Material and Methods

This study considers agricultural activities such us land maintenance, irrigation, fertilization, prune, phytosanitary product's application and grape harvesting. Land preparation and planting are not taking into account because the research is made in an existing vineyard located in Junín, Mendoza.

Figure 1. a) Irrigated vineyard in Mendoza - Argentina; b) Vines in winter in Junín, Mendoza, Argentina

SimaPro V. 7.1 ® is used for the calculation of CF. WF is calculated following the method proposed by [1] from the Water Footprint Network. The model

CROPWAT 8.0 [2] is used to calculate the crop water requirement.

Results and Discussion

Figure 2 shows the results obtained per activity involved in Kg CO_2 eq. The most impacting activities are the use of electricity, the use of Glyphosate, and the use of fossil fuels associated with transport inside and outside the vineyard. The total carbon footprint obtained for production grapes is 0,69 Kg CO_2 eq.

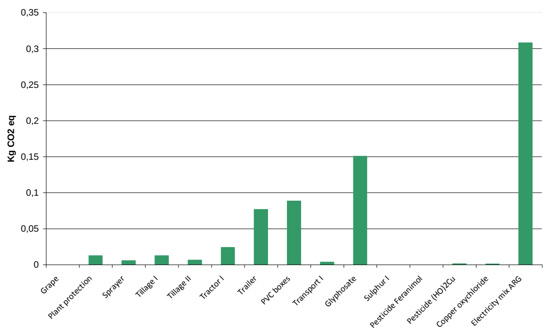


Figure 2. Kg CO2 eq per activity.

Total Water Footprint for grape production in the considered plots is m^3/ton, being green WF 324 m^3/ton and blue WF is 3059.5 m^3/ton. Gray WF is negligible. Total WF is higher than others calculated different wine regions, such as France, California or Italy, mainly because of the scarce rainfall, high temperature and isolation.

Conclusion

The obtained results make a significant contribution to the sustainable resource use according to the local conditions. The agricultural stage is one of *hot spots* where actions to diminish emissions of greenhouse gases and water use should be made.

References

[1] Hoekstra A, Chapagain A, Aldaya M, Mekonnen M. 2009. Water Footprint Manual State of the Art Enschede, The Netherlands. Water Footprint Network

[2] FAO (2009b) CROPWAT 8.0 model, Food and Agriculture Organization, Rome, Italy.

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Implementation of water and carbon flows in the ecoinvent database

Author 1[1], Author2[1]
[1]Affiliation
E-mail contact:

ABSTRACT
The correct assessment of carbon and water contents during LCA studies needs the support of reliable, consistent and balanced flows in the product system. To adequately implement those flows, the mass, carbon and water contents of every product, resource and elementary exchange in the ecoinvent LCI database have been inventoried. On a first stage of data collection, the information regarding mass, and carbon and water contents provided in the database can be seen as validation help: Are mass, water and carbon inputs and outputs in balance for my unit process? Are my assumptions consistent with those made by the ecoinvent database? Secondly, mass, water and carbon balances can be established for the product systems, thus supporting consistent water and carbon accounting for products. The new structure of the ecoinvent database version 3 allows establishing products systems with both partitioning (allocation) and substitution (system expansion). For the models with substitution, mass, water and carbon balances are maintained also for the product systems, since these are simple aggregations of the already balanced unit processes. For system models with allocation, only one balance can be maintained at a time, namely that which is used as allocation key. The ecoinvent database is therefore supplied with separate system models with mass allocation and carbon allocation (in addition to revenue/value allocation). For the system model using value allocation, a carbon correction is applied to ensure correct carbon balancing in spite of the allocation according to value.

Keywords: LCI, Carbon content, Water content

INTRODUCTION

The importance of the water and carbon flows

Today, the term “carbon footprint” is often used as shorthand for the amount of carbon, being emitted by an activity or organization. Similarly, the “water footprint” looks the total volume of freshwater used to produce goods and services.

The calculation of those footprints is being rapidly implemented by several initiatives worldwide. With this in mind, the ecoinvent Centre has decided to include the new properties carbon and water in all datasets. Information on mass, carbon content and water content has been added to every ecoinvent product, resource, and elementary flow and will be available to users.

The ecoinvent database structure

The ecoinvent LCI database has recently implemented the explicit modelling of markets as separate unit processes, proposed by Weidema (2003)[1]. The implementation of market datasets assures the total independence of all and each dataset from each other.

The way the independent datasets are linked in the ecoinvent version 3 database is defined by the system models implemented on it. Those models provide the rules for linking activity datasets into product systems.

Two types of system models are actually supported by the ecoinvent database. Attributional system models create single-product datasets by partitioning (allocation), while consequential system models create single-product datasets through substitution (system expansion).

RESULTS

Implementation of additional mass, carbon and water flows in the ecoinvent database

Regarding mass, carbon and water flows, the following properties were calculated for all products, resources, and elementary exchanges (”Elementary Flows” in the ISO 14040 series): wet mass, dry mass, and water mass, given per unit of the exchange, and water and carbon content per dry mass, the latter subdivided in fossil carbon and biogenic carbon.

Some of those values were already reported in the ecoinvent datasets or reports, but are now systematically available as properties, in separate fields. All missing data have been calculated now. For those calculations, certain assumptions have been made. That way, most frequent species or average molecules have been, when needed, defined in order to represent a category of molecules or products. In the case of undetermined elementary exchanges (“Hydrocarbons, chlorinated”, to air or “Herbicides, unspecified”, to water) the precise compartment (air, soil, water) where they were released was taken into account when defining the most frequent species.

Wet mass, Dry mass, Water mass and Water content

Wet mass (WM), Dry mass (DM), Water mass (W) and Water content (U) were calculated for all exchanges in the ecoinvent database. Dry mass is calculated as the wet mass minus the water mass, and thus includes chemically bound Hydrogen and Oxygen. Water content is defined as the Water mass on a Dry mass basis, and it is calculated by dividing the Water mass of a product by its Dry mass.

Table 1 – Conversion table.

Wet mass (WM)	Dry mass (DM)	Water mass (W)	Water content (U)
WM	WM-W	W	W/(WM-W)
WM	DM	WM-DM	(WM-DM)/DM
WM	WM/(1+U)	U*WM/(1+U)	U
W+DM	DM	W	W/DM
(W/U)+W	W/U	W	U
(1+U)*DM	DM	DM*U	U

Given any two of the four mass and water properties, the remaining two can always be calculated after that. The given properties are marked in grey; the calculations are marked in white.

Fossil and biogenic carbon

The carbon content has been calculated on a Dry mass basis. A distinction is made between fossil and biogenic sources of carbon. The sources of fossil carbon are fossil fuels and calcium carbonate, while the sources of biogenic carbon are plants and animals.

In the case of products, the fossil or biogenic origin of carbon has always been estimated considering the final product, and the production process itself. In most of the cases, the origin of the carbon and the nature of the final product do instinctively fit together. It is the case of agricultural products: carbon content in seeds (calculated with the help of USDA National Nutrient Database[2]) was of course biogenic. The same for carbon content in limestone or fossil fuels, that was obviously fossil. But there are other products, where the origin of the carbon in their composition was surprisingly more diverse.

Let us take the example of paper and board. We have established that LWC (lightweight coated) wood containing paper has a content of 0.28 kg C/kg DM. From that amount, 0.25 kg have a biogenic origin (that will be the carbon imputable to cellulose fibres in pulp, and to starch) and 0.03 kg have a fossil origin (imputable to the carbonate and chemical products contained in the final product[3]). The same situation occurs in the different types of papers and cardboards inventoried in the ecoinvent database. A part of the carbon content in the different types of papers and boards is fossil, due to the chemicals involved in its formulation.

The example of esterquats is also interesting. Esterquats are produced by esterification with triethanolamine (TEA) and quaternisation with dimethylsulphate (DMS) of fats[4]. The ecoinvent database includes two processes concerning the fabrication of esterquats, in one the fat is coconut oil or palm kernel oil, as in the other it is tallow. Therefore, in an esterquat molecule, a part of the carbons in the molecule have a biogenic origin (oil or fat), while the others have a fossil one (TEA, DMS). Precisely, the carbon content of an average esterquat[5], was considered 0.72 kg/kg DM, from which 0.52 kg had a biogenic origin, and 0.20 kg, a fossil origin.

In the case of elementary flows inventoried in the ecoinvent database, many of them had specifically a fossil or biogenic origin. Thus, there exist two flows concerning the carbon dioxide emitted to air: "Carbon dioxide, non-fossil" and "Carbon dioxide, fossil". Similarly, the carbon content in the elementary exchanges "Abamectin" and "Spinosad" (emissions to soil) has unequivocally a biogenic origin. Abamectin[6] and Spinosad[7] are pesticides obtained from the metabolisms of *Streptomyces avermitilis* and *Saccharopolyspora spinosa* respectively. But biogenic and fossil carbon can be found in the same exchange of course. Of the total 0.50 kg/kg DM of carbon in "Ethyl cellulose" emitted to air, 0.38 kg are biogenic, as they correspond to the cellulose fibres in the molecule.

Nevertheless, there are a number of elementary flows where the carbon can have a biogenic or a fossil origin, depending on the activity the flow will be associated to. It is the case of "Oils, unspecified" emitted to soil, or of "Methanol" emitted to air, that can have a biogenic or a fossil origin. It is also the case of many other exchanges, where both a biogenic and a fossil origin are possible.

In those cases, a generic ratio fossil:biogenic carbon has been estimated and applied. This ratio has been calculated using data concerning global material uses and mass flows in Steinberger *et al*. (2010)[8]. This paper presents a new global material flow dataset compiled for the year 2000, covering 175 countries, comprising biomass, construction minerals, fossil energy carriers and ores/industrial minerals. It estimates the Global Domestic Material Consumption (DMC), which represents apparent consumption, in 48.5 billions tonnes/year. Of that, it has been considered that 10.1 billions tonnes are fossil fuels[8], 0.3 billions tonnes are extracted limestone (ecoinvent production volume data), and 17.5 billions tonnes are biomass[8].

Carbon content in fossil fuels was calculated as follows. First, a distinction between high carbon content fossil fuels (petrol and coal) and low carbon content fuels (natural gas, lignite...) was made, using ecoinvent production volume data. 8.9 billion tonnes were then considered being petrol and coal, and 1.2 billion tonnes low carbon content fossil fuels. Carbon content in high carbon content fossil fuels was considered 0.85 kg/kg DM, while carbon content in low carbon content fuels was assumed to be 0.60 kg/kg DM.

Carbon content of limestone has been determined to be 0.11 kg/kg DM, while an average carbon content of 0.50 kg/kg DM of biomass has been used. This last assumption is issued from the carbon content of the different biomolecules composing biomass (proteins, fats, carbohydrates and fibres[9,10]). Biomass was considered to have 10% W; that is DM is 90% of the total WM.

Therefore, total fossil carbon and total biogenic carbon in global DMC where calculated. The addition of both types of carbon yielded the total amount of the carbon flow on a global perspective. Thus, the proportion of the different types of carbon regarding the total gave us a global ratio of fossil:biogenic carbon, that resulted to be 50:50. That ratio was then applied to exchanges where no origin distinction could be predicted for the carbon content. It is expected that the specific activities would have other repartition ratios fossil:biogenic carbon than 50:50, but the adaptation of this default ratio will have to be performed at the level of each activity in the ecoinvent database.

CONCLUSION

The only way a correct water or carbon footprint can be guaranteed is if all flows participating in the final product for which the footprint is implemented are taken into account. The carbon and water contents in those flows need to be accurately calculated, and assumptions have to be transparent and consistent among themselves, to avoid double counting or improper fossil/biogenic classification of carbon. Those flows demand the complementary information of mass content. All those issues have been approached by the ecoinvent database, which has implemented mass, carbon and water content for every product, but also for every resource or elementary exchange.

Because of its modular structure, the ecoinvent database supports the aggregation of those flows in the product system, thus yielding a balanced dimension of carbon and water content, when consequential system models are used. In those models, since all the originally balanced unit processes are maintained intact (no partitioning), and simply scaled to accommodate the required change in product output, there is no way these unit processes can become unbalanced, except by error. On the other hand, when attributional system models are used, only one balance can be maintained at a time, namely that which is used as allocation key. The ecoinvent database provides then separate system models with mass allocation and carbon allocation (in addition to revenue/value allocation). For the system model using value allocation, a carbon correction is applied to ensure correct carbon balancing in spite of the allocation according to value.

Furthermore, the implementation of those new properties allows an instant and continuous self check during data entry, where assumptions regarding mass, carbon and its origin, and water can be cross-checked with data offered by the ecoinvent database.

[2] Weidema BP. 2003. Market information in life cycle assessment. Copenhagen, Denmark: Danish Environmental Protection Agency. Environmental Project no. 863.

[2] United States Department of Agriculture, Agricultural Research Service. 2010. Nutrient Data Laboratory. www.ars.usda.gov/nutrientdata. Accessed 10 01 2011.

[3] Hischier R. 2007. Life Cycle Inventories of Packagings and Graphical Papers: Part III, Papers and Boards. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories. ecoinvent-Report No. 11-III.

[4] Zah R, Hischier R. 2007. Life Cycle Inventories of Detergents. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories. ecoinvent-Report No. 12.

[5] Mishra S, Tyagi VK. 2007. Ester Quats: the novel class of cationic fabric softeners. J Oleo Sci 56:269-276.

[6] Cornell University Cooperative Extension. 2008. Pesticide Management Education Program. Pesticide Information Profile: Abamectin. pmep.cce.cornell.edu. Accessed 10 01 2011.

[7]Oregon State University. Extension Toxicology Network. Pesticide Information Profile: Spinosad. extoxnet.orst.edu. Accessed 10 01 2011.

[8] Steinberger JK, Krausmann F, Eisenmenger N. 2010. Global patterns of materials use: A socioeconomic and geophysical analysis. Ecological Economics 69:1148-1158.

[9] Nemecek T, Kägi T. 2007. Life cycle inventories of Swiss and European agricultural production systems. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories. ecoinvent-Report No. 15a.

[10] Rouwenhorst RJ, Jzn JF, Scheffers WA, van Dijken JP. 1991. Determination of protein concentration by total organic carbon analysis. J Biochem and Biophys Methods 22:119-128.

Rethinking water policy in water-scarce countries: lessons learned from a life-cycle water footprint perspective

Guido Sonnemann, Sonia Valdivia and Maite Aldaya
United Nations Environment Programme, Division of Technology, Industry and Economics, Sustainable Consumption and Production Branch, 15, rue de Milan, F-75441 • Paris CEDEX 09 • France
E-mail contact: Guido.Sonnemann@unep.org

1. Introduction

As water resources are unevenly distributed and, in some regions scarcity and droughts are increasing both in frequency and intensity, concerns about them are also becoming more and more important on the political agenda.

In this context, the United Nations Environment Programme (UNEP) as part of the UNEP's umbrella project entitled 'Water Footprint, Neutrality and Efficiency' (WaFNE) [1, 2] is addressing the growing need to further enhance water efficiency and to improve water quality more holistically, by applying harmonized concepts in water-intensive industries and water-stressed areas especially in the developing world. The final objective is to improve water governance through the engagement of the public and private sectors (business and industry, including financial services) in collaborative work with UNEP.

In the same line, developments and discussions on the water footprint indicator are being held under different forums, such as the UNEP/SETAC framework for life cycle impact assessment [3], the Water Footprint Network [4] and the ISO 14046 Water Footprint Initiative Subcommittee [5].

2. Materials and methods

The water footprint is an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer along the life cycle of products [6]. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. A water footprint can be calculated for a particular product, for any well-defined group of consumers (e.g. an individual, family, village, city, province, state or nation) or producers (e.g. a public organization, private enterprise or economic sector). The water footprint is a geographically explicit indicator, not only showing volumes of water use, but also the locations.

3. Results and discussion

The estimation and analysis of the water footprint is very useful to facilitate an efficient allocation of water and investments. This analysis can provide a transparent and multidisciplinary framework for informing and optimising water policy decisions. Closely linked to the concept of water footprint is the concept of virtual water trade, which represents the amount of water embedded in traded products. A nation can preserve its domestic water resources by importing water-intensive products instead of producing them domestically. These domestic 'water savings' can be used to produce alternative, higher-value crops, to support environmental services, or to serve other domestic needs. At the global level, virtual water embedded in agricultural commodities can be exported from water abundant to water-scarce regions, encouraged by the low cost and speed of food distribution. This could help to improve global water use efficiency, while at the same time ensuring food security.

Traditionally, governments responsible for water resources management have targeted their policies towards direct water users (such as farmers, industries and households). Recently, however, it has been shown that this approach is limited. Indirect water users and managers, such as final consumers, retailers, traders and all sorts of businesses active along the supply chains of final consumer goods remain out of the scope of governmental policies aimed at mitigating water scarcity and pollution. All water use in the world, however, is ultimately linked to final consumption by consumers. It is therefore interesting to analyze these new multi-sectorial policy aspects and multi-actor approach that have the potential contribute to a better management of water resources.

4. Conclusions

The present paper shows the importance of a detailed supply-chain assessment in water footprint accounting. Common practice in business water accounting is mostly restricted to the analysis of operational water use. On the other hand, the traditional national water accounting has mainly focused on the use of domestic water resources.

From the sustainability of national consumption perspective, the use of water outside the borders of the country should also be analysed.

5. References

[1] UNEP, 2010. Water Footprint, Neutrality and Efficiency (WaFNE) http://www.unep.fr/scp/water/WAFNE.html Accessed 30 November 2010

[2] Morrison, J. and Schulte, P., 2010. Corporate Water Accounting - An Analysis of Methods and Tools for Measuring Water Use and its Impacts. UNEP, The CEO Water Mandate. http://www.pacinst.org/reports/corporate_water_accounting_analysis/corporate_water_accounting_analysis.pdf Accessed 30 November 2010

[3] UNEP/SETAC, 2010. The Life Cycle Initiative http://lcinitiative.unep.fr/ Accessed 30 November 2010

[4] Water Footprint Network, 2010. Water Footprint Network http://www.waterfootprint.org/ Accessed 30 November 2010

[5] ISO 14046 Water Footprint Initiative Subcommittee, 2010. http://www.iso.org/iso/iso-focus-plus_index/iso-focusplus_online-bonus-articles/isofocusplus_bonus_water-footprint.htm Accessed 30 November 2010

[6] Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2009) Water footprint manual: State of the art 2009, Water Footprint Network, Enschede, the Netherlands.

Carbon footprint in the international supply chain of Colombian cut roses

Parrado Carmen Alicia[1] and Leiva Fabio R.[2]
[1] Centro de Bio-Sistemas, Universidad de Bogotá Jorge Tadeo Lozano, Bogotá, Colombia. carmen.parrado@utadeo.edu.co
[2] Facultad de Agronomía, Universidad Nacional de Colombia

Abstract

Carbon footprint (CF) and carbon statement are concepts developed to describe the amount of greenhouse gas emissions - GHG generated by a particular good or service in its life cycle and is usually expressed in CO2 equivalents (CO2- eq.) Currently, these concepts are considered hot topics in the debate about climate change and have led to growing interest in estimating and reporting the total amount of GHG emitted in the production, processing, transport, sale and use of many consumer goods, including agricultural products (Smith et al., 2005; Tzilivakis et al., 2005; Nonhebel, 2006).

Colombia with about 7509 hectares in production ranks second in flower-exporting countries. Roses are among the major ornamental products and represent 32% of the value of Colombian export flowers. In recent years, aspects related to environmental responsibility, including energy consumption, GHG emissions and environmental and social impacts caused in this supply chain, have gained an important place within the requirements of traders and consumers, becoming a central factor for competitiveness of the flower sector in this country.

The objective of this study was to determine the CF of rose-cut steam for the UK and USA markets in different production systems of high tropical Colombia in the framework of life cycle assessment, including an analysis of consumer perception about information pertaining to these aspects. Results showed that in the rose supply chains to markets in England and USA, the largest contribution to FC is given by air transport, followed by NO_2 due to fertilization and CO_2 from the cooling process.

Keywords: Flower crops, Life Cycle Assessment, Environmental Responsibility and Sustainable Agriculture.

Conference topics: LCA management trends – Carbon footprint

Introduction

Flower production is an important sector for economic development in Colombia, representing the second largest source of foreign exchange from exports of agricultural products. It is a production system characterized by intensive use of energy, natural resources and labour. In the context of globalized markets, flower growers seek to meet international quality requirement by incorporating technological developments in crop production and marketing, including improvements of logistic for packaging and transport, and by complying with socio-environmental regulations in order to ensure their economic competitiveness (Tenjo, 2007) and sustainability.

Concerns about climate change and its relation to agricultural production and international trade have led to increasing interest in carbon footprint (CF), which allows estimating the total amount of greenhouse gas emissions - GHG during the production, processing, retail and use of consumer goods, including food, fiber and ornamentals. According to Edwards-Jones, et al., (2009) CF may have different uses within the commercial and business context and although not all necessarily have a direct impact on international supply, there are at least three aspects in which CF could impact on trade: carbon labels, producers' commitments to reduce CF and GHG emissions taxes.

In Colombian flower production, determining CF is gaining an important space as a way to face growing requirements of marketers and consumers particularly from Europe. As an added value, farmers have found options to increase production efficiency and to improve communication of their internal environmental management.

The objective of this study was to determine the CF of rose-cut stalk for the UK and USA markets in different production systems of high tropical Colombia in the framework of life cycle assessment, including an analysis of consumer perception about information pertaining to these aspects.

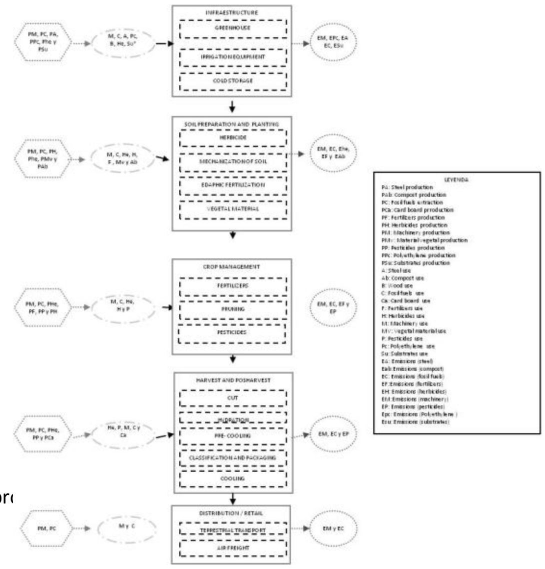
Methods

The standard PAS 2050:2008 - (BSI, 2008a; BSI, 2008b) was the approach used to calculate CF. The study used the four basic steps defined by the Carbon Trust et al., (2008) to calculate the CF of any goods or services: (a) building a process map, (b) defining the study limits and establishing priorities, (c) data collection, and (d) calculation of CF.

Building the process map

The process map was built as comprehensive as possible, including all the components related to GHG emissions in order to achieve the proposed objective (Figure 1).

Figura 1.



General pr

Defining the study limits and establishing priorities

The study used an approach from the cradle to the next business taking into account that transport is a major source of GHG emissions in this supply chain and that detailed information of local distribution, use and waste disposal in England and USA was unavailable. As a functional unit (FU) it was defined a typical rose stalk for such markets and the analysis included all the stages of the supply chain, namely raw material extraction for production, crop management, post harvest, packaging, local ground transportation and air transportation to the point of entry into London or Miami. The analysis for each stage included all the materials, activities and processes that give rise to GHG emissions in the life cycle referred to the UF.

Data collection

Collecting data for a case study was undertaken in the terms of the research project "Indicators of energy use and emissions in the cut flowers supply chains in Colombia, using an approach of life cycle analysis". Between 2009 and 2010 rose growers from Sabana de Bogotá were invited to participate in the development of this project and from this a detailed inventory of materials and energy use in the cut flowers supply chain was made. Though some characteristics of the studied farms may be considered typical of Colombian rose production, outputs of this study cannot considered a statistically representative sample of the country rose production neither be extrapolated to other production systems in the tropical high lands.

Calculation of carbon footprint (CF).

To calculate CF all inputs are multiplied by their respective emission factor and then they are sum up.

Carbon footprint of an activity =	Data from the activity (mass/ volume/kWh/km) **X**	Emission factor (CO2-eq per unit

Emission factors reported for other studies were used for the calculations and then the differences in GHG emissions for both options markets were analyzed. The emission factors were extracted from the database of Ecoinvent (Althaus et al., 2007, Nemecek et al., 2007, Spielmann et al., 2007), Carbon Trust (2008) and IEA (2007).

Assesment of environmental considerations on the part of consumers in England

The study team designed a survey directed to specific contacts in England, especially researchers, for their comments and feedback. The survey was distributed by mail and made available in the Google docs platform.

Results and Discussion

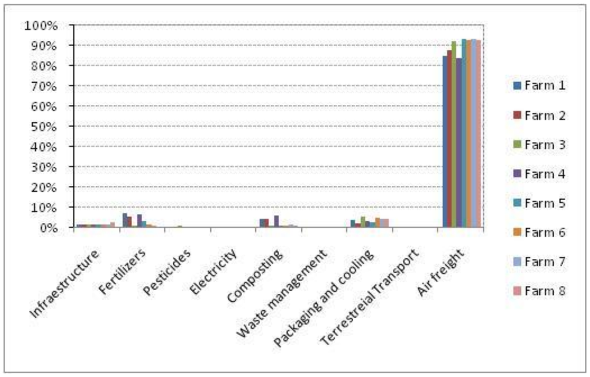
The CF for cut roses to London market was determined in a range between 0,355 to 0,445 kg CO2 eq. by UF meanwhile FC for cut roses destined for buyers in Miami in a range between 0.127 and 0.26 kg CO2e by UF (Table 1). Differences between the sampled farms are due to variability in input energy, use of materials (according to management) and productivity per unit area.

Tabla 1. Carbon footprint values per functional unit of production for the rose farms assessed

Farm	LONDON kgCO2eq/UF^{-1}	MIAMI kgCO2eq/UF^{-1}
Farm 1	0,445	0,21
Farm 2	0,375	0,18
Farm 3	0,441	0,16
Farm 4	0,434	0,26
Farm 5	0,416	0,135
Farm 6	0,396	0,151
Farm 7	0,425	0,127
Farm 8	0,355	0,259

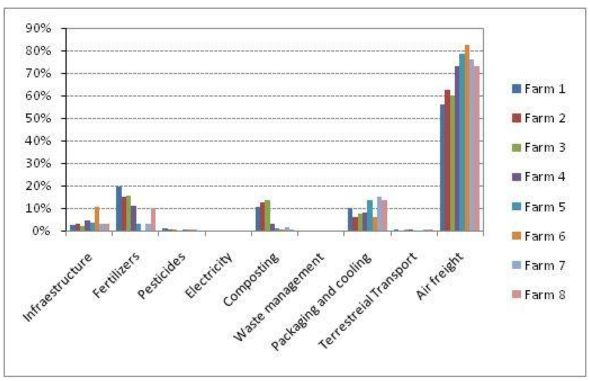
As shown in Figures 2 and 3, in the cut roses supply chain to markets in England and USA the largest contribution to FC is given by air transport. It is clear that the rose marketed in USA has a smaller CF than that sent to England, but it is important to take into that Colombian growers have little control on air transport. Other relevant contributions to CF come from emissions of NO2 due to fertilization and from CO2 in the cooling process. It is also important to consider emissions from composting organic waste, due to the high volume of waste and the considerable time period of the decomposition process which increases methane emissions.

Figure 2



Contribution to carbon footprint of each of the stages of the cut roses supply chain marketed in England

Figure 3



Contribution to carbon footprint of each of the stages of the cut roses supply chain marketed in USA

The breakdown of the CF by contributions from each of the stages is important from the managing standpoint and helps design mitigation strategies aimed at solving critical issues and inefficiencies in both resource and energy use in the cut roses supply chain.

Though the results of FC are site-specific according to characteristics of management, logistics and marketing of each producer, it is important to compare the achieved outputs to other CF reported at international level for flower crops. Williams (2007) calculated CF of the cut roses supply chain by using life cycle analysis and estimated GHG emissions associated with the manufacture and use of inputs in productions systems in both Kenya and the Netherlands for the UK market. He used a functional unit of 12,000 cut stalks of marketable quality. The study limits covered the production and air transport from Kenya and truck transport from Holland to the retail distribution center in Hampshire, England. The CF for roses from Kenya was 0.18 kg CO_2e per stalk and 2.91 kg CO_2e per stalk from The Netherlands. According to that author, the main contributor to the Netherlands rose FC is the fossil fuel used for greenhouse heating. A comparison shows that the values of CF obtained in the present study for the market of England and of the USA are lower than those of Holland reported by Williams (2007). The results show that when the Colombian roses are marketed in Miami the minimum value in the found range (0.13 kg CO_2e per UF) is lower than that from in Kenya, but the maximum value of such a range exceeds the latter. When the Colombian rose is marketed in London, the minimum range value is twice of that found per rose stalk in Kenya (0.18 kg CO_2e).

Comparisons between different CF studies should be viewed with caution, even if the studies have been undertaken according to internationally recognized methodologies. This is because there is no a unique approach of international validity. This means that there is no internationally accepted calculation procedure and therefore it may happen that two values of FC for the same product/process are not comparable due to differences in the calculation methods, in the emission factors or in the limits of the study. Although scientists tend to give preference to the emission factors proposed by the Intergovernmental Panel on Climate Change (IPCC), it is possible to find studies on the same crop using different emission factors, such as when a country has developed own factors.

Given the possible impact that CF may have on trade of Colombian roses on Europe, consumers from England were asked about their perception on Colombian flowers, preferences and willingness to pay for best practice strategies to reduce environmental impact. The overall results of the 72 surveys received are summarized as follows:

- Roses have a special preference in cut flowers among the respondents.
- 57% of respondents qualified as very important the fact that the flowers be produced under friendly practice environment.
- Willingness to pay for a flower produced using clean technology varies between 10% and 20% above the current price

These outputs are an important input for Colombian growers to optimize processes and move toward carbon labelling.

Conclusions

The main findings of this study are as follows:

PAS 2050 standard 2008 from BSI represents a good base for calculating agricultural CF as it recognizes nearly all potential sources of GHG emissions in the supply chain.

It is worthy to compare FC values from different studies using methods of scientific validity for a specific crop, but it should be kept in mind that there is currently no single standard of internationally validity to calculate CF.

The CF values found in this study cannot be considered representative of Colombian roses chain, so they do not aim to become international benchmarks.

One of the greatest potential for the determination of CF should be referred to define mitigation strategies, optimal use of resources and energy efficiency in crop chain.

Results from the undertaken British consumer surveys show that there is a growing positive perception of environmental aspects of the cut roses supply chain, which should be taken into account by producers to optimize their processes and to promote sustainable production.

References

Althaus, H.-J., Chudacoff, M., Hischier, R., Jungbluth, N., Osses, M., Primas, A., 2007. Life cycle inventories of chemicals. Final report ecoinvent data v2.0. Volume 8. Swiss Centre for LCI, Empa–TSL, Du¨ bendorf, Switzerland.

BSI, 2008a. Guide to PAS 2050. How to Assess the Carbon Footprint of Goods and Services. British Standards, London, UK.

BSI,2008b. PAS 2050:2008. Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services. British Standards, London, UK.

Carbon Trust, 2006. Carbon Footprints in the Supply Chain: The Next Step For usiness. The Carbon Trust, London.

Carbon Trust, 2008. Energy and carbon conversions fact sheet– 2008 update. In: Factsheet CTL018, Carbon Trust, London, UK.

Edwards-Jones, G., Plassmann, K., York, E.H., Hounsome, B., Jones, D.L. and Milà i Canals, L. 2009. Vulnerability of exporting nations to the development of a carbon label in the United Kingdom. Environmental science & policy 12 (2009) 479 – 490.

IPCC, 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge.

ISO, 2006a. ISO14040. Environmental Management–Life Cycle Assessment—Principles and Framework. International Organization for Standardization, Geneva, Switzerland.

ISO, 2006b. ISO 14044. Environmental Management–Life Cycle Assessment—Requirements and Guidelines. International Organization for Standardization, Geneva, Switzerland.

Nemecek, T., Heil, A., Huguenin, O., Meier, S., Erzinger, S., Blaser, S., Dux, D., Zimmermann, A., 2004. Life Cycle Inventories of Agricultural Production Systems. Final report ecoinvent 2000 no. 15. Agroscope FAL Reckenholz and FAT Taenikon, Swiss Centre for Life Cycle Inventories, Du¨ bendorf (Switzerland).

Nonhebel, S., 2006. Options and trade-offs: reducing greenhouse gas emissions from food production systems. In: Brouwer, F., McCarl, B.A. (Eds.), Agriculture and Climate Beyond 2015. Springer, pp. 211–230.

Smith, A., Watkiss, P., Tweddle, G., McKinnon, A., Browne, M., Hunt, A., Treleven, C., Nash, C., Cross, S., 2005. The validity of food miles as an indicator of sustainable development. Final report. Defra, London.

Spielmann, M., Ka¨ gi, T., Tietje, O., 2004. Life cycle inventories of transport services. Final report ecoinvent 2000 no. 14. Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland.

Tenjo, F., E., Montes, J., Martínez. Banco de la República. 2007. Comportamiento reciente (2000-2005) del sector floricultor colombiano. www.banrep.gov.co.

Tzilivakis, J., Warner, D.J., May, M., Lewis, K.A., Jaggard, K., 2005. An assessment of the energy inputs and greenhouse gas emissions in sugar beet (Beta vulgaris) production in the UK. Agric. Syst. 85, 101–119.

Williams, A., 2007. Comparative study of cut roses for the British market produced in Kenya and the Netherlands. Report for World Flowers, November 2007, 7 p.

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Methodological challenges in water footprinting

Markus Berger
Matthias Finkbeiner

Technische Universität Berlin
Department of Environmental Technology / Chair of Sustainable Engineering
Office Z1 / Strasse des 17. Juni 135 / 10623 Berlin, Germany
markus.berger@tu-berlin.de

Abstract
As freshwater scarcity leads to manifold problems for human health and ecosystems, it is perceived as the most important environmental problem in many regions of the world. Consequently, water footprinting is an emerging topic in LCA and lots of methods were developed recently ranging from simple inventories to complex impact assessment methods. After reviewing and applying a broad range of methods in industrial case studies, methodological shortcomings were identified. On inventory level, the current determination practice of water consumption seems debatable as all water evaporated is regarded as consumed. Since large shares may be returned to the originating or other catchment areas depending on atmospheric parameters, this assumption may be misleading. Yet, large modelling effort would be required to create more precise inventories. On impact assessment level, most methods use the withdrawal-to-availability ratio (WTA) as water scarcity indicator in their characterisation model. However, as only a fraction of withdrawal is consumed this indicator can overestimate physical water scarcity. Moreover, arid regions can be regarded as uncritical if only small shares of the little renewable supply are used due to a lack of industry or low population densities. Besides neglecting the sensitivity of a region to water shortage, water scarcity indicators used in current methods do not take into account fossil water stocks which can buffer water shortages – at least temporal and for human health effects. Further deficits were noticed in the field of trade-offs between safeguard subjects, environmental credits, and the extent of inventory information required by current methods. In identifying methodological challenges, this paper aims at inspiring future methodological developments.

Key words: water use, water footprint, life cycle assessment, life cycle impact assessment

Introduction
Freshwater is an essential resource sustaining live on our planet and water scarcity is perceived as the most relevant environmental problem in many parts of the world – even more important than climate change.
Having been neglected for many years, freshwater use is now a priority in current sustainability discussions. Next to stand-alone methods like the virtual water concept [1], the water footprint method according to Hoekstra and Hung [2] or the global water tool [3], lots of methods were developed in a life cycle assessment (LCA) [4, 5] context. As shown in Figure 1, LCA related water footprint methods range from simple water inventories [6-8] to complex impact assessment models [9-18] evaluating consequences on human health , ecosystems, and natural resources on both midpoint and endpoint levels.

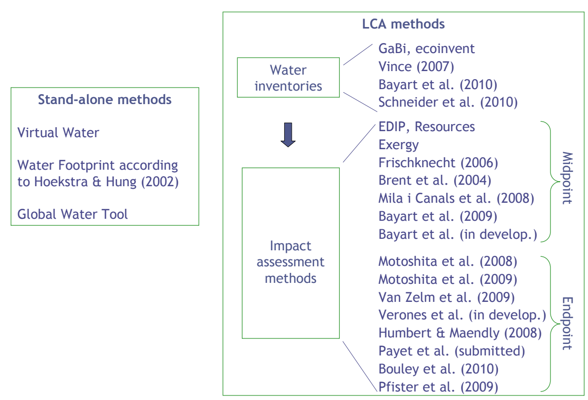

Figure 1 **Overview of methods for inventorying and assessing water use and consumption [1-3, 6-18]**

Theses recent methodological developments, which were comprehensively discussed in a previous work [19], are an important step forward in addressing water use in LCA. By conducting water footprint case studies of industrial products, a broad range of the methods mentioned above were applied and tested in complex industrial product systems. Methodolo–gical challenges on both inventory and impact assessment levels were identified and are presented in this work, which can serve as a "to-do-list" for future methodological developments.

Methodological challenges

In current water inventories, freshwater consump–tion is regarded as water "lost" for a catchment area by either evapo(trans)piration, product integration, or discharge into sea water or another river basin. However, the assumption that water evaporated in a particular river catchment will not return to the same river basin via precipitation is strongly dependent on the size of the catchment area and on the climatic conditions. It may be true for water evaporated in small river basins or in areas with low atmospheric humidity which will absorb evaporated water. In contrast, in large catchment areas or in river basins where the air is water-saturated, it is very likely that evaporated water will return via precipitation in the same river catchment.

Even if water is not returned to the same catchment area from which it originated, it may be returned to another river basin via precipitation. Thus, water consumption in one area may lead to precipitation in another area. As this complex relationship is hard to model, current methods assume all water evapo–rated as lost arguing that 80 % of all precipitation takes place over the oceans.

Furthermore, the combustion of fossil fuels leads to a synthetic creation of water in the chemical reaction. As this water is generated in the form of steam, it is regarded as "lost" right from its production and is neglected, too. However, the phenomenon of "industrial snow" occurring in industrial areas during the winter shows clearly that this assumption is not true at all circumstances.

Next to use and consumption of freshwater, some methods also assess the pollution of freshwater by waster water discharges, e.g. by means of the gray water component in the virtual water concept [1] or by means of quality parameters used in the impact assessment [14]. However, the pollution of water is often covered by other impact categories such as eutrophication, acidification, eco - or human toxicity [20]. Hence, one needs to pay attention to avoid double counting as waste water effluents should be regarded as either freshwater pollution or consum–ption but not as both.

On impact assessment level most methodologies use the withdrawal-to-availability ratio (WTA), denoting the ratio of water use to renewable water supply in a river basin, for expressing local freshwater scarcity.

$$WTA \quad \frac{water \quad use}{renewable \quad water \quad \sup \quad ply} \qquad (1)$$

However, this ratio is influenced by two metrics – use and availability. As shown by means of the method of Pfister and colleagues [18] in Figure 2, this can lead to deceptive effects. Countries like Belgium, where water is abundant, are regarded as relatively critical, just because it uses (not consumes!) large shares of its renewable supply. In contrast, countries in the arid Sahel zone like Sudan are considered as uncritical as only minor fractions of the small renewable water supplies are used due to a lack of industry and low population densities.

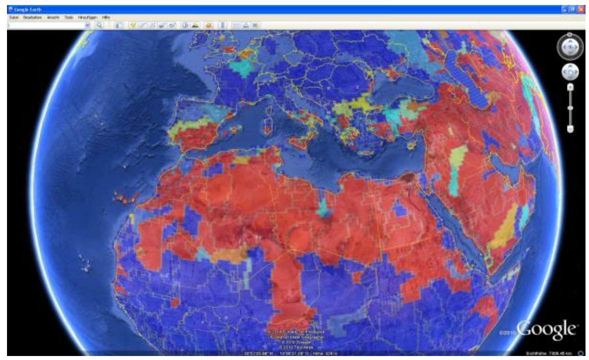

Figure 2 Water stress index (WSI) based on WTA determined by Pfister and colleagues [18] for more than 10.000 watersheds presented in a Google Earth [21] layer

Moreover, as water use also comprises borrowing and degradative water uses [22], like cooling water, WTA does not necessarily reflect the real water shortage. Methods like the impact assessment model developed by Boulay et al. [23] try to overcome this shortcoming by using the ratio of water consumption to renewable water supply instead of WTA. Even though physical water scarcity is expressed in a more meaningful way, this method and the approaches using WTA still do not consider the sensitivity to water scarcity. If the renewable water supply is small (like in Sudan), an additional water use or consumption can lead to a significant change in the water scarcity ratio.

Another shortcoming of water scarcity indicators used in current water footprinting methods is that only renewable water supplies are taken into account. Considering a sustainable use of water resources, this is surely correct. However, large non-renewable water stocks can compensate for an overuse of renewable supplies for a certain time. Even though it is controversial, methods describing consequences on human health should consider non-renewable supplies as it is a big difference if population can buffer a temporal water shortage or not.

Further need for improvement was detected in the question of environmental credits. If, for instance, water is withdrawn from a fossil aquifer and after its use discharged into surface water courses, this water is made available for nature. Thus, depletion of fossil water resources might be beneficial for ecosystems. This argument is often used by the mining industry which in some cases utilizes deep fossil aquifers. Even though parts of this fossil groundwater are evaporated, large shares are discharged into rivers in partly very dry regions. Consensus has to be found on how to deal with this trade-off between two safeguard subjects.

Another methodological challenge was identified regarding the extent of inventory data required by different water footprinting methods. As shown in Table 1, almost all methods require geographically differentiated inventory information in addition to properly inventoried input- output flows. Moreover, some methods demand information about the type of watercourse used and a large number of water quality parameters.

Table 1 Inventory data requirements of different water footprinting methods

Method		Inventory data requirements			
		In-/output water fluxes	Geographical differentiation	Differentiation of watercourses	Differentiation of water quality
LCI	GaBi	■		◧	
	ecoinvent	■		◧	
	Global Water Tool	■	■	■	
	Vince (2007)	■	■	■	■
	Virtuelles Wasser	■		◧	
	Water Footprint	■	■	◧	
LCIA (midpoint)	EDIP, Ressourcen	■	■		
	Exergy	■			
	Methode d. ökol. Knappheit	■	■		
	Brent et al. (2004)	■	■		
	Mila i Canals et al. (2008)	■	■	■	
	Bayart et al. (2009)	■	■	◧	■
LCIA (endpoint)	Motoshita et al. (2008)	■	■		
	Motoshita et al. (2009)	■	■		
	Van Zelm et al. (2009)	■	■		
	Humbert and Maendly (2008)	■	■		
	Pfister et al. (2009)	■	■		

Considering inventory information available in LCA databases [6, 7], hardly any of the requirements can be fulfilled at present which makes it difficult to apply these methods – especially if complex background systems are involved. This trade-off between precision and applicability shows the need for both more detailed inventory datasets and practicable water footprinting methods requiring not too detailed inventory information.

Conclusions

Considering severe problems caused by water scarcity in many parts of the world, water footprinting is an emerging topic in LCA. After reviewing and applying a broad range of water footprinting methods in industrial case studies, this work identified current methodological challenges. Next to inventory related shortcomings detected in the current determination practice for water consumption, most challenges have been noticed on the impact assessment level. First, the withdrawal-to-availability ratio (WTA), which is used in many characterisation models to denote local water scarcity does not reflect complex hydrological relationships in a sufficient manner. By relating water use to renewable water supply the indicator may overestimate physical water scarcity as often only small fractions of water use are really consumed. As WTA is influenced by two metrics – use and availability – arid regions can be regarded as uncritical if only small fractions of the little renewable supply are used. Besides neglecting the sensitivity of a region to water scarcity, WTA does not take into account fossil water stocks which can buffer water shortages – at least temporal and for human health effects. By identifying further shortcomings in the field of trade-offs between safeguard subjects, environmental credits, and inventory data requirements, this work aims to inspire future method developments.

References

[1] Allan JA. 1998. Virtual water: a strategic resource, global solutions to regional deficits., Ground Water. 36, no. 545-546.

[2] Hoekstra AY, Hung PQ, "Virtual Water Trade: A Quantification of Virtual Water Flows between Nations in Relation to International Crop Trade," *Value of Water Research Report Series 11*, UNESCO-IHE, Delft, The Netherlands, 2002.

[3] WBCSD. 2010. Available online: http://www.wbcsd.org/web/watertool.htm. Accessed accessed on 30 June 2010.

[4] ISO 14040. 2006. Environmental management - Life cycle assessment - Principles and framework, European Committee for Standardisation, Brussels, Belgium.

[5] ISO 14044. 2006. Environmental management - Life cycle assessment - Requirements and guidelines, European Committee for Standardisation, Brussels, Belgium.

[6] PE International. 2009. Available online: http://www.gabi-software.com. Accessed accessed on 08 July 2009.

[7] ecoinvent centre. 2008. Available online: http://www.ecoinvent.org/. Accessed accessed on 12 March 2009.

[8] Vince F. 2007. Proposition for the LCI framework (unpublished).

[9] Hauschild M, Wenzel H. 1998. Environmental Assessment of Products.

New York, NY, USA, Chapman & Hall, Thomson Science: 445-460.

[10] Bösch ME, Hellweg S, Huijbregts MAJ, Frischknecht R. 2007. Applying Cumulative Exergy Demand (CExD) Indicators to the ecoinvent Database, Int. J. LCA. 12, no. 181-190.

[11] Frischknecht R, Steiner R, Jungbluth N. 2009. Ökobilanzen: Methode der ökologischen Knappheit - Ökofaktoren 2006 - Methode für die Wirkungsabschätzung in Ökobilanzen. Bern, Swizerland, Öbu - Netzwerk für nachhaltiges Wirtschaften:

[12] Brent AC. 2004. A life cycle impact assessment procedure with resource groups as area of protection, Int. J. LCA. 9, no. 172-179.

[13] Mila i Canals L, Chenoweth J, Chapagain A, Orr S, Anton A, Clift R. 2008. Assessing freshwater use in LCA: Part I - inventory modelling and characterisation factors for the main impact pathways, Int. J. LCA. 14, no. 28-42.

[14] Bayart JB, Bulle C, Margni M, Vince F, Deschenes L, Aoustin E. 31 May-04 June 2009. Operational characterisation method and factors for a new midpoint impact category: freshwater deprivation for human uses, Gothenborg, Sweden.

[15] Motoshita M, Itsubo N, Inaba A. 10-12 December 2008. Development of impact assessment method on health damages of undernourishment related to agricultural water scarcity, Tokyo, Japan.

[16] Motoshita M, Itsubo N, Inaba A, Aoustin E. 31 May-04 June 2009. Development of damage assessment model for infectious diseases arising from domestic water consumption, Gothenburgborg, Sweden.

[17] Maendly R, Humbert S. 2009. Empirical characterization model and factors assessing aquatic biodiversity damages of hydropower water use, Int. J. LCA (submitted).

[18] Pfister S, Koehler A, Hellweg S. 2009. Assessing the environmental impacts of freshwater consumption in LCA, Environ. Sci. Technol. 43, no. 4098-4104.

[19] Berger M, Finkbeiner M. 2010. Water footprinting - how to address ater use in life cycle assessment?, Sustainability. 2, no. 4, 919-944.

[20] Guinee JB, de Bruijn H, van Duin R, Gorree M, Heijungs R, Huijbregts MAJ, Huppes G, Kleijn R, de Koning A, van Oers L, Sleeswijk AW, Suh S, Udo de Haes HA. 2001. Life Cycle Assessment—An Operational Guide to the ISO Standards. Leiden, The Netherlands,

[21] Google Inc. 2010. Available online: http://earth.google.com/. Accessed accessed on 07 January 2010.

[22] Bayart JB, Bulle C, Koehler A, Margni M, Pfister S, Vince F, Deschenes L. 2009. A framework for assessing off-stream freshwater use in LCA, Int. J. LCA. 15, no. 5, 439-453.

[23] Boulay et al. (submitted). LCA characterization of freshwater use impacts on human health and through compensation scenarios. , Submitted to Environmental Science & Technology.

Carbon Footprint of Pine and Eucalyptus ECF Bleached kraft Cellulose Production in Chile

González Patricia[1], Vega Mabel[2], Zaror Claudio[2]
[1]Environmental Sciences Centre (EULA),
[2]Chemical Engineering Department
University of Concepcion
PO Box 160-C, Correo 3, Concepción. Chile
czaror@udec.cl

Topic: Carbon Footprint

Keywords: Carbon footprint, ECF bleached kraft Cellulose, Forestry.

Abstract
This paper presents the overall carbon footprint of cellulose production in Chile. Cellulose exports amount to around 5,000,000 tonnes per year, supported by more than 2 million hectare of pine and eucalyptus plantations. Recently, carbon footprint has become an important environmental attribute. The close relationship between forestry activity and industrial processing motivates a broader assessment of GHG emissions, throughout the life cycle of the cellulosic product. This work followed a cradle-to-gate carbon footprint, and fossil and biomass carbon emissions were calculated on the basis of real industrial data, and reported for each process from nursery to cellulose mills. Primary data was used in this study and represent 100% of Chilean cellulose production capacity. The overall fossil carbon footprint averages 600 and 510 kg CO_2 /bone dry ton (bdt), for Chilean pine and eucalyptus bleached pulp, respectively. Details of GHG emissions, both biogenic and fossil, throughout the cycle are reported.

Introduction
Cellulose production is a complex system involving forestry and industrial processes [1]. Greenhouse gases, both biogenic and fossil, are emitted throughout the production cycle. The cellulose life cycle begins at the forestry resource, where lignocellulosic compounds are produced by photosynthesis. Carbon sequestration takes place during this phase. After harvesting, wood is transported to cellulose mills, where cellulosic fibres are separated and purified from the rest of wood components, using physical and chemical processes. Bleached cellulose could then be used for the manufacturing a wide range of printing papers, adsorbent products, and other cellulose-based goods.
Previous work on life cycle inventory analysis for Chilean cellulose production was based on literature and laboratory simulation results [2]. This paper reports greenhouse gas (GHG) emissions using primary data from covering all production plants.

Methodology
ISO 14040/2006 [3], and PAS 2050 [4] standards were used as methodological guidelines. Allocation between co-products was conducted on material basis. Main material and energy inputs and outputs were obtained from direct sources. A total of 7 bleached kraft cellulose mills, representing 100% of Chilean bleached kraft cellulose production were included in this study. Leading Chilean forestry and cellulose companies kindly provided information about their production practices, and material and energy inputs.

Results
The first boundary is set at the nursery, where plant seedlings are produced, and the end point is drawn at the pulp mill factory gate, where bleached cellulose is ready for marketing. Thus, the life cycle inventory analysis presented in this paper follows a cradle-to-gate approach. This is justified by the fact that cellulose is a basic raw material used in the manufacturing of a wide range of final consumer goods. As mentioned above, most bleached cellulose produced in Chile is exported abroad, and final destinations and uses vary with time, according to market conditions. Thus, a comprehensive cradle-to-grave analysis would be impracticable.

Life cycle stages.
Nursing stage: Current nursing practises in Chile include careful site selection, optimal nutrient addition, genetic improvement, disease control, controlled irrigation, and careful handling. Since *Eucalyptus globulus* is sensitive to low temperature, covered root methods are used, with 300 plants/m^2. In the case of *Pinus radiata*, bare-root procedures are also found, with 200 plants/m^2. Usually, seeds are sown in spring/ summer, and transplanted during winter.
Establishment of Plantation: The prospective site has to be thoroughly cleaned using manual, mechanical and/or chemical means to remove existing vegetation. In some cases, controlled burning is used to eliminate those residues.

Deep ripping on compacted soils is usually carried out in order to improve the soil physical properties, and water retention capacity. Planting is carried out during winter, and beginning of spring. In Chile, the average initial stocking is around 1,600 trees/ha, both for pine and eucalyptus plantations. In some cases, preventive fertilisation is conducted when required. Post-plantation chemical weed control is carried out in spring. During the first few years, competition by other species, and pests should be kept under control, since small tress may not be able to survive under those conditions.

Forest Management: This includes all activities carried out between the establishment of plantation and harvesting. In Chile, pine plantations are managed to obtain knot-free wood, timber, and pulpwood. On the other hand, most eucalyptus plantations are aimed at producing pulpwood, with negligible uses in plywood, and board making. Pruning is necessary to produce knot-free timber. Thinning is carried out to stimulate growth by regulating stand density. In the case of pine plantations, non-commercial thinning is practised at about 4-5 years, whereas commercial thinning is carried out at 7-14 years, mostly for pulp making, reaching a final density around 300-500 trees/ha. Depending on management, soil quality, and climate, 30-80 m^3/ha pulpwood could be obtained from commercial thinning.

Harvesting: Chilean *Pinus radiata* and *Eucalyptus globulus* harvest cycles are 20 and 10 years, respectively. Harvesting comprises felling, delimbing, bucking, transport to roadside, loading, and hauling. Transport to roadside could be accomplished using animals or tractors, transported in the bunk of an off-road vehicle, or moved by cable. Depending on forest management practises, and soil quality, around 200-500 m^3/ha and 200-300 m^3/ha are harvested, for pinewood and eucalyptus, respectively. All major forestry companies maintain active reforestation programs, to keep a reliable biomass stock for long term industrial processing, and sustainability. Reforestation of harvested plots is conducted after appropriate site preparation.

Pulp Production

All leading Chilean companies feature a close integration between forestry and industrial processing. Around 50% harvested pinewood goes directly as a raw material for pulping, while the rest is sent to sawmills. In turn, sawmills generate pulping residues that represent 30% of total input. In this context, wood from sawmill could be regarded as a by-product of cellulose production. On the other hand, most harvested eucalyptus wood is used for pulping, with negligible associated sawmill processing.

Wood preparation: This includes wood debarking, and chipping. Chips are then screened, and stored. These operations involve considerable electrical power consumption. In modern plants, bark and other woody residues are used as fuel for steam and electricity production.

Cooking: Chips are treated at high temperature and pressure (160-180°C), with a NaOH and Na_2S solution at high pH (white liquor). As a result, around 52-54 % and 46-48 % of initial wood is dissolved, for pine and eucalyptus, respectively. Crude pulp with kappa values around 24 and 14, for pine and eucalyptus, respectively, are obtained. After cooking, crude fibres are separated from the black liquor, and washed to remove residual chemicals.

Oxygen delignification: Oxygen delignification under alkaline conditions reduces lignin content by around 50%, to reach a kappa value in the range 11-13 and 6-8, for pine and eucalyptus, respectively.

Energy and Chemicals Recovery Systems: The black liquor has a high calorific potential and contains most of the digestion chemicals. The black liquor is concentrated using evaporators, and burnt in the recovery boiler, where all organic matter is oxidised to CO_2. The solid residue (Na_2CO_3 and Na_2S) is dissolved and mixed with CaO to regenerate the white liquor for digestion, leaving Na_2CO_3 as a residue. In turn, the CaO is regenerated by thermal treatment of Na_2CO_3 in a lime furnace.

Bleaching: All Chilean mills use elementary chlorine free (ECF) bleaching sequences. This features the use of ClO_2 as oxidation agent (D), and oxidative alkaline extraction, with O_2 and H_2O_2 (E_{OP}). In the case of pine pulp, a $D_0E_{OP}D_1D_2$ sequence is normally used, whereas a shorter sequence ($D_0E_{OP}D_1$) is used for eucalyptus pulp. Liquid waste from bleaching contains chlorine compounds that are not suitable for burning in the recovery boiler due to potential corrosive effects. These effluents account for most of the contaminant load of final waste waters.

ClO_2 in-plant Generation: ClO_2 is produced in-situ by reduction of $NaClO_3$ in the presence of H_2SO_4 and CH_3OH as the reducing agent. It is interesting to note that $NaClO_3$ is produced by a local chemical plant, that also generates NaOH, using NaCl as a common raw material.

Residual Gas Treatment and Disposal Systems: Gas emissions mainly come from the recovery boiler, the lime furnace, the power boiler, and vents. These are composed of particular matter, SO_2, mercaptans, and other volatile hazardous organic and inorganic pollutants (eg. chloroform, methanol, chlorine dioxide). In this study, gas emissions are characterised on the basis of CO_2, SO_2, TRS (total reduced sulphur), and HAP (Hazardous Airborne Pollutants). Abatement measures heavily rely on process optimisation and control. Additionally, plants feature end-of-pipe systems, such as, electrostatic precipitators, gas filters, scrubbers, and gas incinerators..

Residual Liquid Treatment and Disposal Systems: Liquid wastes are generated from bleaching, and from general washing and cleaning operations. Bleaching effluents are highly coloured and contain dissolved organic and chlorinated organic compounds, and residual bleaching chemicals. Washing effluents may contain suspended solids, and other components from accidental spills. Environmental loads from final effluents are expressed in terms of generic parameters: COD, and AOX, to account for the total organic load and organic-chlorinated compounds, respectively. Effluent treatment systems feature pH neutralisation, cooling, primary sedimentation, and biological treatment. Two modern plants also include tertiary treatment based on physical-chemical treatment.

Residual Solid Treatment and Disposal Systems: All woody residues from processing (eg. bark, knots) and effluent treatment sludge, are burnt in power boilers, to generate steam and electricity. Solid residues (eg. boiler ash, dregs, grits, sand, stones, spent oils, dirty chips, dust, etc) are disposed in in-plant controlled landfills.

Material and Energy Inventories

Data collected in this study showed wide variations from company to company. Main discrepancies were found in forestry practices, where seedling and soil quality, climatic conditions, and management practises, play a strong effect on productivity. Inputs and outputs were estimated using average values from different sources. Main material and energy loads are shown in Table 1, using 1 ton air dried cellulose as the reference flow.

Eucalyptus plantations demand about a third of the total land required by pine plantations, to maintain a sustainable production of cellulose. This is due to the shorter harvest cycle of eucalyptus, greater density of eucalyptus wood, and greater cellulose content.

Main inventories and GHG emissions are summarised in Tables 1 and 2, respectively. No credits have been included

Energy demand is mostly associated with wood industrial processing and, to a lesser extent, to transport and chemicals production. Pinewood processing requires 30% more energy than eucalyptus. On the other hand, pinewood processing generates more than twice electrical energy than eucalyptus. This is due to the greater amount of combustible solid and liquid residues generated from pinewood processing. The overall energy balance shows an energy deficit along the cycle, equivalent to 1.54 and 1.39 MJ/tonne cellulose, from eucalyptus and pinewood, respectively.

Chemicals manufacturing contributes with 27-31% of total CO_2 emissions.

All biogenic CO_2 emissions come from biomass burning in harvesting, and in the recovery and power boilers. Inventory results clearly show a net uptake of CO_2 in the order of 1.5 and 4.2 tonne CO_2 per tonne of cellulose from eucalyptus and pinewood, respectively. Finally, values shown in Table 2 do not include any credit for sold electricity. In this respect, 330 and 740 kWh/bdt surplus electricity are sold to the interconnected network (SIC), representing 145 and 326 kg CO_2/bdt for eucalyptus and pine pulp, respectively.

Conclusions

Results obtained in this study show that greater fossil CO_2 emissions occur when cellulose is produced from pinewood, as compared with eucalyptus. Significant carbon sequestration in forestry plantations was observed, exceeding total GHG emissions across the life cycle.

References

[1] Wertz J.L; Mercier J.P.; Bédué O. 2010. Cellulose Science and Technology. 1st edition. EFPL Press.

[2] González P. 1999. "Desarrollo de un Modelo Conceptual para Evaluar el Impacto Ambiental de la Industria Celulósica" Concepción. Chile. Universidad de Concepción.

[3] ISO 14040. 2006. “Environmental management. Life Cycle Assessment. Principles and framework”.

[4] PAS 2050. 2008 “How to assess carbon footprint of goods and services”. British Standard. BSI. .

TABLE 1: MAIN INVENTORY RESULTS AND CARBON FOOTPRINT
Reference Flow: 1 tonne bone dried cellulose (bdt)

	EUCALYPTUS	**PINE**
FORESTRY PRODUCTION	**Kg /bdt**	**Kg / bdt**
Land for Sustainable Rotation (m^2)	1.205	4.220
Harvested Area (m^2)	119	211
Energy Requirements (MJ)	5.5	8.2
Thinning and Harvesting		
Energy Requirements (MJ)	101	301
Wood to Pulpmill	-1,786	-1,589
Wood to Sawmill	0	-2,055
CELLULOSE PRODUCTION		
Pulpwood Requirement	1,786	2,205
Mill Processing energy requirements (MJ)	1,836	2,493
Wood transport energy requirements (MJ)	384	712
Sodium Hydroxide	25	35
Sodium Chlorate	24	34
Calcium Carbonate	15	18
Oxygen	23	30
Sulphuric Acid	21	33
Hydrogen Peroxide	3	4
Methanol	3	4
Fuel Oil no.6	51	48
Pulp Production	-1,000	-1,000
Sawmill Wood Production	0	-1,040
Sold Electricity (MJ)	-1,184	-2,660

(negative values depict outputs from processes)

TABLE 2. CARBON FOOTPRINT OF CHILEAN CELLULOSE
Reference Flow: 1 tonne bone dried cellulose (bdt)

	Eucalyptus	**Pine**
	kg CO_2 / bdt	kg CO_2 / bdt
FOSSIL CO_2 eq		
Forestry processes	44	59
Boilers and Limestone Kiln	218	200
Chemicals & Fuels Production	187	232
Wood, Chemicals & Fuels Transport	61	109
TOTAL FOSSIL CO_2 EMISSIONS	510	600
BIOGENIC CO_2 eq		
Net CO_2 sequestration in plantations	-9,320	-3,840
CO_2 sequestered in product	-1,467	-1,467
Total CO_2 biogenic emissions	4,970	2,151

(negative values depict GHG capture)

Carbon footprint associated to the production of natural cork stoppers

Rives, Jesus[1]; Fernandez-Rodriguez, Ivan[2]; Rieradevall, Joan[1,3]; Gabarrell, Xavier[1,3]

[1] SosteniPrA: ICTA– Inèdit Innovació SL - IRTA, Insitut de Ciència i Tecnologia Ambientals (ICTA), Universitat Autònoma de Barcelona (UAB), 08193 Bellaterra, Barcelona.

[2] Insitut Català del Suro, 17200 Palafrugell, Girona.

[3] Departament d'Enginyeria Química, Universitat Autònoma de Barcelona (UAB), 08193 Bellaterra, Barcelona.

E-mail: jesus.rives@uab.cat

Abstract

Cork is a resource that is exploited in western Mediterranean regions and it can substitute other non-renewable raw materials in different applications. Traditionally, cork had been used to generate different type of products, but specially stoppers. Natural cork stopper is the most representative product and has the highest economical added value. It is made of solid cork and it is a packaging product used to put the top at the neck of still wine bottles.

The current research about the production of natural cork stoppers pretends to analyse the industries involved in the production as a sector. Following the Life Cycle Assessment (LCA) methodology and the ISO 14040, the carbon emission equivalent was calculated using the global warming potential (GWP) impact category. The system includes the transportation of cork raw material from the forest to the disposal of the product after consumption, including all the production stages and operations involved. Data was provided directly by 5 representative Catalan companies and subsequently was averaged in order to obtain the results for this industrial sector and to avoid particular company case studies.

Results show that 10.9 kg CO_2 equivalent was emitted per thousand of natural cork stopper produced, without considering the biogenic carbon dioxide that is fixed by cork oak forests. Also, it was found that differences existed between the results obtained depending on the different companies considered in the project, with a range between 5.5 kg and 17.1 kg of CO_2 eq. These differences indicate that some companies have the opportunity to improve their production according to this indicator, with the technology used by their competitors at the moment.

Transportation of raw cork from the forest to the industry and the manufacture stage, in which slabs are transformed into cylindrical pieces, were the stages that contributed most to the carbon footprint of the product.

Key words

Natural cork stopper production, life cycle assessment, carbon footprint, ecomaterial, wine sector, packaging.

Introduction

Cork oak (*Quercus suber L.*) forests are located in the western Mediterranean areas due to climate and environmental conditions. In the world, 2,277,700 Ha of cork oak forests exists and the Iberian Peninsula concentrates more than 55% of them. Moreover, 245.500 tons of raw cork material are generated in the Iberian Peninsula every year, concretely it represents 83% of the world cork production [1]. Cork can be harvested any 9 years in Portugal and South Spain, while in Northern Spain the cork is harvested every 12 years because climatic conditions imply a lowest rate of growth of the cork oak tree. In addition to the supply of raw cork, biomass, honey, mushrooms, medicinal herbs and many more, these forests are important because they provide other environmental functions such as prevention of desertification, conservation of biodiversity, carbon sequestration and so on [2].

Cork is an ecomaterial because it is obtained from the extraction of a thick bark of the cork oak tree, which is a natural and renewable source. Its properties are used to create a wide range of products. Some of those properties are flexibility, compressibility, a very low thermal conductivity, impermeability to liquids and gases, energy-absorbing capacity and an apparent lack of chemical reactivity [3].

Natural cork products are a group of applications that present a high added value. They are made directly of solid cork, while granulated-agglomerated products have a lower value but are a profitable solution to take economical benefits from the huge amount of wastes generated during the production of natural cork products. The best example of a natural cork product is the natural cork stopper, while some examples of granulated-agglomerated items are technical stoppers, floorings, boards and insulator panels [4].

The development of cork sector in the Iberian Peninsula was due because cork exploitation takes place in these regions and because more than 60% of the world's wine production is located within the EU [5]. The cork sector is constituted mainly for two basic systems: the forestry system, which consist of cork raw material extraction and forestry management operations, and the industrial system, where the raw material is transformed to different items. In this study we are going to evaluate the industrial system because at present time data about forestry management is not available.

Methodology

Environmental assessment was carried out using the life cycle assessment (LCA) methodology and according to the ISO 14040 standard [6]. However, in this paper, we are bringing into focus the global warming potential (GWP) impact category that measures the emissions of carbon dioxide generated by product, process or activity by accounting and evaluating the resources' consumption and emissions. LCA is divided into four basic steps: (1) goal and scope definition, (2) inventory analysis, (3) impact assessment and (4) interpretation. The environmental analysis was developed using the software program Gabi 4.3 [7] and using the obligatory phases of CLM 2001 method [8]: classification and characterization.

The main objective of the research was the evaluation of carbon burdens emitted during the production of natural cork stoppers. Besides, stages and operations involved in the production were analysed to find which of them caused the biggest part of the impact.

Data collection was carried out using a specific questionnaire of natural cork stoppers production. All the companies involved in the project filled the questionnaire and afterwards, averages of the inventory flows of each company were averaged to obtain a sector inventory. During the data collection from the companies, authors carried out fieldwork and visited all the companies in order to assure the quality of the data. In addition, the Catalan Cork Institute revised and verified all the collected data. Finally, environmental assessment was performed and GWP category is presented in this research.

The functional unit (FU) was defined as the production of one thousand standard natural cork stoppers, with a diameter of 24±0.5 mm, a length of 44-49 mm and a weight of 3.7 g.

Although a natural cork stopper is a little piece of solid cork, lots of processes are involved during their production. It was observed during the data collection phase of the study that each company has their own way to produce and little difference in the process exist. However, in this section, a consensus production system will be briefly described from the transport of the raw cork material from the forest to the final disposal of the product after consumption. Figure 1 presented the main stages involved in the industrial system of natural cork stoppers production.

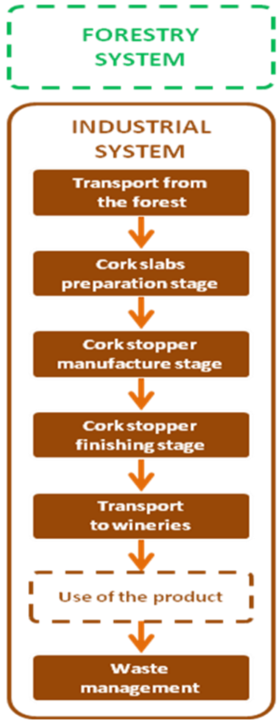

Figure 1 - Natural cork stoppers production system

Natural cork stopper production can be basically divided in the next stages:

a) Initial transportation of the raw material from cork oak forest to the industry.

b) Cork slabs preparation: during this stage raw cork slabs are cleaned in hot water at 95ºC in big tanks by immersion during 1 hour. During this stage slabs are selected, so that those slabs with a thickness above 27 mm are introduced to the next stage [9].

c) Cork stopper manufacture: during this stage a second boiling takes place, but only for 30 minutes. Later, the slabs are cut into strips and then punched into cylindrical pieces. Finally, those pieces are sanded to get the desired dimensions.

d) Cork stopper finishing: before the commercialization of the natural cork stoppers, they are washed and selected using cameras [10]. Then the surface treatment operation takes place: a thin film of silicone or paraffin is applied to the stopper in order to ease the insertion and removal of the stopper from the wine bottles. At the end of this industrial process the stoppers are packaged depending on customer's preferences.

e) Transport to wineries: in some cases this transportation is carried out by using lorries, but in some cases, specially for wines produced in South America, South Africa and Australia, the transport is done by freight ships.

f) Use of the product: this stage is considered negligible and it is not even attributable to the production.

g) Waste management: for this stage a transportation of 50 km after usage of the natural cork stopper was considered, and due to the fact that existing systems of cork stoppers collection are at the moment very few isolated initiatives, it was considered that cork stoppers were disposed.

Due to a lack of data and their little amount in the production system, some inputs that represented less than 2% in mass were not considered in the environmental assessment. Therefore, machinery and industrial buildings were not considered because they produce millions of stoppers every year and their utilization was considered negligible.

Results and discussion

Results pointed out that 10.9 Kg of CO_2 eq were generated to produce a thousand natural cork stoppers. However, the biogenic carbon wasn't considered in this study because the perspective was the improvement of industrial systems and not forestry practices.

Important differences between the carbon dioxide equivalent emissions by companies were observed. Concretely, a natural cork stopper produced in the best company presented an emission of 5.5 kg of CO_2 eq per FU, while the most polluting company produced 17.1 Kg of CO_2 eq. These differences were caused because of the higher quantities of materials and energy consumed, and also because the first company produced natural cork stoppers with raw cork extracted and transported from local forests, while the most polluting company used raw cork from distant forests.

Analysing the stages of production, it was found that transportation from the forest contributed to generate 3.77 kg of CO_2 eq., and during the cork stopper manufacture stage 3.72 kg of CO_2 were produced. This means that each stage contributed 34%. On the other hand, the emission associated to waste management only represented 0.28 kg of CO_2 eq., and it weighted only 3% of the total impact of the natural cork stoppers production. These results can be observed in Figure 2.

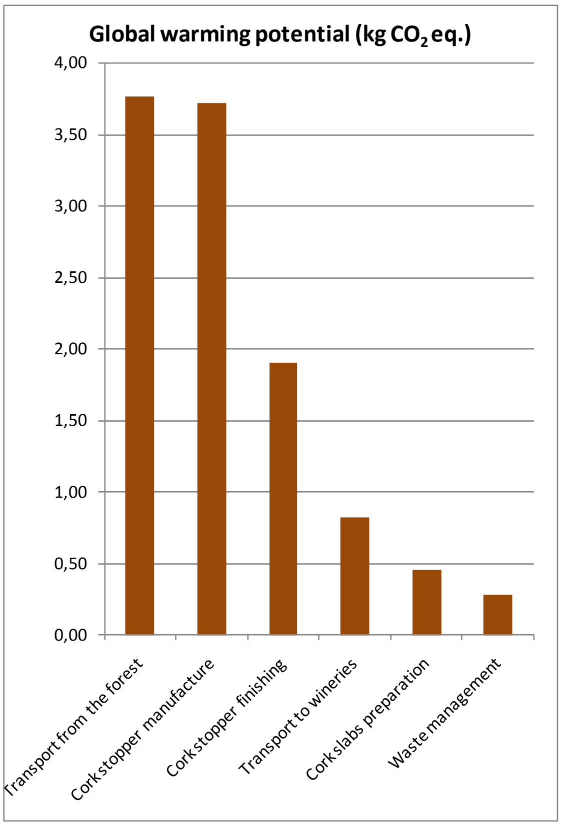

Figure 2 - Emissions of carbon dioxide equivalent associated to the production of thousand natural cork stoppers production by stages.

Figure 3 shows disaggregated results. It can be observed that 65% of the emissions generated during preparation stage were caused by first boiled operation, and 19% was caused by slab selection process. On the other hand, the punched into cylindrical pieces contributed to 41% of the carbon dioxide emission for cork stopper manufacture and size correction contributed 37%. And the analysis of results for cork stopper finishing stage showed that 32% of their impact was caused because of counting and packaging and, 26% of the impact was caused because of washing and drying process. Disaggregate results are very important to give criteria to companies about which operations are to be improved if they want to reduce their carbon dioxide emissions.

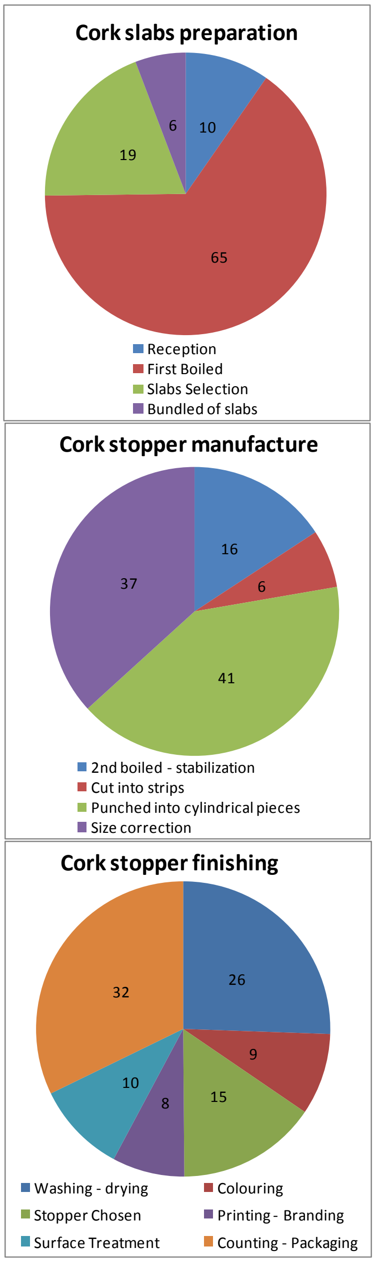

Figure 3 - Percentage of the carbon dioxide emission attributed to the three main stages: cork slabs preparation, cork stopper manufacture and cork stopper finishing by operations.

Conclusions

It was found that 10.9 kg of carbon dioxide was generated during the life cycle system of a thousand natural cork stoppers for still wine.

Also differences were found in the emission related to different companies studied, between 5.5 and 17.1 Kg of CO_2 eq. This means that some of the companies can improve their production applying available technology.

Transportation from the forest and cork stopper manufacture were the stages that contributed most to the GWP impact category, with 34% of the total impact. On the opposite site, waste management contributed less than 3%.

Acknowledgements

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References

1. APCOR. 2009. APCOR yearbook. 2009. Available: http://www.apcor.pt (10-01-2010).

2. Aronson, J., J.S. Pereira, and J.G. Pausas. 2009 Cork oak woodlands on the edge: ecology, adaptive management, and restoration. Washington, DC: Island Press, cop.

3. Silva, S.P., et al. 2005. Cork: properties, capabilities and applications. International Materials Reviews. 50(6): p. 345-365.

4. Pereira, H., Cork products and uses, in Cork. 2007, Elsevier Science B.V.: Amsterdam. p. 243-261.

5. FAOSTAT. 2010 Available on: http://faostat.fao.org.

6. ISO, 14040:2006 (E). 2006. Environmental management - Life cycle assessment - Principles and framework. International Organization of Standardization, Geneva, Switzerland.

7. IKP. 2003 I.U.o.S.a.P.E.G., IKP University of Stuttgart, PE Europe GmbH, 2003. GaBi 4.3 Software and database for Life Cycle Assessment. Leinfelden–Echterdingen, Germany.

8. Guinée, J., et al. 2001. Life cycle assessment; An operational guide to the ISO standars; Part 1 and 2. Ministry of Housing, Spatial planning and Environment (VROM) and Centre of Envornmental Science (CML), Den Haag and Leiden. Neederland.

9. Pereira, H. 2007. Production of cork stoppers and discs, in Cork. Elsevier Science B.V.: Amsterdam. p. 263-288.

10. Brunetti, A., et al. 2002. Cork quality estimation by using Compton tomography. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms. 196(1-2): p. 161-168.

Life cycle assessment for the environmental impact comparison of synthetic and natural turf

Valenti Morales Gonzalo, [1] Bautista Orduña Guillermo, [1] Güereca Hernández Leonor Patricia[2]

Email: gvalentimorales@hotmail.com

Abstract

Introduction

Because of synthetic turf is commercialized as eco friendly product due its low water consumption, rubber utilization, avoid fertilizers and pesticides in relation to natural turf, a comparative analysis was made applying the Life Cycle Assessment tool (LCA) to evaluate the environmental impact for each of them and make decisions about its installation. For the analysis were taken 10000m^2 as a functional unit for a sport field of constant use for training and official games, with a horizon of 5 years. The analysis was made for the sport field of the Instituto Tecnológico y de Estudios Superiores de Monterrey Campus Estado de México, actually installed with synthetic turf.

Key words: *synthetic turf, natural turf, LCA, environmental impacts*

Methodology

It was considered the production of synthetic turf in USA and a national production of natural turf from Xochimilco in Mexico DF 55Km far away. The provisioning of materials (asphalt, gravel, silice stone, rubber grain, and farm land) comes from near places no more than 10 km. The landfill is located 30 km far away. Electric energy, gasoline, diesel, natural fertilizer, binder, chemical fertilizers, pesticides, water and their corresponding outputs were accounted in the inventory.

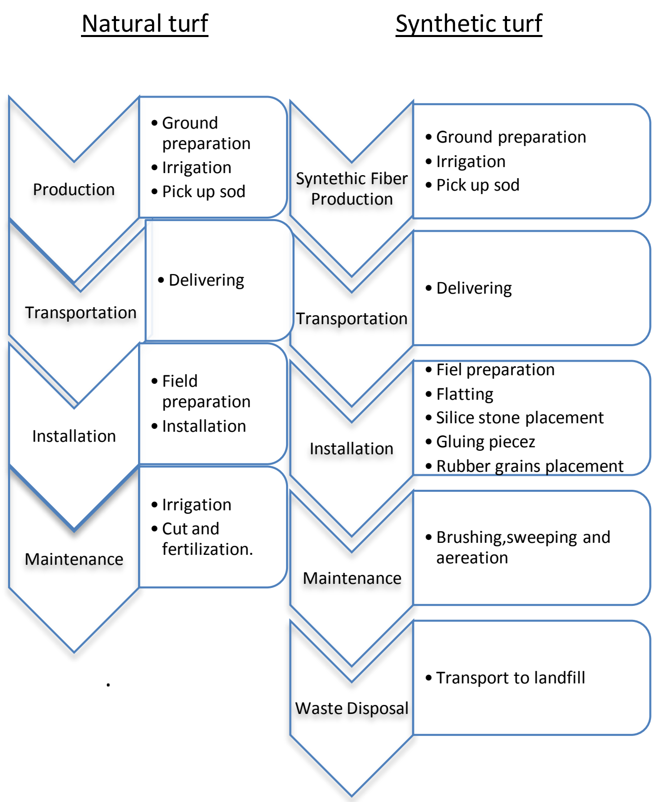

Figure 1. Process diagram for each product

The characterization and the result classification were realized by the software TEAM (Tool for Environmental Analysis Management). Nine impact categories were evaluated by CML 2000 method and six general processes (synthetic fiber production, sod production, transportation, maintenance and final disposal) as is in figure 1.

Results

The results show that synthetic turf represents more impacts than natural turf in each one of the categories, having 5.71 times (average) more environmental impacts. On the other hand, transport and installation are having the most impact concentration, for the synthetic turf near to 70% and for the natural turf near to 89%. Fuel consumption by machinery and transport trucks and its chain production associated causes great impact in the photo oxidant formation, green house effect and acidification. For the case of terrestrial toxicity and depletion of a biotic resource, the major responsible is the synthetic fiber production.

Next are shown four of the most important impacts obtained in the study:

Category 1: Air Acidification

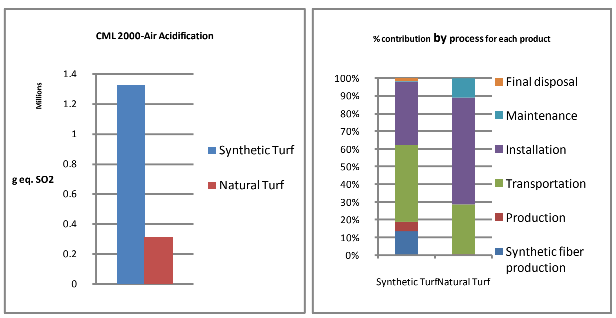

Figure 2. Total values per scenario and percentage of contribution by scenario and process

Category 2: Eutrophication

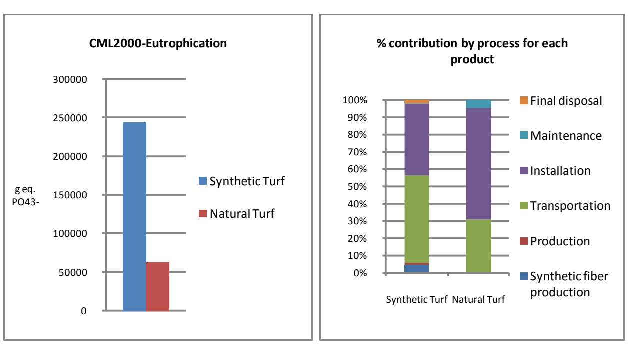

Figure 3. Total values per scenario and percentage of contribution by scenario and process

Category 3: Greenhouse effect

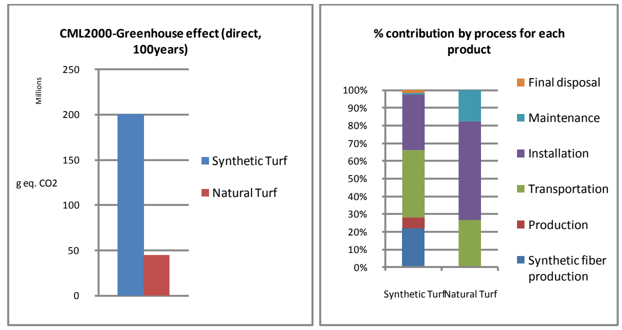

Figure 4. Total values per scenario and percentage of contribution by scenario and process

Category 4: Photo oxidant formation

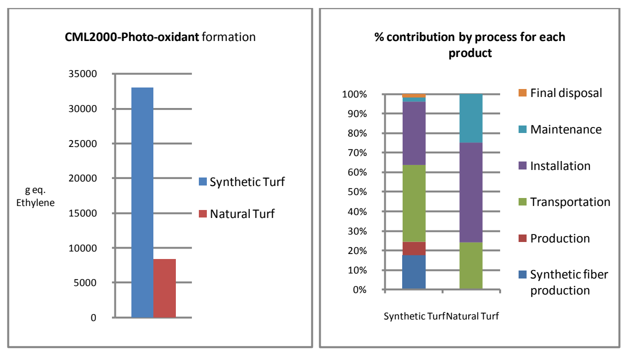

Figure 5. Total values per scenario and percentage of contribution by scenario and process

Discussion

One of the environmental impacts is the acidification which is caused for the use of fossil fuel that are used in the installation and transportation process (in both cases) and maintenance in the case of natural turf. As is mentioned in the emissions inventory for natural, made by Townsend-Small and Czimczik in the 2010: "the main source of emissions are caused by the fuel use"

The eutrophication is caused by the use of fuel, energy and fertilizers. Because of the majority of impacts are located in the transportation and maintenance process that emit SO_x in form of SO_2, causes the problem of acidification and at the moment of the contact with the ground in form of rain produces eutrophication.

Rachel Simon of the Barkeley University, in his article: “Review of the impacts of Crumb Rubber in artificial turf application”, published in February 2010, mentions that the maintenance of natural turf its associated with great quantities of fuel so it is evident that the photo oxidants formation is present in the natural turf maintenance, due frequency of this activity. The European Journal of Turf Grass Science (EJTS) in its publication “Ecological Balance of natural and artificial turf” by Stahl H. and Schuled D., present similar results in the categories of photo oxidants formation and green house effect, which proves the validity of the results.

Another study made by The Athena Institute located in Toronto, Canada, compared two sport fields (natural turf vs. synthetic turf) considering 9000 m^2. The study was focused in the quantification of emissions of green house effect for each sport field. Their results shown that synthetic turf have more environmental impacts than natural turf, related to CO_2 including a negative value for the last one. In our case the results not show negatives value but small values compared with synthetic turf.

Conclusions

According to the analysis made in this paper is concluded that here is a significant difference in the life cycle assessment for each product. Although both of the products have impacts in each category, synthetic turf is the responsible for generate more environmental impact for the characteristics of the study and its limitations.

Analyzing the sub processes, it is important to mention that the most impacts are concentrated in the transport and the installation and not in the maintenance process although this process is executed during five years of study.

Despite synthetic turf is shown as an eco friendly product because of the useless of water, fertilizers and pesticides in the maintenance process, is not enough, given that production of raw material, sod production, transportation and final disposal, become it in a product with greater environmental impacts than natural turf, in the global analysis.

It is important to consider that the no regional data in Mexico in some process and sub process produce results with uncertainty. However, the discussion with other papers and accepted bibliography support the results and validate them what means that the analysis made becomes as a useful tool to make decisions at the time to install a natural turf or synthetic turf for a sport field.

References

1. Townsend-Small, A., and C. I. Czimczik (2010), Carbon sequestration and greenhouse gas emissions in urban turf, *Geophys. Res. Lett.*, 37. 2009
2. Meil, Jamie, Bushi Lindita. 2006. Estimating the required global warming offsets to achieve a carbon neutral synthetic field turf system installation, ATHENA INSTITUTE, Ontario, Canada.
3. Swedish Chemicals Inspecorate, 2006. Synthetic turf from a chemical perspective. Status Report, Sundbyberg
4. Simon, Rachel. 2010. Review of the impacts of crumb rubber in artificial turf application, University of California Berkeley, Laboratory for Manufacturing and Sustainability College of Engineering.
5. Stahl H., Schuler D., 2009. Ecological balance of natural and artificial turf, European Journal of TurfGrass Science publicado por: Deutsche Rasen Gesellshaft, Alemania.
6. Proyecto de conversión de campo de fútbol tierra en césped artificial en polideportivo "Isabel Fernández de Torrellano" Fondo de Inversión local para el empleo 2008.- Gobierno de España
7. STA-1000 SYNTHETIC TURF ADHESIVE. Obtenido de la páginahttp://shop.tjb-inc.com/sta-1000-two-part-flexible-synthetic-turf-polyurethane-seam-adhesive--glue---colored-turf-green-p1031.aspx

8. Campaña, Josep. Mantenimiento de Instalaciones deportivas, piscinas cubiertas y campos de césped artificial. Técnicas para la instalación de campos deportivos de césped artificial.
9. Información sobre césped natural y artificial. Consultado el 05 de septiembre de 2010 Obtenido de la página: http://www.cesped.es/
10. Máquina de extrusión para film plano de plástico, Guangzhou Guoyan Machinery Making Co., Ltd. Obtenido de la página: http://www.cn-packaging.es/4-1-plastic-film.html
11. Qingdao Longxinweiye Truck Commercial Co. Ltd. Consultado el 08 de Octubre de 2010 Obtenido de la página: http://www.truckchina.es/5-road-roller-3.html
12. Turf Industria Semanales. Consultado el 08 de octubre de 2010. Obtenido de la página: http://www.turfindustryweekly.com/default_sp.asp
13. Barredora kersten k-2000 para césped artificial. Consultado el 08 de octubre de 2010. Obtenido de la página: http://www.jardineroshoy.es/es/node/419, 2009
14. Césped artificial Pavigreen Futbol MB16. Revisado el 06 de Septiembre de 2010. Obtenido de la página: http://www.pavigreen.com/cesped-artificial-deportivo-pavigreen-futbol-mb16
15. Synthetic (Artificial) Turf vs. Natural Grass Athletic Fields. University of Arkansas – Turfgrass Science. Revisado el 10 Noviembre 2010. Obtenido de la página: http://turf.uark.edu/turfhelp/archives/021109.html
16. Natural Grass and Artificial Turf: Separating Myths and Facts. Published by the Turfgrass Resource Center. Revisado 09 de Noviembre de 2010. Obtenido de la página: http://www.turfgrasssod.org/images/documents/033120095256858.pdf

The use of Carbon Footprint in horticulture: Environmental performance of two horticultural products in the Mediterranean region

ABSTRACT

Nowadays, evaluating the environmental behavior of products has become an essential issue, not only to fight against global warming and other Earth threats but also because productive sectors, consumers and administrations demand this information. Two of the tools that allow us to calculate the total greenhouse gas emissions are Life cycle assessment (LCA) and Carbon footprint (CF). Presently CF methodology is gaining strength in the field of environmental assessment. A CF study is easier, shorter and cheaper than an LCA and therefore can be easier presented as an eco-label. However, CF is omitting all the other impact categories apart from global warming. Besides, according to the Public available specification 2050:2008, used for the CF calculation in the study, the capital goods must be considered out of the boundaries of the system. In this paper, CF methodology have been performed for two common crops (tomato and cauliflower) in an open field sited in the Mediterranean area (Maresme, Barcelona), as a representative case study of horticulture in the region. The functional unit was 1 ton of commercial tomato or cauliflower, respectively. Between 130-319 kg of CO_2 equivalent were emitted per ton of commercial product. The contribution by stages was assessed for each crop, being the mineral fertilizers production the most impacting stage for both of them. Omitting the greenhouse gas emissions arising from capital goods leaded to the omission of about 10 % of the total impact with CF.

Topic: LCA Management Trends. Carbon and water footprinting

Keywords: Carbon footprint; eco-label; horticulture; open field

INTRODUCTION

In the last century Agrifood-sector has been intensifying production techniques. As a consequence, food production has become a relevant contributor to the depletion of natural resources and climate change. Smith et al. [1] reported that agriculture is currently accounting for 10-12% of total global anthropogenic emissions of greenhouse gas (GHG) generated in the whole world.

Most vegetable crops are relatively concentrated in areas with a mild winter climate where typical weather is generally more favourable, for example Mediterranean regions. Horticultural products are generally worthier than products from extensive agriculture.

In this context, it is necessary to quantify the environmental behaviour, such as the carbon dioxide equivalent emissions, of horticultural products. There are many different tools for doing it, but a large part of scientific community considers life cycle thinking as the most appropriate approach to assess the environmental impact of products, processes and services. Two of the tools that allow us to calculate it are Life cycle assessment (LCA) and Carbon footprint (CF).

Traditionally, LCA has been the tool more widely used in a research context and it has been also promoted with different European directives for specific sectors and products as a suitable environmental quantitative tool. The results obtained from a LCA study include several environmental indicators.

Nowadays, CF has been driven by retail chains, proactive companies and nongovernmental organizations because the analysis is limited to GHG emissions which make the study shorter and cheaper and therefore the results can be easily converted to an eco-label [2]. Among the CF available methodologies, PAS 2050:2008 [3] was chosen for this study mainly because it has been previously used to evaluate a large amount and different type of products.

In this study, the main goal was to point out the main issues for CF application to horticultural production, throughout the GHG assessment of two Mediterranean horticultural crops. In addition, final CF results have been compared with LCA results in order to assess the relevance of the GHG emission omitted.

METHODOLOGY AND CASE STUDY

Broaden explanations of the considerations could be found in previous publications of the authors [4-7].

Agricultural methodology

The experimental field was located at the IRTA research plots (el Maresme, Barcelona, Spain). The soil was a Typic Xerothent. The site has a Mediterranean climate with an average annual ET0 and rainfall of 771 and 649 mm, respectively, for the period 1990-2008. The cultivation followed the best available techniques for integrated crop management guidelines aiming to compare efficient systems in resources, energy and emissions. The main characteristics of the two crops are reported in Table 1.

Crops were irrigated (Table 1) depending on the tensiometer reading that determined the matric water potential evapotranspiration demands of the soil.

The doses of fertilizers were decided by taking into account the previous nutrient content of soil and the real agricultural necessities. The high nitrogen content of the irrigation water (192 $g \cdot m^{-3}$ of NO_3^-), which is the result of the excessive use of mineral fertilizers in the region, was included in the inventory as a mineral fertilizer addition, considering its production and transport.

The experiment had a block design with three replicates of 35 m^2 per crop. Commercial and non-commercial yields were determined per block and per cultivation option during harvest time. The nitrogen applied and the uptake were considered for the emissions calculation.

CF assessment methodology

- Methodology: Public Available Specification 2050:2008 [3] considering a business-to-business approach.
- Functional unit: Horticultural production of 1 ton of each commercial vegetable (tomato and cauliflower, respectively). The impacts of each crop system were distributed among the tons of product collected.
- System description: seven stages were considered for each crop: mineral fertilizers production, mineral fertilizers transport, machinery, collecting packaging, phytosanitary substances and fertirrigation emissions.

Table 1 - Summary of the characteristics for the two crops.

Crop	**Tomato**	**Cauliflower**
Variety	El Virado®	Trevi
Scientific name	*Lycopersicon esculentum*	*Brassica oleracea*
Starting day	12/05/2007	28/09/2007
Finishing day	25/09/2007	18/01/2008
Length (days)	133	110
Plant density ($plants \cdot m^{-2}$)	2.30	2.08
Commercial harvest ($t \cdot ha^{-1}$)	98.9	17.0
Irrigation water ($l \cdot m^{-2}$)	555	*238*
Mineral fertilizers	HNO_3, KNO_3	HNO_3, KNO_3
Amount of product per collecting crate (kg)	12	*4.5*

- System boundaries: The processes included and not included for all the stages are pointed out in Table 2. Capital goods among other processes have been excluded of the study. Furthermore, land use changes were not considered because the fields were converted to agricultural use before 1990.
  Waste that had a recycling or recovery treatment was not considered on the inventory but it was attributed to the system which uses waste as a raw material. Dumped waste was accounted for [4].
- Data origin and quality: Most data used in this study has been collected experimentally in the fields. When local information is not available, bibliographical sources and ecoinvent database v2.2 are used to complete the inventory.

Table 2 - Processes included and not included for CF following PAS 2050:2008 specification [3].

Included	**Not included**
- Energy consumption - Raw materials consumption and transport - Transports (vehicle and road are not included) - Waste management - Soil, air and water emissions - Packaging production - Land use changes (after 1990)	- Production, maintenance and waste management of machinery, tools, infrastructures, buildings and vehicles - Animal and human energy - Workers transport - Changes in the carbon content of soils

LCA assessment methodology

The LCA assessment was based on the ISO 14044 series [8]. The impact assessment was made according to CML 2001 baseline method taking into account just the GWP indicator. The GHG emissions arising from production, maintenance and waste management of capital goods (Table 2) were considered for the LCA.

RESULTS AND DISCUSSION

GHG emission contribution per stages

For each crop, the contribution of the stages to the total GHG emissions, which was calculated with the CF methodology, is presented in Figure 1. The mineral fertilizers production was by far the stage with a major contribution, 70 % for cauliflower and 71 % for tomato. These higher contributions of the mineral fertilizers were consequence of the larger energy consumption and emissions than in the rest of processes but also because the other stages were not intensive consumers of energy or generators of GHG emissions.

The packaging stage, which considered the plastic crate for the harvesting, was the second more important contributor, about 12 % of the total impact. The more relevant impact of the former was due to the smaller amount of product held per harvesting crate.

Apart from irrigation stage, which contributed with about 9 %, the remaining stages had a contribution below 10 % for both crops (Figure 1).

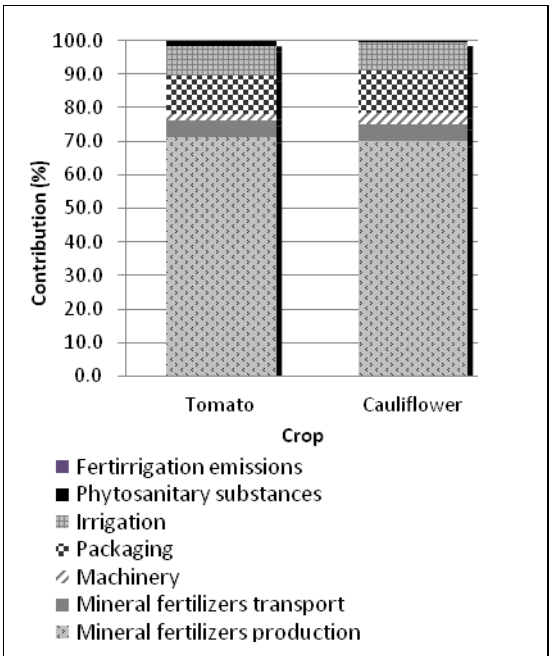

Figure 1 – GHG emissions contribution by stages (Carbon Footprint).

Total GHG emissions

According to the Table 3, 130 (for tomato) and 319 (for cauliflower) kg CO_2 equivalent were emitted per ton of commercial horticultural product, which is the functional unit. An important factor is the harvest obtained (Table 1) because the impacts of each system were distributed among the tons of product collected. Therefore, cauliflower, with a fifth of the harvest of the other crop, had the higher impacts per ton.

Table 3 – GHG emissions assessed with CF [3] and compared with LCA [8] results.
Units: kg CO_2 eq · FU^{-1}

	CF	LCA
Tomato	129.8	143.3
Cauliflower	319.4	355.0

CF and LCA results comparison

The use of CF methodology for the environmental assessment of the horticultural crops leaded to the omission of about 10% of the total GHG emissions accounted with LCA methodology (Table 3). This difference was consequence of do not consider the emissions arising from capital goods, and mainly due to the fertirrigation infrastructure omission and the buildings, machineries and other infrastructures of the mineral fertilizers production stage.

CONCLUSIONS

According to CF assessment, between 130-319 kg of CO_2 equivalent were emitted per ton of commercial product, having cauliflower the higher and tomato, the lower impacts. The use of other functional units, such as the nutritional content, may lead to different conclusions [7].

These figures could easily be used for an eco-label measuring the environmental performance of the agricultural system used for the production of a certain amount of tomato or cauliflower.

The mineral fertilizers production was by far the stage with a major contribution to these total GHG emissions for both crops. In crop systems with low level of infrastructures the type and amount of fertilizers applied are an important issue from an environmental standpoint.

The recommendation, with CF, of do not consider emissions arising from capital goods entailed the omission of 10% of the total GHG emissions accounted with LCA methodology. The case study was a horticultural option with low infrastructures and inputs, in systems under greenhouse protection [5], with heating, using artificial substrates, among others, the importance of the capital goods could be higher.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Smith P, Martino D, Cai Z, et al. 2007. Agriculture. In: Metz B, Davidson OR, Bosch PR, et al. editors. Climate Change 2007 Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge (UK) and New York (USA), Cambridge University Press.

[2] International Standard Organization. 2000. ISO 14020: Environmental Labelling - Principles. Geneva, Switzerland, ISO.

[3] British Standard Institution. 2008. PAS 2050:2008 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. London, BSI.

[4] Martínez-Blanco J, Muñoz P, Antón A, et al. 2010. Assessment of tomato Mediterranean production in open-field and in standard multi-tunnel greenhouse with compost or mineral fertilizers from an agricultural and environmental standpoint. J Cleaner Prod. DOI: 10.1016/j.jclepro.2010.11.018

[5] Pascual P, Gasol JM, et al. 2010. Calculation of CO2 equivalent emissions in agri-food sector applying different methodologies. In: Proceedings 7th International Conference on Life Cycle Assessment in the Agri-Food Sector 2010; 2010 22-24 September; Bari, Italy.

[6] Martínez-Blanco J, Rives J, et al. 2010. Agronomic and environmental viability of compost application in Mediterranean horticultural crops. In: Proceedings International Conference on EcoBalance 2010. Towards & Beyond 2020; 2010 9-12 November. Tokyo, Japan.

[7] Martínez-Blanco J, Antón A, Rieradevall J, et al. 2011. Comparing nutritional value and yield as functional units in the environmental assessment of horticultural production with organic or mineral fertilization. The case of Mediterranean cauliflower production. Int. J. Life Cycle Assess. 16 (1), 12-26.

[8] International Standard Organization. 2006. ISO 14044: Environmental Management - Life Cycle Assessment - Requirements and Guidelines. Geneva, Switzerland, ISO.

Strategies for reducing the carbon footprint in a social housing district in Merida, Yucatan, Mexico

Cerón-Palma Ileana[1]*, Sanye Esther[4], Oliver-Solà Jordi[1-4], Rieradevall Joan[1-3], Montero Juan-Ignacio[2]
[1]Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain.
[2]Institute of Research and Technlology in Agrifood Sector (IRTA), 08348 Cabrils, Barcelona, Spain.
[3]Chemical Engineering Department, Universitat Autónoma de Barcelona (UAB), 08193 Bellaterra, Barcelona, Spain.
[4]Inedit Innovació SL.UAB Research Park. Carretera de Cabrils, km 2 (IRTA), 08348 Cabrils, Barcelona, Spain.
***Corresponding autor phone: (+34)935813760; fax: (+34)935868008 email: Ileana.ceron@uab.cat**

Abstract
Mérida (Yucatán, Mexico) is an example of a city with big problems of deforestation due to the fast urban growth and housing demand. Massive structures are being built to meet this demand, without taking into account important aspects that can increase environmental impacts, as well as affect health and comfort of residents. Moreover, the uncontrolled use of energy through appliances, interior lightning, gas and air conditioning generates greenhouse gas emissions (GHG). Another important part of these contaminants are generated in the construction phase of the housing through the use of materials.
This paper aims to propose urban green spaces as a strategy to reduce carbon footprint associated to direct energy consumption in a social housing district in Mérida, and compare it with conventional eco-technologies strategy.
Social surveys were used in order to collect data of energy habits and consumption and, through a Life Cycle Assessment of the use stage of the building, the analysis was focused on Global Warming Potential (GWP) to calculate carbon footprint. After that, two strategies were defined in order to reduce the energy consumption and, consequently, the environmental impact.
Results. The Eco-technologies strategy was limited to the direct energy demand and changed the existing technology for eco-technology (improving equipment efficiency), reducing energy demand by 25%. On the other hand, the urban green spaces strategy, with green roofs, horticulture and citrus trees crops, represents an important carbon sink, as they could fix between 32,609 and 43, 272 tonnes of CO_2 eq. yearly for the overall city of Merida.

Topic: LCA MAnagement Trends. Carbon and water footprinting
Keywords: LCA, Green roof, Carbon footprint, urban agriculture, social housing district.

Introduction
Cities exert enormous pressure on the natural environment (1). World's cities represent only 2.7% of the world's surface area (2) however urban population reaches up 80% in America, 70% both in Europe and Oceania and even 50% at a global level. This increasing urban share is likely to reach figures of 70% worldwide in 2050 (3). World's cities are responsible for 80% of global energy consumption, generating more than 70% of total waste and contributing to more than 60% of greenhouse gas emissions of the planet (4). In developing countries, like Latino America region, the rapid growth of urban areas has led to complex problems, including exploitation of natural resources, environmental pollution, greenhouse gas emissions (GHG), reduced open space and unplanned or poorly planned land development (5).
In this context, green spaces play a significant role in urban environments (6) contributing to public health and increasing the quality of life of urban citizens (7). Parks, forests, green roofs and farmlands are four main types of urban green space that can sequestrate carbon in plants and soils (8). According to a recent study by researchers from Michigan (USA), carbon fixation in green roofs with sedum plants is 375 g CO_2/m^2 (9). Another study of green roofs in buildings accounts for 2% savings in electricity consumption and 11% in heating through computer energy simulation models (10).

On the other hand, the high rates of urban growth in Mexican cities produced rapid urbanization and severe housing demand. To meet this demand, massive and standardized social houses are being built (11), and this pattern is repeated in different regions of Mexico, ignoring the climatic conditions differences (12).
Moreover, the building sector is responsible for almost 40% of Mexico´s total greenhouse gas emissions, including the emissions associated to building materials and direct energy consumption (13). Finally, electricity is the type of energy which is more related to GHG emissions in housing, due to uncontrolled use of energy through appliances, interior lighting, gas and air conditioning (14).
In this sense, this paper aims to propose urban green spaces as a strategy to reduce carbon footprint in the use phase of buildings, and compare them to conventional eco-technology strategies for reduce energy consumption, based on a case study in the social district of Merida city in Yucatan, Mexico.

Materials and methods

Selection of study system

This study was done in a social housing district located at south of Merida city, in the state of Yucatan (East of Mexico), with a population of approximately 781,000 inhabitants and an area of 883 km^2. It has a warm-humid climate with average rainfall of 990 mm and average annual temperature of 29°C (15)
Merida city has a high rate of deforestation due to its rapid growth, spreading to the periphery with social housing buildings (16). This type of construction is predominant in Mexican territory and there are social housing projects for 14 years as the city continues to grow horizontally (17).

Study scale

Study system is a social housing and the results are presented at 3 scales (Figure 1):
-*Single housing (SH):* The house has a plot of 160 m^2 with 58 m^2 of construction. The construction system is concrete block with the traditional ceiling joist and vault.
-*Social Housing District (SHD):* The entire project consists of 1903 houses built in 62 ha. Housing district has recreational areas for green spaces and equipment buildings.
-*City Housing (CH):* There are approximately 112,000 social housing in the city of Merida.

The three scales present different available surfaces for the implementation of green urban areas strategy, including the recreational area at district and city level (Table 1).

Table 1. Surfaces available in roof, plot and recreational areas for the 3 scales.

Area	Surface (m^2)		
	SH	**SH**	**CH**
Roof	58	110,374	6,496,000
Plot	71.4	135,874	7,996,800
Recreational	0	29,760	1,581,176

Strategies

After obtaining the energy consumption of the use stage of the building, there were two low-cost strategies (Figure 1) for implementation at three scales: home, district and city.
1. *Eco-technologies:* The existing equipment is changed by more efficient one. This strategy considers two scenarios:
Scenario A: Housing ventilation systems without air conditioning.
Scenario B: Housing ventilation systems include air-conditioning.
2. *Urban green spaces:* This strategy considers:
Green roofs: We propose an extensive green roof system, with Sedum species, as it requires less maintenance and installation is simple for the home building system.
Food production: Considers the inclusion of food to the city through horticultural crops and citrus trees in social districts. It is used as an example for the study of common products in food consumption of the study area.

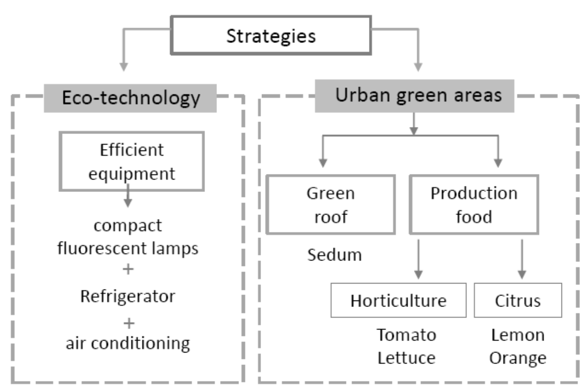


Figure 1. Eco-technologies and Green urban areas strategies for reducing carbon footprint.

Environmental tools

Through a Life cycle assessment (LCA), the global warming potential (GWP) has been calculated in order to obtain the carbon footprint, measuring the emissions of carbon dioxide associated to the energy

use in the home, by accounting and evaluating the resources consumption and emissions.
For the calculation of carbon fixation in Green urban areas strategy, data of the literature has been used (Table 2). The length of time that carbon remains in the soil has not been quantified yet in this data.

Table 2. Mean values of CO_2 fixation by different crops

Green spaces	CO_2 eq/Annual
Green Roof (Sedum)	0.375 kg/m² (9)
Tomato crop	3.18 kg/m² (18)
Lettuce crop	2.53 kg/m² (18)
Lemon tree	3.04 kg/m² (18)
Orange tree	2.07 kg/m² (18)

Social tools
A survey was used with a sample of 100 people in 57 homes. The survey collected data on the habits of energy consumption: number and model of each appliance, operating hours, use of cooling systems, gas, hot water and annual consumption.

Results
According to the survey data of energy consumption habits, there are great differences in the energy consumption profile for the Scenarios A and B (Figure 2). While for scenario A the greater relative contribution to energy consumption corresponded to household appliances, where the refrigerator was responsible for 70% of the consumption; in Scenario B, the main consumption was related to the ventilation and air-conditioning.
Consequently, the annual carbon dioxide emissions associated to the Scenario A were 1,863 kg CO_2 eq., almost two times lower than the Scenario B emissions, 3,543 kg CO_2 eq.

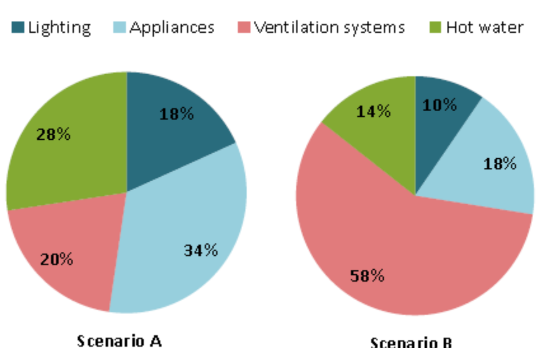


Figure 2. Results of the annual consumption in social housing.

Strategy one: Eco-technologies
The proposal for this scenario considered replacing incandescent bulbs of 60W by compact fluorescent lamps of 12W, saving 75% of the energy consumption related to the lighting, and replacing the refrigerator by more efficient one. Finally, for Scenario B, these changes also included a more efficient air conditioner.
At SH scale, this strategy reduced 25% of the total energy consumption, representing 1,422.86 kg CO_2eq/annual, for Scenario A. And, for Scenario B, these same changes reduced 25% of the energy consumption, with an annual emission of 2,621.86 kg CO_2eq /annual.
Table 3 presents a summary of the results of emissions avoided by energy saving.

Table 3. Annual carbon dioxide emissions savings for Eco-technologies strategy, by Scenario and study scale.

Scenario	$tonCO_2$ eq/annual		
	SH	SHD	CH
A	0.44	837.32	49280
B	0.92	1750,76	103040

Strategy two: Urban green spaces
The incorporation of urban green spaces in social district housing was analyzed for three scenarios: green roof with Sedum (C), mixed green and food crops (D) and food crops (F) (Table 4).

Table 4. Annual carbon fixation for Scenarios C, D and E, by area and strategy, and study scale.

Scenario	Area	Strategy	Annual Carbon fixation $tonCO_2$ eq		
			SH	SHD	CH
C	Roof	Sedum	0.02	41.39	2,436
	Plot	Sedum	0.027	50.95	2,998
	Recreational	Sedum	0	11.16	592
			0.047	103.5	6,026
D	Roof	Sedum	0.02	41.39	2,436
	Plot	Tomato	0.227	432	25,430
	Recreational	Lemon tree	0	89.28	4,743
			0.247	562.67	32,609
E	Roof	Lettuce	0.14	279.24	16,434
	Plot	50% lettuce 50% tomato	0.2	387.92	22,830
	Recreational	Orange tree Lemon tree	0	75.44	4,008
			0.34	742.6	43,272

For the green urban areas strategy, Scenario E, showed the maximum carbon fixation, that represents 43,272 tonnes of CO_2 eq. in a year at city scale (Table 4).
This is due to the biomass dry weight of food products is greater than grass, Sedum sp., and this represents also a higher carbon fixation rate. However scenario D presented high values by

combining green roof and food crops. This may be the ideal scenario for this type of housing as the weight of sedum grass might not affect the current structure of the roof.
Scenarios C showed a lower carbon dioxide fixation due to green roof strategy.

Discussion and conclusions

This study shows the importance of using eco.technologies such as improved lighting systems and improved air conditioning systems in current social houses. It is also important to note that the implementation of eco-technologies has more potential for reducing CO_2 emissions than the urban green spaces strategies. Nevertheless, food production in cities has the additional advantages of avoiding the GHG associated with long distance food transportation (for this case study from Mexico DF to Merida), as well as improving the quality of food within households and promoting sociability
For an isolated house the results may not be significant, but if we make a projection for 2030 to consider these strategies for all social quarters of the city of Merida, would have prevented more than 2 million tons of CO_2 into the atmosphere and set more than half a million tonnes in landscaping and agriculture.
So, this study also indicates that the construction and planning sector could contribute to increase the atmospheric CO_2 fixation rate, through strategies like green areas integrated in buildings and social districts, which also integrate agriculture as part of cities.
A sustainable management applied to this strategy would enable environmental, social and economic benefits.

References

1. Farreny R, Oliver-Solà J, Rieradevall J, Gabarrell X, Escribà E, Montelló M. 2010. The ecodesign and planning of sustainable neighbourhoods: the case study of Vallbona (Barcelona). Sustainable Building Conference SB10, Madrid (Spain).
2. United Nations, 2007. Urban population, Development and the Environment. Department of Economic and Social Affairs. Available in http://www.un.org/esa/population/publications/2007_PopDevt/Urban_2007.pdf
3. United Nations, 2008 World Urbanization Prospects: The 2007 Revision Population Database, available in http://us-cdn.creamermedia.co.za /assets/articles /attachments/11764_prospects.pdf
4. Ash C, Jasny B R, Roberts L, Stone R, Sugden A. 2008. Reimagining cities – Introduction. Science 319(5864) 739-739.
5. Maya E.; Cervantes, J.F y Rivas, A. (2008). Crítica a la promoción privada de grandes conjuntos urbanos habitacionales. In: Actas del X Coloquio Internacional de Geocrítica, Universidad de Barcelona. Disponible en http://www.ub.es/geocrit/-xcol/45.htm.
6. Budruk, Megha, Thomas, Heidi and Tyrell, Timothy. 2009. Urban Green Spaces: A Study of Place Attachment and Environmental Attitudes in India, Society&Natural Resources. 22:9, 824-839
7. Thompson C. 2002. Urban open space in the 21st century. Landscape Urban Plann. 60: 59–72.
8. L¨utz, M., Bastian, O. 2002. Implementation of landscape planning and nature conservation in the agricultural landscape—a case study from Saxony. Agric. Ecosyst. Environ. 92, 159–170.
9. Getter K, Bradley R, Robertson P, Bert M, Andresen A. 2009. Carbon Sequestration Potential of Extensive Green Roofs. Environ. Sci. Technol. 43:19, 7564-7570
10. Sailor D. 2008. A green roof model for building energy simulation programs Energy and Buildings 40: 1466– 1478
11. Ceron, Ileana. 2006. Evaluación de factores de confort y contaminación ambiental en la vivienda económica. Tesis de Maestría. Facultad de Ingeniería. Universidad Autónoma de Yucatán.
12. CORTÈS, J.L. 2001. Reflexiones sobre el problema de la vivienda en México. Revista tiempo. Universidad autónoma metropolitana.
13. CCA Comisión para la Cooperación Ambiental. 2008. Edificación sustentable en America del norte: retos y oportunidades. Canadá.
14. SENER Sistema Nacional de Energías Renovables. (2006). Balance de energía de México. Secretaría de Energía. Disponible en www.energia.gob.mx.
15.INEGI. Instituto Nacional de Estadística y Geografía. 2005. México en cifras: Mérida, Yucatán. Disponible en http:// www.inegi.org.mx/sistemas /mexicocifras/default.aspx?ent=31
16. Sanchez Rodolfo, Rebollar Silvia. 1999. Deforestación en la Península de Yucatán, los retos que enfrentar. Maderas y bosques. 5:2,3-17
17.Villavicencio O., Durán, A. M. 2003. Treinta años de vivienda social en la Ciudad de México. Scripta Nova. 7:146. Disponible en http://www.ub.es / geocrit/sn/sn-
18.Carvajal M. 2008. Investigación sobre la absorción de CO_2 de los cultivos más representativos. CSIC. Disponible en: www.lessco2.es/documentacion.htm

Introducing the Water Footprint methodology in a company: First results and learnings of Natura Cosméticos, Brazil

Francke, Ines C. M.
Tachard, André L. R.
Bronès, Fabien A.

Natura Cosméticos - Tecnologias Sustentáveis. Rod. Anhanguera km 30,5 S/N, Cajamar-SP, Brazil CEP 07750-000, phone: +55 (11) 4446-2863
inesfrancke@natura.net

Abstract
Although water is a renewable resource, its presence with acceptable levels of quality is subject to scarcity, and security of water supply is currently a worldwide concern. Processes that use freshwater, whether embodied in the product or used in the production process, are forcing companies to turn their attention to this feature. However, the largest consumption and water pollution usually is not happening in their direct operations, but throughout their supply chain or in the use phase of the products. The "water footprint" is an indicator of freshwater use that accounts both the direct water use of a consumer or producer and the indirect water use, being a more complete indicator than the traditional measure of water withdrawal. Its application with an integrated approach - that is, with a vision of the product life cycle - offers a wider perspective on how a consumer or producer relates to the use of freshwater systems. Natura, a cosmetic company with strong commitments towards sustainability, defined water as one of the main environmental issues, and chose to better understanding the impacts of their activities on freshwater. The water footprint methodology was applied in a product and corporate perspective, and the initial results allowed us to identify the major impacts of our value chain and design a freshwater sustainability strategy.

Keywords: Water footprint; Sustainability; Life Cycle Thinking

Introduction

Freshwater of adequate quality is not only a prerequisite for human societies, but also for natural ecosystems that perform essential functions for human existence and life on earth. The efficient use of freshwater and control of pollution is often part of sustainability issues addressed by business, and one of the main challenges faced today by corporations.

Natura, one of the largest cosmetic companies in Brazil is guided since its creation in 1969 by values and beliefs in which sustainability and quality of relationships play an essential part. Therefore, Natura seeks to behave sustainably to generate value, considering the entire value chain of its operations, from extraction of raw materials to the final disposal of products and packaging. In line with this commitment, initiatives and principles of life cycle management have been used increasingly over the years to reduce its environmental impacts. To continue the advancements in the capacity to sustainably manage the products portfolio and activities, which requires the consolidation and updating of current indicators (such as new standards of the "GHG Protocol" in development), Natura wants to further develop its social and environmental indicators. Following this path, a project was initiated in 2008 to develop models of water footprint of products, with a life cycle approach. This paper reports Natura's first results based on the studies on water footprint, as well as the initial learnings and challenges for further improvement of this model.

Sustainability in Natura Cosméticos

Natura Cosméticos, a leading cosmetic company in Latin America, has adopted strong compromises in Sustainability to create value in all its supply chain, with a balance between economic, social and environmental impacts for more than four decades. Consistently with this principle, the company has launched initiatives to minimize its environmental impacts, such as the iconic example of refill packs since the early 1980´s. Since 2001 several environmental indicators and associated management systems have been implemented in three waves:

- The first model was a simplified Life Cycle Assessment for packaging which helped initiating Ecodesign practices in the Development process;

- In 2007, a second model was launched: the Environmental Table, a self-declaration stated in the label of all products or website, composed by 6 indicators regarding the product content and packaging;
- The third model, the Greenhouse Gas (GHG) Emissions Corporate Inventory, was also created in 2007. Natura's externally verified Scope 3 Inventory accounts the GHG Emissions starting from the extraction of raw materials up to the disposal of products and packaging. This model was recently updated including two additional levels of accounting: inventory split by internal macro-process and carbon footprint of all products, to give an even more effective support to the Carbon Reduction Program. This reduction effort refers to a publicly reported reduction target of 33% in carbon intensity adopted in 2007 for a 5 years period.

Based on this initial successful experience in Life Cycle Management, Natura has perceived the necessity to extend the scope of the assessment and indicators, and priority was initially given to the environmental impacts on freshwater. Indeed, within the last five years, society and businesses have shown increasing awareness and concern of water as a key challenge to the long-term sustainability of businesses – some have called it the 'new carbon'. The World Business Council for Sustainable Development (WBCSD), a global association of companies dealing with business and sustainable development, believes that businesses can play an active and responsible role in ensuring socially equitable, ecologically respectful, and economically viable water management [1].

With that in mind, Natura began a series of studies to support the future implementation of a freshwater sustainability strategy, considering the three main pillars involved in the same current Carbon Program: measuring, reducing and offsetting the impacts.

Water Footprint

The term "water footprint" (WF) was first used during discussions on "virtual water", a concept introduced by Tony Allan in the early 90's, aiming to express how some countries tend to withstand water stress by importing products with high water requirement for its production. Water footprint has been defined as the amount of freshwater needed, directly or indirectly, to produce goods and services consumed by an individual or community or produced by a business [2]. The method addresses three different types of freshwater use: blue, green and grey. The blue water footprint is the volume of freshwater that evaporated from the global blue water resources (surface water and ground water) to produce the goods and services. The green water footprint is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). The grey water footprint is the volume of polluted water that associates with the production of goods and services. The water footprint is a geographically explicit indicator, not only showing volumes of water use and pollution, but also the locations [3].

To experiment the use of water footprint indicators, Natura joined the "Water Footprint Network" (WFN), a global initiative aimed at coordinating efforts for further develop and disseminate knowledge on water footprint concepts, methods and tools.

Experiences and future challenges

WFN Pilot Project – A product perspective

As the first step, for a better understanding of impacts and the applicability of the water footprint method, we chose to carry out a pilot project in partnership with WFN. Two cosmetics from the product portfolio were chosen, a perfume and body oil, and the water footprint was explored and quantified considering the life cycle approach and applying the WFN methodology. The scope and boundaries were defined as wide and inclusive as possible, considering the green, blue and grey water footprint involved through the complete life cycle of the products – extraction of raw materials, production processes and consumer use phase (Figure 1).

Corporate data for all of Natura's operations was collected, as well as data from our direct suppliers based on the industrial formula specifications. Then, it was complemented with data extracted from known LCA databases.

For the grey water footprint, data from Ecoinvent [4] described as "outputs to water" was used representing the load of pollutant discharged by each process stage. In an attempt to quantify the potential pollution of water resources at the consumer use phase (bath ritual), a chemical analysis of a product sample was conducted by a laboratory and 20 parameters described in national water legislations were compared, resulting in a theoretical dilution volume necessary to assimilate the load of pollutants - the grey water footprint.

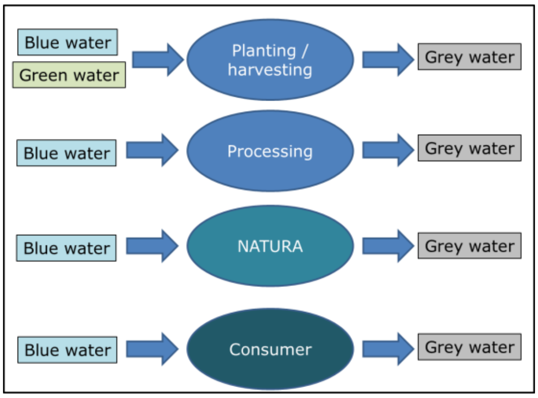


Figure 1 - Boundaries of the water footprint study.

The end of a rinsible product's life cycle is the use phase, represented by the bathing ritual and the treatment of the wastewater generated during the process, if applicable. In this study, the reality in Brazil was considered - wastewater treatment deficit is around 75% of the collected sewage flow [5]. For the body oil WF was considered that only 25% of the wastewater generated is treated in wastewater treatment facilities and that the remaining goes directly into the water bodies.
The results were compiled in a table, describing the blue, green and grey water footprints of each input.

Blue WF Screening – a Corporate Perspective
As a next step, to understand the magnitude of freshwater impacts in a corporate level, a study was conducted to estimate the total blue water footprint of Natura's activities. The green and grey water footprints weren't considered at this stage because of complexity of parameters and unavailability of data. To that purpose, a database screening was chosen. The total mass consumption of Raw Materials (RM) and Packaging Materials (PM) by Natura in 2009 was gathered and the materials were classified according to their contribution to the total mass. The materials with accumulated weight mass of 90% were considered of high relevance and studied individually, and the remaining 10% were considered through categorization by similarity, choosing one representative for each category that was also studied individually. For each material the blue water footprint was estimated based in water withdrawal data from Ecoinvent [4] and presented through eight different indicators, of which only the first four were considered (Table 1).
To estimate the blue water footprint through water withdrawal data, we considered previous studies which state that the water footprint related to industrial goods consists mostly (90%) of a grey water footprint (pollution), the remainder (10%) being a blue water footprint (evaporation of ground and surface water) [6].

Table 1 - Categories of water in Ecoinvent 2.1.

Water categories in Ecoinvent 2.1 via SimaPro 7.2
Water, lake
Water, river
Water, well, in ground
Water, unspecified natural origin
Water, cooling, unspecified natural origin
Water, salt, ocean
Water, salt, sole
Water, turbine use, unspecified natural origin

Due to the high amount of RM and different types of PM used by Natura and considering the continuance of water footprint studies, an analysis of intrinsic representation was applied to define the efforts for each material. Three lists of materials for each category (RM and PM) were generated by applying the following criteria for optimization of the original list: list A, comprising materials with accumulated freshwater consumption of 85% (high relevance); List B presenting materials with consumption between 85% and 95% (average importance) list C with all other materials included above 95% (low relevance).
Evaluating the results, the packaging material "fabric" is the input that contributes the most to the final value. The textiles, which corresponds to 1.2% of the total PMs mass and 0.6% of the total mass of inputs (RMs + PMs), would be responsible for 74% of all freshwater consumed by PMs and 26 % of Natura's total freshwater consumption. This is because the data for cotton in textiles consider the production in China, where they rely on a furrow irrigation system. This does not represent the reality of the textiles used by Natura, but is the only data available.
The next step will be the calculation of the water footprint of Natura, considering the blue, green and grey indicators as well as the life cycle of all products and activities, to support the development of a sustainability strategy for freshwater use, by collecting data that will be more representative of the real supply chain.

Discussion
Although the methodology had already been applied in a product level and several studies were published, most of them described the water footprint of agricultural commodities, like cotton, coffee and tea [7, 8]. More complex

examples, like industrial products, are not available. But even though many premises were assumed to conclude the product analysis, it was possible to understand our major points of impacts in the value chain.

The pilot study to calculate the water footprint of two products allowed the identification of difficulties and methodological limitations. Firstly, the lack of regional inventories led us to use a foreign database, which could not be used to upgrade the technological frontier. Moreover, the load of pollutants discharged by each process unit has been fully adopted from the database, without the possibility of questioning the veracity of this information for each technology used and with the risk of considering a different technology that the one employed in Brazil. The pilot identified the hotspots through Natura's value chain. The grey water footprint of the use phase represented 95% to 98% of the total water footprint when analyzing rinsible products.

The water footprint of energy was also an important point of discussion. After applying the WFN model to estimate indirect water consumption associated to energy production, it was concluded that those results presented a very high level of uncertainty, and more accurate data is required before incorporating the water footprint of energy in the WF calculations. For Brazil, specific data on hydropower energy is essential to generate indicators that represent local impacts.

Another limiting factor is the lack of databases that describe consumption of water as defined by the water footprint methodology. Currently, the existing databases have information only on water withdrawal and do not consider the water flows. According to the WF concept, the term 'consumptive water use' refers to one of the following four cases: water evaporates; water is incorporated into the product; water does not return to the same catchment area; water does not return in the same period [3].

Next to the traditional and restricted measure of water withdrawal, the water footprint can be regarded as a comprehensive indicator of freshwater resources appropriation [9]. The difference between the traditional measurements and the new concept has a major impact in how companies report environmental indicators today. Databases must be updated to allow more accurate calculations of water footprint indicators.

Conclusions

The main conclusions of our first studies and experience can be summarized as follow:

- It is possible to apply the Water Footprint methodology to build a consistent freshwater corporate inventory and product analysis;
- The Water Footprint as a tool is a fundamental instrument for establishing a water sustainability strategy including reduction plans and quantified compensation/offsetting initiatives for mitigating impacts.

References

[1] World Business Council for Sustainable Development (WBCSD). 2011. www.wbcsd.org. Accessed january 15th 2011.

[2] Hoekstra, A.Y. 2003. Virtual water trade. In: Proceedings of the International Expert Meeting on Virtual Water Trade, Delft, The Netherlands, 2002 12-13 December, Value of Water Research Report Series No.12, UNESCO-IHE, Delft, The Netherlands.

[3] Hoekstra, A. Y., et al. 2009. Water Footprint Manual, State of the art. Water Footprint Network; University of Twente, Enschede, Netherlands. 2009. 127p.

[4] ECOINVENT. Swiss Centre for Life-Cycle Inventories. Database v2.1, 2009; Dübendorf: Switzerland.

[5] Sperling, M. 2008. Standards for Wastewater Treatment in Brazil - Standards and Thresholds for Impact Assessment Environmental Protection in the European Union, Volume 3, Part IIa, 125-132.

[6] Van Oel, P.R., Mekonnen M.M. and Hoekstra, A.Y. 2009. The external water footprint of the Netherlands: Geographically-explicit quantification and impact assessment, Ecological Economics 69(1): 82-92.

[7] Chapagain, A.K., Hoekstra, A.Y., Savenije, H.H.G. and Gautam, R. 2006. The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries, Ecological Economics. 60(1): 186-203.

[8] Chapagain, A.K., and Hoekstra, A.Y. 2007. The water footprint of coffee and tea consumption in the Netherlands, Ecological Economics 64(1): 109-118.

[9] Lennes, P.W.; A.Y. Hoekstra. 2008. Business water footprint accounting. A tool to assess how production of goods and services impacts on freshwater resources worldwide. Value of Water. Research Report Series No. 27.

CARBONFOOTPRINT FOR A CRACKER IN COLOMBIA

Naranjo, Carlos[1]
López, Oscar[2]
Botero, Edgar[3]
[1]GAIA Servicios Ambientales Medellín - Colombia. cnaranjo@gaiasa.com
[2]Compañía de Galletas NOEL S.A.S Medellín - Colombia. oflopez@noel.com
[1]Ecothermia S.A.S. Medellín - Colombia. ebotero@ecothermia.com

ABSTRACT
The carbon footprint of a cracker in Colombia was calculated from the weath plantation to cracker packaging. The PAS2050 of the British Standard Institute methodology was applied. The Ecoinvent database and primary data was used. In the results the great impact of the life cycle in a cracker is in the wheat grains at farm with 40% of carbon footprint. Another important critical point is in the packaging, with 17% of impacts. The company use the results for new research proposals to reduce carbon footprint.

Keywords: Cracker, Greenhouse gas, carbon footprint

1. INTRODUCTION

The cracker is one of the most important item in the diet, they provide energy, protein, iron, vitamin B1. "The consume of cookies is closer to 120,000 tonnes a year in Colombia" (Gómez, 2007) This means a consumption of about three kilograms per person, while in countries like USA, Brazil or Argentina, consumption located between five and eight kilograms per person. However, in comparison to other markets such as Venezuela, Peru, Central America and Ecuador, Colombia has a use a little above average in that region" (Gómez, 2007).

NOEL Company participates with 70% of sales of cookies in the Colombian market (Gómez, 2007). One of most important cookies is "Saltin", it is a cracker. It is NOEL's interest to study the carbon footprint of the Saltin Cracker to identify the stages of life cycle with greater impact and to propose strategies to reduce the impact, as this provides evidence that carbon footprinting and labelling matter to consumers.

Colombia has a few studies in Life Cycle Assessment of products, and this is the first approach for this topic for food industries.

2. METHODOLOGY

The analysis of the environmental impacts of a Saltin Cracker of the company located in Colombia was investigated by applying Life Cycle Assessment (LCA). LCA is a methodology used for analyzing and assessing the environmental loads and potential environmental impacts of a material, product or service throughout its entire life cycle, from raw materials extraction and processing, through manufacturing, transport, use and final disposal (ISO 14040, ISO 14044). For the Carbon Footprint assessment uses the PAS2050 (2008) Guide of the British Standard Institute.

Goal and Scope. The company in its Sustainable Development Policy, wishes to make the Life Cycle Assessment of a Saltin Cracker, aligning this strategy with the requirements of customers. The results of the study will enable the company to identify new projects that reduce the environmental impact of product throughout its life cycle, and also will be a first input for a possible international certification of product carbon footprint. Results of LCA will be used by the Environmental Department of the Company and Research and Development Department, which with this work propose new policies for sustainable development products in according to group policies.

Scope. The functional unit is "one kilogram of cracker", because it is the sales unit for the company.

The system investigated in this study is for Colombian conditions, from wheat farming to cracker production and distribution. Figure1.

For the wheat mill, the assignation was by weight to flour and bran. For the cracker production, the power and times for each machine was measured. For the distribution uses an average of 2000 data for fuel consume and efficiency.

Life Cycle Inventory, the data recorded for the study was related to 2009. Table 1, presents a view of the primary activity data and secondary data used in the study.

Table 1: Primary activity data and Secondary data

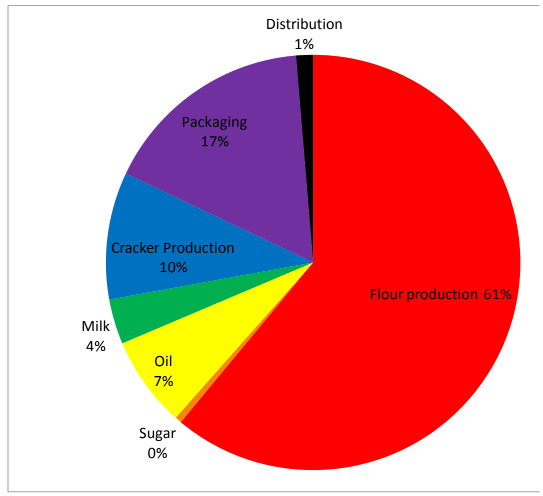
Inventory Data Input	Inventory Data Source
Wheat grains, at farm/US	Ecoinvent
Transport, freight, rail, diesel/tkm/US	Ecoinvent
Transport, barge tanker/tkm/RER	Ecoinvent
Transport, transoceanic freight ship/tkm/OCE	Ecoinvent
Transport, lorry 16-32t	Use of emissions factors for diesel use. UPME.
Wheat Mill	Primary activity data
Electricity mix for Colombia	Emission factor to Colombia. UPME
Sugar, from sugarcane, at sugar refinery/BR S	Ecoinvent
Palm oil, at oil mill/MY	Ecoinvent
Milk production	Hospido
Oriented polypropylene film	Primary activity data, APME Ecoinvent
Corrugated Cardboard	Ecoinvent, FEFCO

4. Discussion

The Figure 2 shows the critical point for the product. For the cracker, the flour production from the wheat production at farm, and transport from USA to Colombia has the biggest influence, it associated with the fertilizer use and emissions of different equipments. It is 61% of the total carbon footprint of the cracker.

For the flour production, the wheat production at farm it is the 74% of carbon footprint of this stage.

The packaging is from oriented polypropylene film, and it is 12% of CO_2eq associated to the product. While the cracker production is only the 10% of the total carbon footprint of the product and it is associated to bake in an industrial gas furnace.



The Life Cycle Assessment of product was modelled for different scenarios for reducing the impact, and assessing possible improvement alternatives:

- Change of location of production plant, it decrease the carbon footprint only at 2%
- Use a mix of aluminium/plastic or Polypropylene for the packaging, increase the carbon footprint at 7%
- Improve the efficiency of baked of the cracker, decrease the carbon footprint at 1,5%.
- Decrease the reject of the cracker baked, decrease the carbon footprint at 3%

Increase the efficiency of the baker, with less rejection of product, decrease the carbon footprint of the cracker; at proposed alternatives, this is the one with a better scenario for reducing emissions.

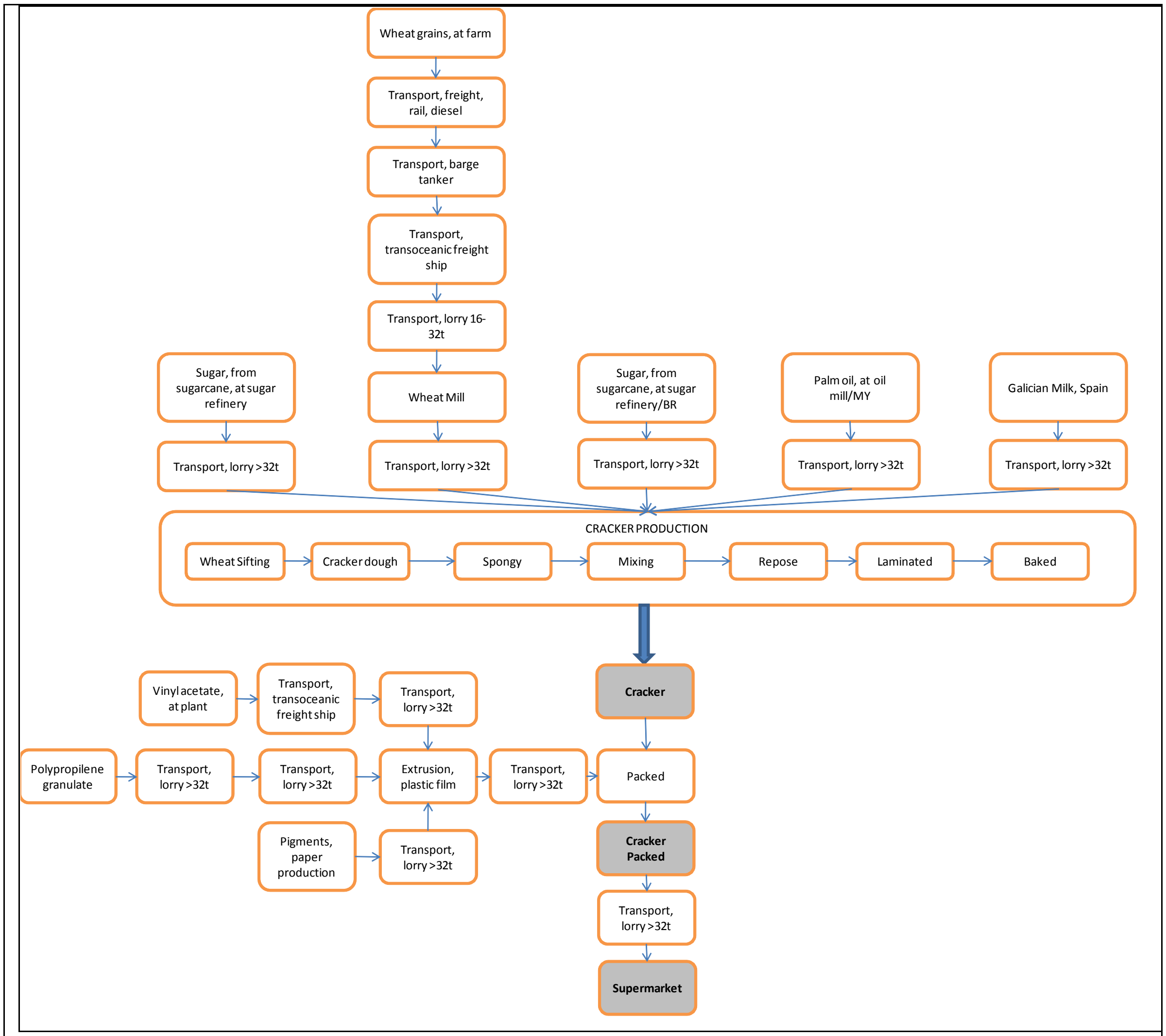


Figure 1. System of study of cracker.

3. Conclusion

American wheat grain production is the most important commodity in the Climate Change impact for the Colombian cracker, it represents a 74% of carbon footprint of the fluor life cycle. The fluor life cycle is the 61% of the carbon footprint of a cracker.

The Carbon footprint of product, with Life Cycle Assessment focus, it is an important tool to make decisions that decrease the impact of a product, in this case study, to select the alternative to reduction of a carbon footprint, decreasing the cracker rejection of the baked. It reduces the carbon footprint at 4%.

Latin America, specially Colombia needs Life Cycle Inventories (LCI) and academic studies in Life Cycle Assessment (LCA) for agricultural and food productions. When this LCA and LCI would be publicated, this study will be adjusted for local conditions.

3. References

Gómez, I. (2007) La Batalla de las galletas. *Revista Dinero* (283), pp 125-128 . <http://www.dinero.com/edicion-impresa/caratula/batalla-galletas_37405.aspx>

F. Brentrup et al.(2004). Environmental impact assessment of agricultural production systems using the life cycle assessment (LCA) methodology II. The application to N fertilizer use in winter wheat production systems *Europe. J. Agronomy* (20), pp 265–279. Charles, et al. (2006). Environmental analysis of intensity level in wheat crop production using life cycle assessment. *Agriculture, Ecosystems and Environment* (113), pp 216–225. N. Pelletier et al. (2008). Scenario Modeling Potential Eco-Efficiency Gains from a Transition to Organic Agriculture: Life Cycle Perspectives on Canadian Canola, Corn, Soy, and Wheat Production. *Environmental Management* (42), pp 989–1001. Biswas, et al. (2008). N. Pelletier et al. (2008). Life Cycle global warming potential of wheat production in Western Australia. Curin University of Technology, Australia. Hospido, et al. (2003). Simplified life cycle assessment of galician milk production. *International Dairy Journal (13),* pp 783–796.	

Developing a Network for Environmental Product Declarations and Product Category Rules in the Americas: A Concept Paper

Schenck Rita[1]; Quirós Ana[2]; Romero Omar

TOPIC: **LCA MANAGEMENT TRENDS – Environmental Product Declarations and Certification**
KEYWORDS: **Product Category Rules,**

The use of environmental product declarations (EPDs) is sweeping the globe. There are EPD programs in almost every country in Western Europe, and much of the Asia Pacific, too. The US has programs, and there are programs in development in Canada. In addition, the Marrakech Process works with several Task Forces (MTF) which in turn have developed methodologies and support pilot projects across the world which would be greatly enhanced by EPDs; for example the work on Sustainable Public Procurement (SPP) currently involving countries such as: Chile, Uruguay, Costa Rica, Colombia, Lebanon, Tunisia and Mauritius.

The pivot point of EPD programs is the development of Product Category Rules, or PCRs. So far, there are no more than 500 PCRs developed globally, out of the estimated 40,000 or more that may be currently needed. Despite, that small number, there is already a tendency towards redundancy. Countries develop their own PCRs, or use the PCRs developed elsewhere and modify them for local conditions.

Indeed there is a logic to localized PCRs. Different countries have different environmental and social conditions and therefore different value systems. A perfect example of this is the difference between how those living in Europe and those living in the Americas think of land use and biodiversity conservation. In Europe, there are essentially no natural or near-natural ecosystems: biodiversity is fostered in enclaves. In contrast, every county in the Americas has examples of native or near-native ecosystems: biodiversity is fostered by protecting these ecosystems.

So the challenge is: how can we develop PCRs that address the global nature of value chains while respecting local perceptions of environmental value? There are basically two approaches: take existing PCRs and try to harmonize them, country by country, or collaborate among countries when PCRs are being developed to integrate national and regional issues, agreeing, for example, that the label may look somewhat different in different countries.

We propose to take the latter approach for the Americas, inviting active international participation in developing PCRs, setting up a system where we can work together. Such a system would:

[1] rita@iere.org
[2] aquiros@ecoglobala.com

1. Set up national PCR centers in the Americas (with each country setting up the center as made sense to them);
2. Identify some example products (priority products) for which companies or governments are interested in EPDs in several countries –links with current work done with pilot projects on related subjects, such as the one UNEP carries on SPP, are recommended;
3. Develop a trans-national committee to develop the PCRs in accordance with ISO 14025;
4. Post the PCRs in the language of the country;
5. Based on these examples, develop methods of working together, identifying what parts of the PCR must be constant in all countries and what parts may vary country by country; and draft agreements for cross-recognition of PCRs and the EPDs that come from them;
6. Develop marketing materials that will inform countries and governments of these efforts, to assist in green purchasing using the work of the international system.

It is a big task, but together the Americas can use market forces to improve our environment, using LCA as our measuring system. The approach could be replicated for other regions of the world and global harmonization facilitated through the common scientific based language LCA provides.

CARBONFOOTPRINT FOR CHOCOLATE IN COLOMBIA

Naranjo, Carlos[1]
Rada, Maria[2]
Pantano, Esperanza[3]
[1]**GAIA Servicios Ambientales Medellín - Colombia.** cnaranjo@gaiasa.com
[2,3]**Compañía Nacional de Chocolates-Colombia.** mrada@chocolates.com.co, lepantano@chocolates.com.co
[1]**Ecothermia S.A.S. Medellín - Colombia.** ebotero@ecothermia.com

ABSTRACT

The carbon footprint of a chocolate in Colombia was calculated including the cultivation of cocoa beans, transport, process and packaging. The PAS2050 of the British Standard Institute methodology was applied. The Eco invent database and primary data from farms and production was used. In the results the great impact of the life cycle in a chocolate with milk is in the milk farm and production with 56% of carbon footprint. Another important critical point is in the sugar, with 15% of impacts. The company use the results for new research proposals to reduce carbon footprint.

Keywords: Chocolate, Greenhouse gas, carbon footprint

1. INTRODUCTION

Cocoa is mainly used in the production of chocolate. The world production in 2007 was 3,7 million tones. Colombia is producing about to 40.000 tones of cocoa beans annualy, with a yield of 492kg per hectárea aprox.

The production of cocoa in Colombia is characterized being established in agroforestey systems with low nutrient requirements.

This study was aimed at quantify carbón footprint of a chocolate with milk, using the Life Cycle Assessment (LCA) tool and the PAS2050.

1. METHODOLOGY

The analysis of the environmental impacts of a Chocolate with milk of the company located in Colombia was investigated by applying Life Cycle Assessment (LCA). LCA is a methodology used for analyzing and assessing the environmental loads and potential environmental impacts of a material, product or service throughout its entire life cycle, from raw materials extraction and processing, through manufacturing, transport, use and final disposal (ISO 14040, ISO 14044). For the Carbon Footprint assessment uses the PAS2050 (2008) Guide of the British Standard Institute.

Goal and Scope. The company in its Sustainable Development Police, wishes to make the Life Cycle Assessment of a Chocolate with milk, aligning this strategy with the requirements of customers. The results of the study will let Company to identify new projects that reduce the environmental impact of product throughout its life cycle, and also will be a first input for a possible international certification of product carbon footprint. Results of LCA will be used by the Environmental Department of the Company and Research and Development Department, which with this work propose new policies for sustainable development products in according to group policies.

Scope. The functional unit is "one kilogram of Chocolate with milk", because it is the sales unit for the company.

The system investigated in this study is for Colombian conditions, from cocoa beans production at farm, to Chocolate production and distribution. Figure1.

Life Cycle Inventory, the data recorded for the study was related to 2009. Table 1, presents a view of the primary activity data and secondary data used in the study.

The cocoa beans (*Theobroma cacao)* are harvested in agroforestry systems with Laurel and other species. Carbon accumulation in these systems could contribute to the household economy if a market for carbon certificates for greenhouse gases reduction is created.

For the cacao liquor and cacao butter production, the electricity and times for each machine was measured. For the distribution uses an average of data for fuel consume and efficiency. The mass and energy balance for the process was made.

Table 1: Primary activity data and Secondary data

Inventory Data Input	Inventory Data Source
Cocoa beans, at farm/COL	FEDECACAO, Primary data
Transport, lorry 16-32t	Ecoinvent
Chocolate company	Primary activity data
Electricity mix for Colombia	Emission factor to Colombia.
Sugar, from sugarcane, at sugar refinery/BR S	Ecoinvent
Milk production	Hospido
Sulphite pulp bleached, at plant/RER	Ecoinvent
Aluminium foil	Ecoinvent and secondary information
Corrugated board base paper, kraftliner, at plant/RER	Ecoinvent

4. Discussion

The Figure 2 shows the critical point for the product.

For the Chocolate with milk, the Milk production at farm, has the biggest influence, it associated with enteric emissions of livestock. It is 43% of the total carbon footprint of the Chocolate with milk.

For the Cocoa beans production, the wheat production at farm it is the 16% of carbon footprint and the process too

The packaging is 12% of CO_2eq associated to the product. While the distribution is only the 3% of the total carbon footprint of the product.

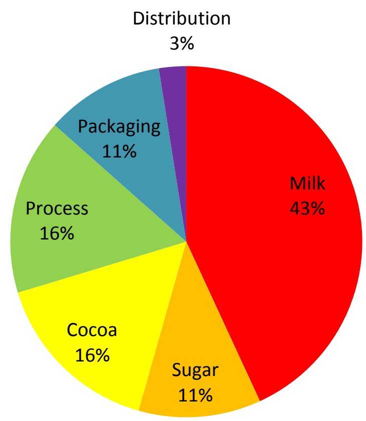


Figure 1. Carbon footprint

The Life Cycle Assessment of product was modelled for different scenarios for reducing the impact, and assessing possible improvement alternatives:

- Cocoa beans used, with differences in the plantation density and carbon sequestration.
- Another source of milk, like soy milk. This option needs a new research for the company.

3. Conclusion

The milk production is the most important commodity in the Climate Change impact for the Colombian Chocolate with milk, it represents a 43% of carbon footprint of the cocoa life cycle.

The Carbon footprint of product, with Life Cycle Assessment focus, it is an important tool to make decisions that decrease the impact of a product, in this case study, to select the alternative to reduction of a carbon footprint.

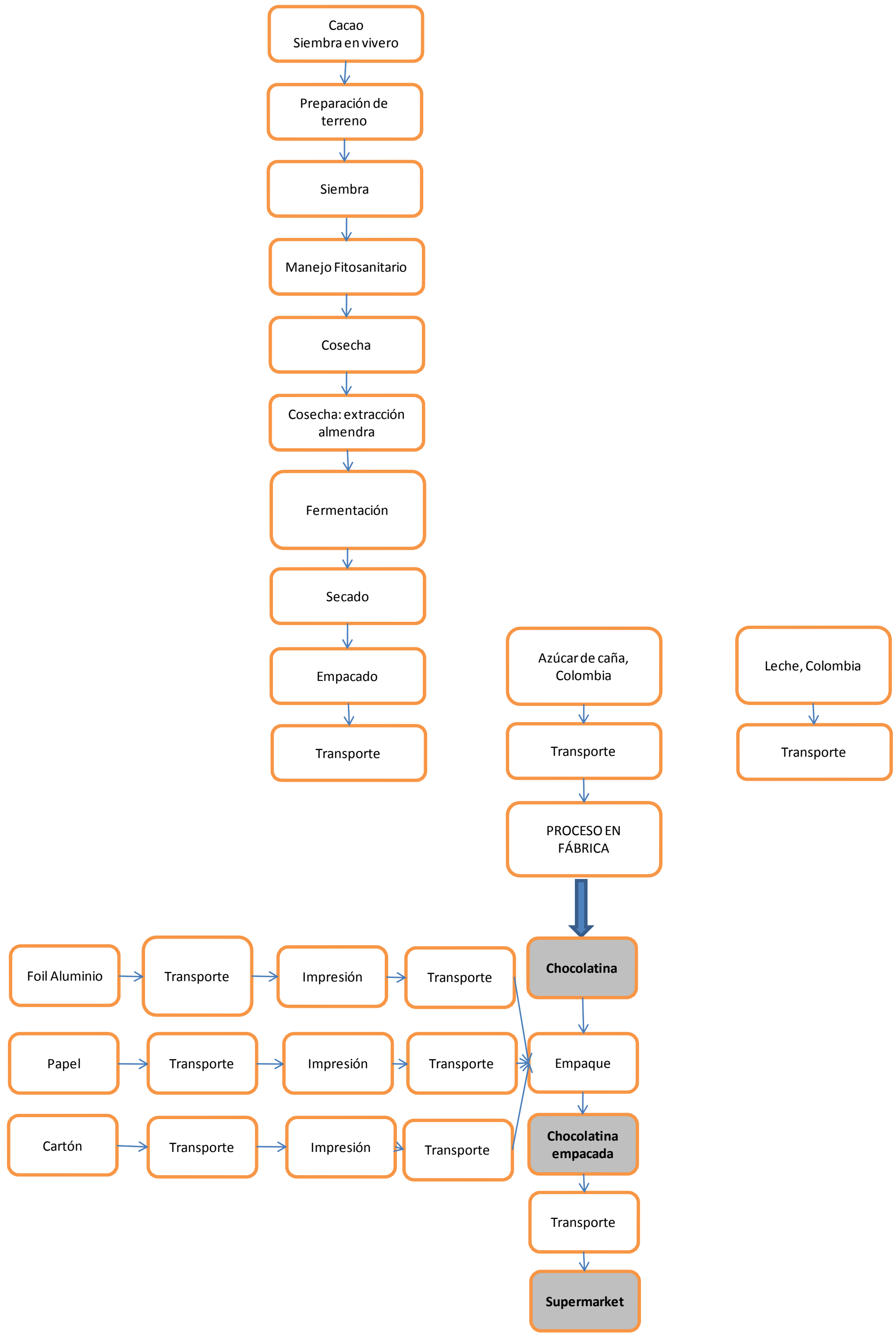


Figure 1. System of study of Chocolate with milk.

Latin America, specially Colombia needs Life Cycle Inventories (LCI) and academic studies in Life Cycle Assessment (LCA) for agricultural and food productions. When this LCA and LCI would be publicated, this study will be adjusted for local conditions.

3. References

BSI, et al (2008). Guide to PAS2050. How to assess the carbon footprint of goods and services. Londres: 2008. 59 páginas

Ntiamoah, et al (2008). Environmental impacts of cocoa production and processing in Ghana: life cycle assessment approach. *Journal of Cleaner Production* (16), pp 1735-1740

Hospido, et al. (2003). Simplified life cycle assessment of galician milk production. *International Dairy Journal (13),* pp 783–796.

BSI (2008). PAS2050:2008. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. Londrés: 2008. 36 pages.

FEDECACAO (2004). Cacao culture en el Departamento de Cundinamarca. Bogotá. Página 8.

ORTIZ (2008), Angela et.al. Almacenamiento y tasas de fijación de biomasa y carbono en sistemas agroforestales de cacao (*Theobroma cacao*) y laurel (*Cordia alliodora).* Agroforestería en las Américas No 46.. Página 26 a 29.

IPCC. Directrices del IPCC de 2006 para los inventarios nacionales de gases de efecto invernadero. Volumen 4: Agricultura, silvicultura y otros usos de la tierra. Capítulo 11. Emisiones de N_2O de los suelos gestionados y emisiones de CO_2 derivadas de la aplicación de cal y urea

Figueira A, Janick J, BeMiller JN. New products from Theobroma cacao:seed pulp and pod gum. In: Janick J, Simon JE, editors. New crops. New York: Wiley; 1993. p. 475e8

Forestry

CILCA 2011

MÉXICO

Life cycle assessment of a fishmeal and oil production plant in Peru, in a context of sustainable development
Peru

Applications of Life Cycle Assessment methodology for the evaluation of a Cuban cane sugar mill, by means of, parameterized inventories
Cuba

Environmental Performance Evaluation in Brazilian Pesticide Sector
Brazil

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Life Cycle Assessment and its relevance for community forest enterprises of Oaxaca, Mexico
Spain

Applying the framework of Life Cycle Analysis to Forestry Social Sector in the Region of Bío Bío in Chile. First approaches and results
Chile

Life cycle assessment in the evaluation of environmental impact at Panchito gomez toro sugar enterprise
Cuba

Life cycle assessment of a fishmeal and oil production plant in Peru, in a context of sustainable development

Durand, Hermine[1]; **Fréon, Pierre**[2]; **Sayda Huaranca**[3] ; **Isabel Quispe**[4]

[1]**Ecole Nationale Supérieure, Paris, France**
[2]**Institut de Recherche pour le Développement, UMR-212, CRH, Sète, France**
[3]**Pesquera Diamante, Lima, Peru**
[4]**Peruvian Network on LCA, Pontificia Universidad Católica del Perú, Lima, Peru, iquispe@pucp.edu.pe**

ABSTRACT

Peru is the first fishmeal and oil producer in the world and this industry has a major socio-economic impact. Fishmeal production consists in extracting all fish's proteins by cooking, pressing, drying and grinding the anchovy. Every machine in the plant consumes energy: driers and boilers (which generate all the steam needed at plant) burn heavy fuel oil or natural gas in their motors, generators burn light fuel oil to produce a certain amount of electricity and all other machines have electric motors, consuming electricity bought to local companies or generated at plant.

We aimed at performing a detailed analysis of the environmental impact of two Peruvian fishmeal and oil plant in a context of sustainable development using life cycle assessment (LCA). We consider as functional unit one ton of fishmeal leaving the plant at the end of the production process. We used the SimaPro 7.2 software and quantified the impact assessment using the CML 2 baseline 2000 V2.05/World 1990 method.

As expected plant use was the most impacting stage, due to fuel combustion, but for some indicators construction and maintenance represented up to 15% and 32% of total impact respectively. The analysis of maintenance impact stressed the importance of epoxy paints and lubricating oils. Then we observed the decrease of use impacts between 2008 and 2010 one plant moving progressively from burning heavy fuel to natural gas and from a simulation deduced that a full change of energy supply would reduced impacts from 12 to 97% according to the categories, except for abiotic depletion that remains nearly the same. We showed that construction and maintenance data should not be neglected and that burning natural gas significantly reduces the plant environmental impact.

o Topic: LCA Industrial applications (Agroindustry, forestry, fisheries)

o Keywords: ACV, fishmeal, anchovy, Peru

Introduction

Peru is the first fishmeal and oil producer (2 million tons a year, *i.e.* 30% of global production) and exporter in the world. The industry has a major socio-economic impact as it operates about 130 processing plants and directly employs 23,000 workers (7,000 in the factories). Production mainly consists in animal feedstuffs and is exported, mainly towards Asian markets. Fishmeal production consists in extracting all fish's proteins by cooking, pressing, drying and grinding the anchovy. In many steps of this process, liquids are recuperated, centrifuged and the solid phase returns to the fishmeal production line, whereas the liquid phase is processed to make fish oil. Every machine in the plant consumes energy: driers and boilers (which generate all the steam needed at plant) burn heavy fuel oil or natural gas in their motors, generators burn light fuel oil to produce a certain amount of electricity and all other machines have electric motors, consuming electricity bought to local companies or generated at plant.

Methodology

We aimed at performing a detailed analysis of the environmental impact of two Peruvian fishmeal and oil plant in a context of sustainable development using life cycle assessment (LCA). The first plant used only heavy fuel oil for drying the fish directly whereas the second mostly used natural gas for producing steam used in dryers.

We consider as functional unit one ton of fishmeal leaving the plant at the end of the production process. In contrast to the few previous research works made on fishmeal factories, we did not only focus on plant use and took also into account two other stages of the life cycle: construction and maintenance (Fig. 1). We used the SimaPro 7.2 software and quantified the impact assessment using the CML 2 baseline 2000 V2.05/World 1990 method, a mid-point approach which calculates the environmental impact on 10 indicators.

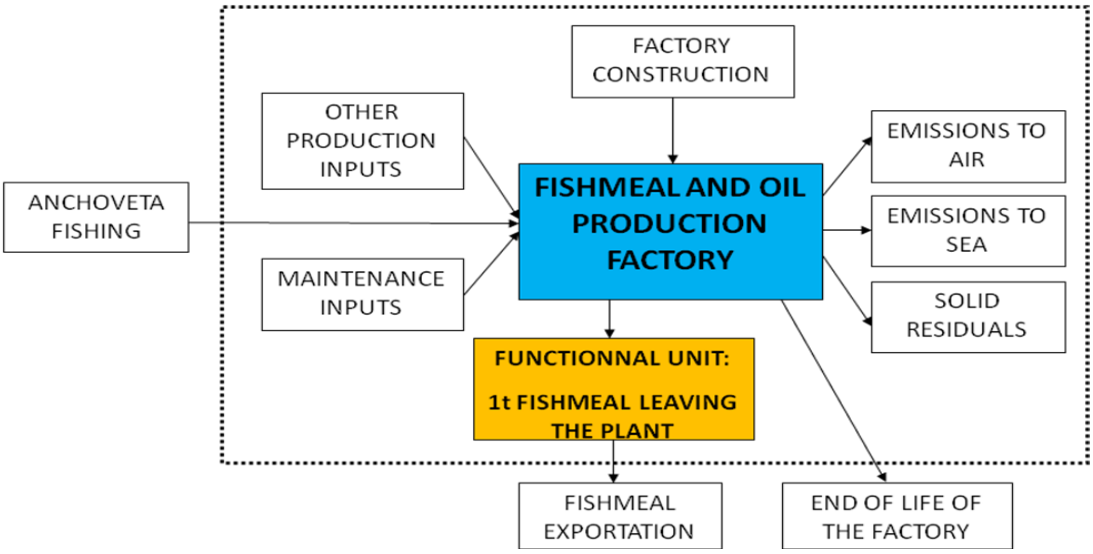


Fig. 1. Perimeter of the study.

Results and Discussion

As expected plant use was the most impacting stage, due to fuel combustion (Fig. 2), but for some indicators (those related to toxicity) construction and maintenance represented up to 15% and 32% of total impact respectively (Fig. 3). The analysis of maintenance impact stressed the importance of epoxy paints and lubricating oils (Fig. 4). Then we observed the decrease of use impacts between 2008 and 2010 in the plant moving progressively from burning heavy fuel to natural gas and from a simulation deduced that a full change of energy supply would reduced impacts from 12 to 97% according to the categories, except for abiotic depletion that remains nearly the same (Fig. 3). Our results on fuel and electricity consumption to produce one ton of fishmeal were consistent with previous studies. Although collecting data on the chemical composition of equipment was sometimes difficult, we showed that construction and maintenance data should not be neglected and that burning natural gas significantly reduces the plant environmental impact.

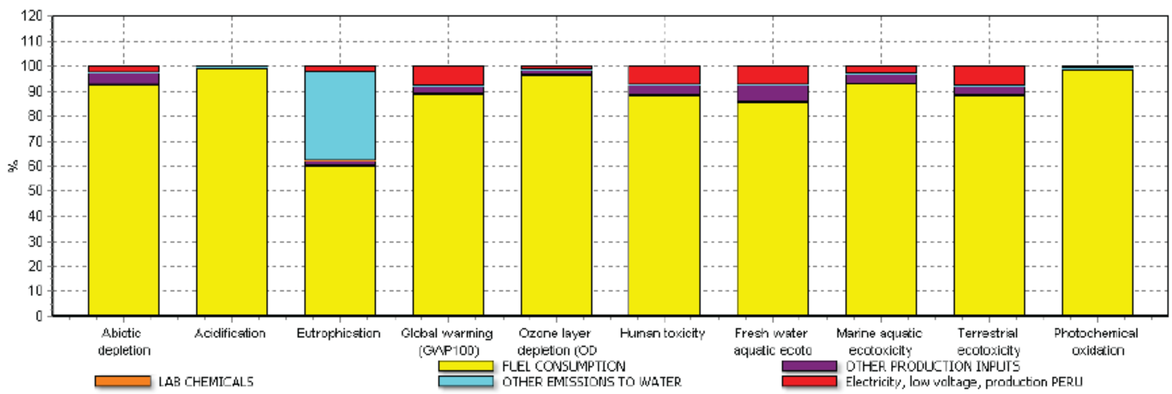


Fig.2. Analysis of use impact (Plant 1, 2009)

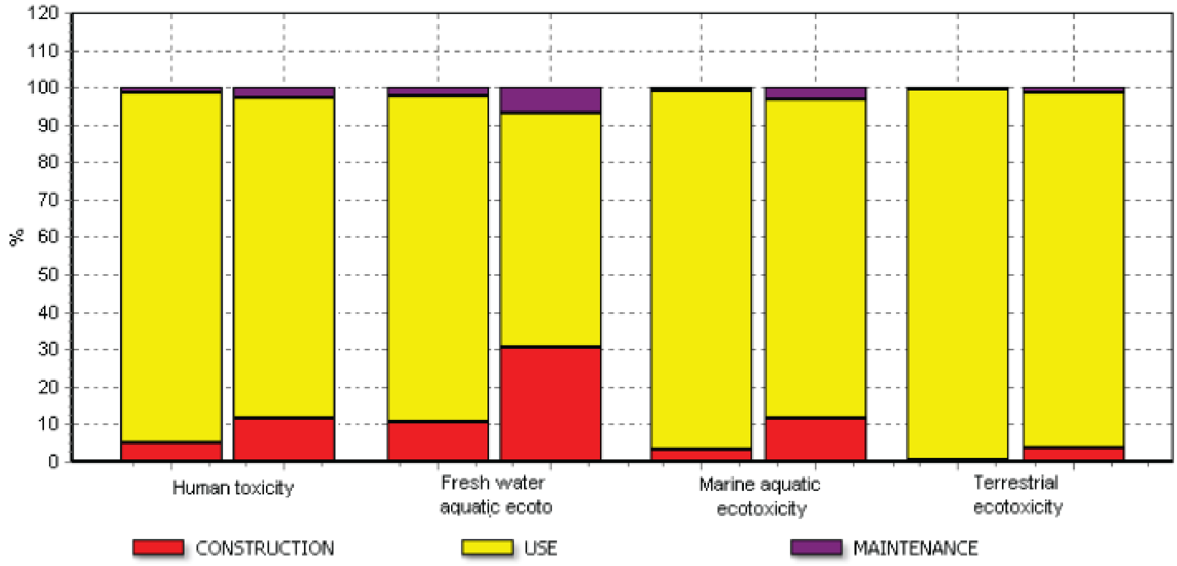


Fig. 3. Comparison of LCA between plant 1 with heavy fuel oil (left bars) and with natural gas (right bars) in 2009

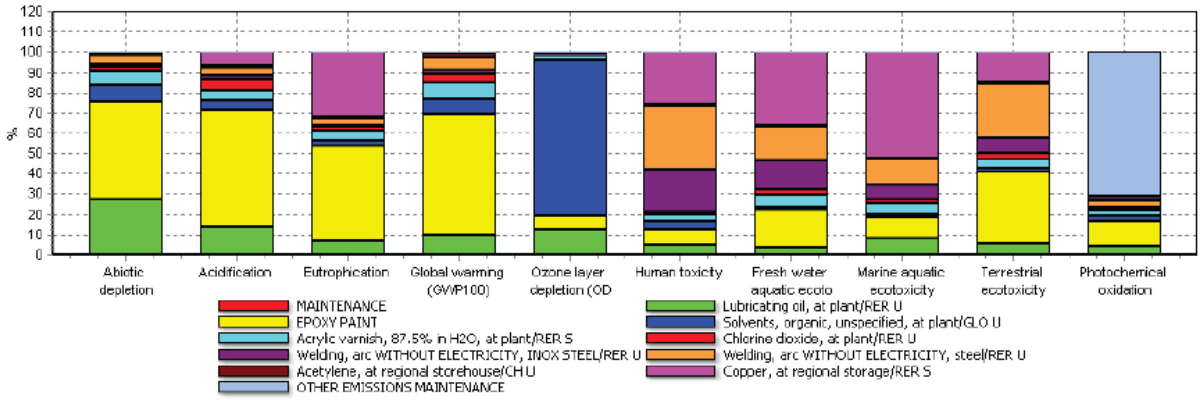


Fig. 4. Analysis of maintenance impact (plant 1 in 2009)

Applications of Life Cycle Assessment methodology for the evaluation of a Cuban cane sugar mill, by means of, parameterized inventories.

Contreras Moya, Ana M; Pérez Gil, Maylier; Rosa Domínguez, Elena; Espinosa Rodríguez, Vianka
Central University "Martha Abreu" of Las Villas. Faculty of Chemistry and Pharmacy. Highway to Camajuaní, km 5 ½, Santa Clara, Villa Clara, Cuba. Postal Code: 54 830. Fax: 53-42-281608. Telephone: 53-42- 281164.

E-mail: anama@uclv.edu.cu

Abstract

Life Cycle Assessment can be considered one of the best tools in assessing the environmental sustainability of different technological options, since it considers all the effects in the ecosystem and population that endanger the possibilities of current and future generations. Cuban sugar industry has a great impact on the environment because of the resources consumption and wastes generation. The parameterized Inventories for the Life Cycle of the crude sugar production in the Cuban Sugar Industry through a detailed record of all input and output currents involved in the process has been modeled and they allow evaluating the sugar production with the variation of different parameters.
In the present work, it is evaluated the environmental impact of a Cuban cane sugar mill by means of Eco-indicator 99 and the software SimaPro 7.2, using parameterized Inventories, during three production stages.
The results show that the sugar cane composition is the most significant parameters, because it is related with the bagasse production and cogeneration process. The last process is the most impacting stage in the analyzed mill; it exhibits the major harmful impact values for the category of respiratory effects of inorganic compounds and this effect is emphasized during the 2009 production stage. Similarly, this production stage shows the best results for the fossil fuels category due to avoided fuel consumption. It was evidenced the advantage of this procedure in order to analyze the relation of cane sugar production impacts and operational variables.
Topic: Applications of LCA in the Industry: Agro industry, forests and fishing
Key words: Life Cycle, cane sugar production, parameterized Inventories.

Introduction

The sugar cane industry has environmental impacts through the loss of natural habitats, intensive use of water, heavy use of agro-chemicals, discharge of polluted effluent and air pollution. Sugarcane is widely grown around the world and sugar production does not involve the use of any hazardous or toxic materials, there are no hazardous or toxic effluents or emissions. The sugar production process is self-sufficient in energy, providing all the energy for sugar manufacture from bagasse, the renewable fiber content of cane [1, 2].

Life Cycle Assessment (LCA) can be considered one of the best tools in assessing the environmental sustainability of different technological options, since it considers all the effects in the ecosystem and population that endanger the possibilities of current and future generations [3]

The methodology of LCA, according to standard [4–7] and the use of Eco-indicator 99 [8-10], considers the consumption of resources and the effects of the emissions onto the ecosystem and the human health. LCA tool, by using SimaPro software allows analyzing the impact of each stage of the sugar production process according to different impact categories considering several alternatives [11]

Cuban sugar industry has a great impact on the environment because of the resources consumption and wastes generation. The parameterized Inventories for the Life Cycle of the crude sugar production in the Cuban Sugar Industry through a detailed record of all input and output currents involved in the process has been modeled and they allow evaluating the sugar production with the variation of different parameters.

The objective of the present work is to evaluate the environmental impact of a Cuban cane sugar mill, using parameterized Inventories, during three production stages.

Methods

The parameterization, to model a process, requires using calculation rules in place of fixed data to construct the model, which can be used in different stages and processes. It makes possible to construct models varying the inputs and outputs parameters of the process, moreover helps to compare between two or more scenarios [12].

The studied system consists of a local cane sugar mill in the central region of Cuba for the conventional production conditions. It was evaluated its environmental impact during three production stages (2008, 2009 and 2010 year) for the scenarios comparison.

The assessment is done by means of Life Cycle Assessment, according to the ISO 14040 series and the SimaPro 7.2 LCA software, by means of the hierarchist version of Eco-indicator 99 methodology with average weighting (H/A) for Human Health, Ecosystem Quality and Resources. It was used Ecoinvent Data, new process data adapted to Cuban sugar production conditions and parameterized Inventories [12, 13].

As functional unit the daily sugar cane processed was defined. The sugar was selected as main product and all the by-products were assumed as avoided products.

Results and Discussion

From the parameterized inventory, according to the fixed and calculated parameters defined previously [12], it was evaluated the environmental impacts of the studied mill.

The results of comparative analysis demonstrate the advantage of this procedure in order to analyze the relation of cane sugar production impacts and operational variables.

Part of the tabulated results of scenarios comparison by process contribution is shown in the Table 1. The cogeneration process is the most impacting stage in the three scenarios analyzed.

Table 1. Scenarios comparison. Process contribution

Method: Eco-indicator 99 (EI 99 H/A)
Indicator: Single score
Unit: Pt

Process	**2008**	**2009**	**2010**
Total of all processes	3.5E-01	4.0E-01	3.9E-01
Cogeneration process	3.8E-01	4.4E-01	4.3E-01
Lime hydrated	2.1E-02	2.3E-02	2.2E-02
Phosphoric acid	1.8E-03	1.9E-03	1.8E-03
Hydrochloric acid	2.4E-05	2.7E-05	2.6E-05
Compost	-4.8-03	-5.2E-03	-5.1E-03
Electricity from oil	-5.7E-02	-6.2E-02	-6.1E-02

As can see, the 2009 production stage has the most significant value of total impact, although it presents the best results by avoided product concept.

The cogeneration process contributes to several impacts categories considered in the Ecoindicator 99. The Figure 1 shows the major harmful impact values for the category of respiratory effects of inorganic compounds and this effect is emphasized during the

2009 production stage as was analyzed previously. The particulate material is the main contributor to this category.

Similarly, this production stage (2009) illustrates the best results for the fossil fuels category due to saved consumption of this kind of fuel. The beneficial effect is explained by the augment of bagasse production, which enhances the electricity generation and the consequent reduction of fossil fuels consumption.

These results demonstrate the relation of respiratory effects of inorganic compounds and fossil fuels categories with one of the parameters changed in the study (sugar cane fiber). It is verified by the expressions of calculation rules established in the parameterization of inventories:

$$B = \frac{SCF * SC}{BF} \quad (1)$$

$$PM = 0{,}011875 * B \quad (2)$$

Where:
B: Bagasse
SCF: Sugar Cane Fiber
SC: Sugar Cane
BF: Bagasse Fiber
PM: Particulate material

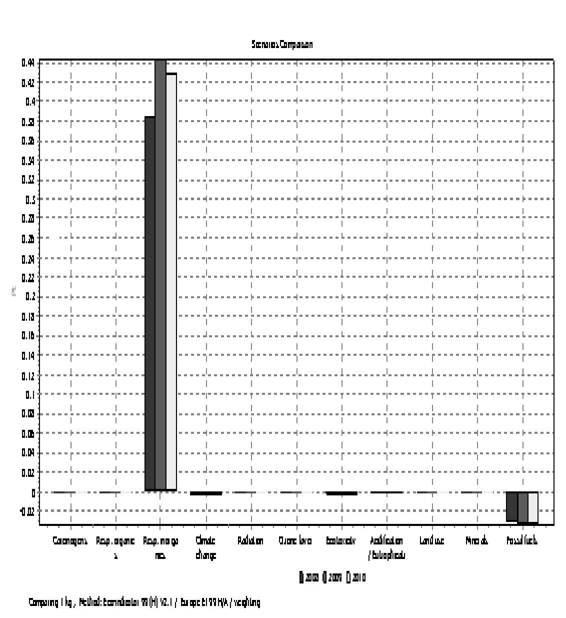


Figure 1. Scenarios comparison. Impact categories

The Table 2 reveals the damage category of Human Health as the most damaging results during the 2009 production stage in this mill and the Resources category with the most favorable values, according to the previous analysis.

Table 2. Scenarios comparison. Damage categories

Method: Eco-indicator 99 (EI 99 H/A)
Indicator: Single score
Per damage category
Unit: Pt

Damage category	**2008**	**2009**	**2010**
Total	3.5E-01	4.0E-01	3.9E-01
Human Health	3.8E-01	4.4E-01	4.2E-01
Ecosystem Quality	-4.1E-03	-4.5E-03	-4.4E-03
Resources	-3.1E-02	-3.4E-02	-3.3E-02

Conclusions

1. Results evidence the advantage of the parameterized inventories of life cycle to analyze the relation of cane sugar production impacts and operational variables.
2. The major harmful impact of the cane sugar mill studied is on the category of respiratory effects of inorganic compounds during the 2009 production stage.
3. The most important beneficial effect is obtained on the fossil fuels category during the 2009 production stage given by the concept of the avoided product.

References

1. Suarez R, Morı´n R. Sugar cane and sustainability: approaches and Cuban experiences, http://www.laneta.apc.org/desal/spip/article. 2005.
2. WWWF. Global Freshwater Programme. Sugar and the Environment. Encouraging Better

Management Practices in sugar production. www.panda.org/freshwater1

3. Dewulf J and Van Langenhove H. Assessment of the sustainability of technology by means of a thermodynamically based life cycle analysis. Environ Sci Pollut Res 2002; 4:267–73.
4. NC NC ISO 14040. Environmental management. Life cycle assessment. Principles and framework, Havana; 2005.
5. NC ISO 14041. Environmental management. Life cycle assessment. Goal and scope definition and inventory analysis, Havana; 2000.
6. NC ISO 14042. Environmental management. Life cycle assessment. Assessment of life cycle impact, Havana; 2001.
7. NC ISO 14043. Environmental management. Life cycle assessment. Life cycle interpretation, Havana; 2001
8. Goedkoop M, Spriensma R. The eco-indicator'99. A damage oriented method for Life Cycle Impact Assessment. In: Methodology Report. 3rd ed. Amersfoort: Pre´ Consultants BV, www.pre.nl; 2001.
9. Goedkoop M, Spriensma R. The eco-indicator'99. A damage oriented method for Life Cycle Impact Assessment. In: Methodology Annex. 3rd ed. Amersfoort: Pre´ Consultants BV, www.pre.nl; 2001
10. Goedkoop M, Oele M. Introduction to LCA (Life Cycle Assessment) with SimaPro, www.pre.nl; 2004.
11. Contreras A.M. et al. Comparative Life Cycle Assessment of four alternatives for using by-products of cane sugar production. Journal of Cleaner Production. Vol 17, No 8 (2009) 772–779
12. Pérez, M. et al. Modelation of life cycle inventory in the Heriberto Duquesne Enterprise. Memories of International Congress of Chemistry and Chemical Engineering. Central University of Las Villas, Cuba, 2010
13. Contreras AM. Methodology for the Life Cycle Assessment combined with the exergetic analysis in the Cuban sugar industry. Thesis for the PhD degree. Santa Clara, Cuba; 2007.

Environmental Performance Evaluation in Brazilian Pesticide Sector

Kulay, Luiz[1]
Grippe, Victor Sette[1]
Silva, Gil Anderi [1]
[1] Escola Politécnica da Universidade de São Paulo
E-mail contact: luiz.kulay@poli.usp.br

Abstract
A company from agrochemicals in Brazil that produces and sells pesticides decided to better evaluate the environmental impacts caused by its products. This action was carried out as technical partnership with Group of Pollution Prevention from Polytechnic School of University of Sao Paulo. The project evaluated the environmental sustainability of SC 50 a fungal growth controller widely used for soybean crops. Product system was modeled with cradle-o-grave approach and CML baseline 2000 was used to perform Life Cycle Impact Assessment. Regarding the results, it was observed important contributions in terms of Global Warming, Terrestrial Ecotoxicity, Human Toxicity ad Eutrophication. LCA exposed logistic and management problems, which directly reflect on the performance of the product. That’s the case of raw materials import from foreigner countries. Additionally to recommendations arising from impact profile, other actions could be taken in-site to improve the environmental performance of SC 50 production. These would be the revision of measurement and control systems from the process, and review the operational conditions of liquid effluent treatment.

Topic: Agribusiness, Forestry and Fishing

Keywords: thiophanate methyl; pesticides; agribusiness; LCA.

Introdução
Modern society observes chemicals compounds class called pesticides in a derogatory manner. In a general sense, such agents are considered no more than necessary evils employed only to provide enough agricultural productivity to meet the basic need for food mass of human beings. In return it is also generally believed, almost always unfounded, that its use entails damage to ecosystems in areas in which are applied as well brings human health diseases of medium and long terms.
A company from agrochemicals in Brazil that produces and sells pesticides worried about that scenario. Committed to get closer from farmers providing assistance and disseminating technology it decided to evaluate the environmental performance of their products. Its interest was to identify opportunities for improving environmental performance that could make the products more sustainable in the triple bottom line bias.
To carry out its purposes, the company decides to establish a technical partnership Group of Prevention of Pollution (GP2) from Polytechnic School of the University of Sao Paulo. The project embraces a LCA of one of the most important products in its portfolio: thiophanate methyl.
This active principle was selected for two main reasons: first of all, because it corresponds to a fairly significant percentage of total company sales in 2009. Second of all, being this is one of the few molecules that can be synthesized in the Brazilian site of the company. Moreover, it is a fungicide with great diversity in terms of applications. Thiophanate methyl is frequently used for cultivation of soybeans, cotton, beans, rice, tomatoes, citrus, among others crops being , therefore, widely applied in different regions of the country.
The company has two products in which the Thiophanate Methyl acts as the active principle: suspension concentrate at 50% (or SC 50), and the wettable powder with active concentration of around 70% (WP 70). Taking as a selection criterion for this sample, the volume of sales in the last five years, we chose to perform the LCA study of SC 50.
As in the opinion of many consumers the main environmental impacts related to any pesticide occurs during its application, technical body involved in the project decided to carry out the LCA with a "cradle to grave” approach.
Because of this, it was decided to adopt just one culture, whose cultivation occurred in an specific region of the country, and to which the use stage of the life cycle of the product could be representative of such agricultural practices, and be modeled in consistently and accurately way, both in terms of Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA).

As a criterion for this choice it was selected the product sales amount once again.

Thus, the study considered the application of SC 50 for soybean cultivation in the Brazilian Cerrado. The soybean crop amounted to 70.4% of sales by the organization on the SC 50 during 2009-2010[1].

The region called Brazilian Cerrado was defined in terms of geographical dimension for the LCA by the states of Mato Grosso, Goiás and Bahia. Together these zones accounted for 83.5% of SC 50's sales used to grow the oleaginous in the period between 2008 -2010.

As stated earlier, the company hopes to use the results of the LCA study to support its decision-making processes. In this context, the study surpassed the formulation of an environmental performance diagnosis. From the LCA's results were also made suggestions - even at primary level – in order to bring marginal gains in terms of sustainability.

Product System description

Thiophanate methyl manufacturing technology occurs basically in two steps: active ingredient synthesis, and product formulation. Active principle synthesis happens by reaction among three compounds: ethyl acetate; methyl chloroformate (MCF) and o-Phenylenediamine (OPDA). The reactor is indirectly heated by steam, because the endothermic profile of the transformation. Besides these reactants sodium cyanide (NaCN), amorphous sulfur, and sodium hypochlorite – all of them playing well-defined roles for acceleration of reaction and increasing its conversion rate - are also used in this step of the process[2],[3].

The second step of 50 SC formulation follows by addition of thiophanate methyl to calcium lignosulfonate (LS-Ca). The reaction happens in presence of urea technique and formaldehyde. As in the previous stage, reaction adjutants are also used. Often play this role naphthalene, silicone, and glycerin.

Particularly to the process under study, part of thiophanate methyl used to SC 50 obtaining is produced in Japan, being incorporated to the other reactants at this step. Similarly, imports are made of NaCN (from Germany), MCF (from Germany and USA) and OPDA (USA, Japan and China). All such operations were considered in its various modes of occurrence in this study.

LCA for SC 50 – Tiophanate methyl

LCA study of SC 50 for fungi controlling during soybeans cultivation in the Cerrado was based on methodological standardization of ABNT NBR ISO 14040[4] and 14044[5].

Regarding the scope of the study were defined the following technical requirements:

Product system: consists of an aqueous solution of thiophanate methyl in water, prepared with a dilution ratio of (1:1) wt.

Function: control growth of fungi responsible for soybean diseases such as white mold, leaf blight, and brown spot.

Functional Unit: control fungal growth that causes diseases like white mold, leaf blight, and brown spot in 100ha planting soybeans planted in the Brazilian Cerrado.

Performance coefficient: Brazilian Agricultural Research Corporation (EMBRAPA) recommends that fungi's control for soybean cultivation in Cerrado zone is done with a dosage of 1L of thiophanate methyl per hectare [6].

Reference flow: perform the addition of 100L of thiophanate methyl in order to control fungal growth that causes diseases like white mold, leaf blight, and brown spot, in 100ha planting of soybeans in Brazilian Cerrado.

Product system's boundaries: company decided that should be considered in the LCA product system all elementary processes that were directly linked to it. Besides these, should be added other elementary processes that could be influenced by it regarding environmental performance improvement. So, product system comprises: SC 50 processing stages; transport activities; raw materials manufactured in Brazil; SC 50 use stage for soybean cultivation; process utilities – like water treatment, and generation and transmission of electricity bought from the concessionaire – were included.

e) Data Quality: resource consumption and waste emission related to SC 50 manufacture were modeled using primary data provided by the organization interested in LCA. The same happened with environmental aspects related to transport of supplies and industrial utilities. Other elements from product system were defined using secondary data.

f) Exclusion criteria: were excluded from the ICV environmental loads which mass or energy cumulative contributions are below of 2% level. Were also excluded any environmental burdens with low environmental significance according statements defined in ABNT NBR ISO 14044.

g) Data Quality: regarding temporal dimension primary data were collected continuously over 2009-2010 periods. In terms of geographical dimension it was included states of Sao Paulo –

the production of SC 50 and its raw materials, and Mato Grosso, Goiás and Bahia in order to take in account its application for soybean crop. Environmental burdens from inputs produced abroad were not considered. Finally, the route described above for SC 50 processing was used in order to express technological dimension.

h) Allocation: it weren't applied any allocation criteria for this study.

i) Impact Assessment Categories and Models: company decided that it would be more useful to its purposes to adopt an impact model which output brings environmental profile expressed by midpoint indicators.

In this frame, CML baseline 2000 was selected to perform LCIA stage.

General Assumptions for ICVs Modeling

Product system modeling for ICV construction took into account several assumptions and premises. Some of these general principles are presented as following:

a) For those cases of primary data unavailability and lack of conditions to make it measurement environmental loads were estimated from mass and energy balances using some other process parameters;

b) Internal transportation in foreign countries was determined by pre-determined distances;

c) Equitative proportioning was used for cases which imports occur from two or more centers simultaneously;

d) Environmental burdens that are associated to solid waste disposal were excluded;

e) Modeling the environmental performance of SC 50 application for soybean crop cultivation just considers fuel consumption;

f) Only input and output flows that could be verified were effectively modeled;

g) Airborne emissions from power boiler were determined by stoichiometric balance;

Results

Impact Assessment Profile for SC 50 application to control fungal growth in soybean cultivation in Brazilian Cerrado was generated by using the SimaPro 7.0 – version 7.2.4 [7], a computational tool for such specificity.

Table 1 presents consolidated figures for all of the impact assessment categories analyzed by CML 2000 baseline application, LCIAs method selected to LCA's conditions.

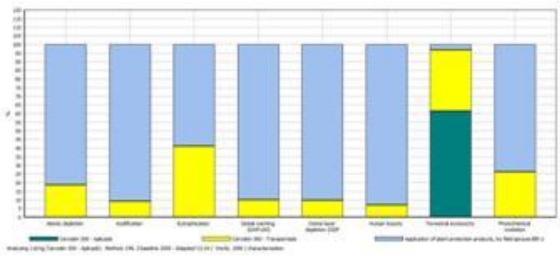
According to modeling conditions all figures of impact assessment categories regards 116.2kg reference flow's value in weight basis.

Table 1 – Environmental Impact profile for fungal growth control in soybean crops using SC 50 – CML baseline 2000

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	6.41
Acidification	kg SO_2 eq	6.78
Eutrophication	kg PO_4^{3-} eq	2.34
Global warming (GWP100)	kg CO_2 eq	902
Ozone layer depletion (ODP)	kg CFC-11 eq	0.00014
Human toxicity	kg 1,4-DB eq	529
Terrestrial ecotoxicity	kg 1,4-DB eq	56.2
Photochemical oxidation	kg C_2H_4	0.155

A detailed analysis from the results expressed in Table 1 indicates a significant influence from the method used to disperse SC 50 at soybean plantation – mechanical tractor – on the overall impacts reported in the environmental profile. This can be better observed in Figure 1.

Figure 1 – Environmental Impact profile for fungal growth control in soybean crops using SC 50 – elementary process individual contributions



All the contributions assigned to "application of plant protection products" are represented in Figure 1 as blue color bars.

The most significant contribution from SC 50 to the product system occurs as Eutrophication – with more de 40% of the total impact's amount – and Terrestrial Ecotoxicity – around of 38%.

Predictably, the most significant contribution in terms of Terrestrial Ecotoxicity is associated to SC 50 addition in ground.

Table 2 brings environmental impacts values of SC 50 obtaining. In order to permit establishing comparisons, these results were estimated to 116.2 kg of product.

Table 2 – Environmental Impact profile for SC 50 obtaining – CML baseline 2000

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	0.745
Acidification	kg SO_2 eq	0.354
Eutrophication	kg PO_4^{3-} eq	0.751
Global warming (GWP100)	kg CO_2 eq	41.459
Ozone layer depletion (ODP)	kg CFC-11 eq	0.0000058
Human toxicity	kg 1,4-DB eq	24.691
Terrestrial ecotoxicity	kg 1,4-DB eq	16.092
Photochemical oxidation	kg C_2H_4	0.027

The result of 0.75kg Sb eq. for abiotic resources depletion category corresponds in 60.7% to natural gas consumption. This natural resource is commonly used by methanol obtaining, one of the raw materials of SC 50. Other important contribution refers to crude oil consumption (17.9%) used mainly for transport.

The main contribution for the total amount of 0.35kg SO_2 eq. observed as Acidification can be attributed to atmospheric emissions of sulfur dioxide (SO_2) of 211g per 116.2kg SC 50.

The most important agent to Eutrophication (which amounts 0.75kg PO_4^{3-}/116.2kg SC 50) is mainly affected by Chemical oxygen Demand (COD) losses that occur during SC 50 production Brazil. Apparently, synthesis of SC 50 in Japan does not repeat the same behavior.

Global Warming profile of 41.5kg eq. CO_2 was deeply influenced by carbon dioxide emission from burning fossil fuels (38.5kg CO_2).

This performance is however dampened due to the CO_2 fixation on behalf soybean cultivation – (–) 31.8kg CO_2, from which it generates glycerin used in court.

Production of SC 50 brought significant impacts regarding toxicities in its most variable sense.

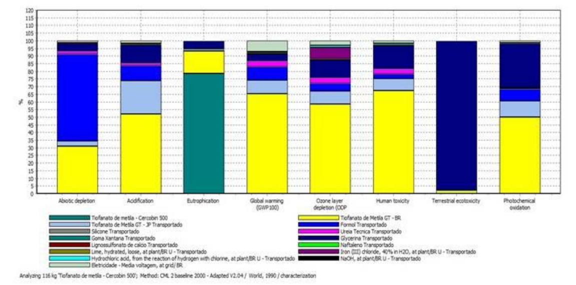
Human Toxicity's contribution of 24.7kg 1,4-DB eq. mainly comprises emission of heavy metals to air (48.4% of the total).

For Terrestrial Ecotoxicity about 98% of 16.1kg 1,4-DB eq. refers to pesticides used by soybean and sugarcane cultivation. These effects were introduced in the process system from glycerin, obtained by transesterification of soybean oil and ethanol.

Finally total impacts of Ozone Layer Depletion and Photochemical Oxidation were considered to be discrete in terms of their contributions – 5.8E-6 kg CFC-11 eq. and 2.7E-2kg C_2H_4 eq.

Figure 2 specifies individual's contributions per process for SC 50 production.

Figure 2 – Environmental Impact profile for SC 50 obtaining – elementary process individual contributions



In Figure 2, special attention should be given to tiophanate metyl production manly because of transoceanic displacement of import inputs like NaCN, MCF and OPDA.

Even if these transported quantities represent low percentages of contribution in terms of mass compared to the total capacity of vessels, such effects are balanced by the long distances between ports. So this elementary process appears as an important contributor for most of the environmental impacts analyzed. That's the case of Acidification; Eutrophication; Global Warming and Human Toxicity.

Conclusions

Environmental performance evaluation of SC 50 met the expectations to which it proposed to its current stage of development.

This action helped to define its environmental sustainability to the function of soybean crop protection in Brazilian Cerrado.

LCA also exposed process aspects, logistic and management problems, which directly reflect on the performance of the product. That's the case of raw materials import from foreigner countries.

Additionally to recommendations arising from impact profile, other actions could be taken in-site to improve the environmental performance of SC 50 production. These would be revision of process measurement and control systems and evaluation the operational conditions of liquid effluent treatment.

References

[1] ABIQUIM – ABIQUIM – Brazilian Association of Chemical Industries - Statistical Yearbook 2010. 563pg. São Paulo. 2010.

[2] USEPA. [USEPA] U.S. Environmental Protection Agency. 1986. Registration Eligibility Decision: Thiophanate Methyl. 2005. OPPTS GLN 830.1620 - Starting Materials and Manufacturing Process

[3] Watanabe, I. (1986) Thiophanate-methyl - Description of Beginning Materials and Manufacturing Process: Study No. TL-6182. Unpub- lishedstudy prepared by Nippon Soda Co., Ltd., Takaoka Labora- tory. 13 p.

[4] ABNT – Brazilian Association of Technical Standards. NBR ISO 14040 - Gestão ambiental - Avaliação do ciclo de vida - Princípios e estrutura. 2009.

[5] ABNT – Brazilian Association of Technical Standards. NBR 14044 - Gestão ambiental - Avaliação do ciclo de vida - Requisitos e orientações. 2009.

[6] EMBRAPA. Brazilian Agricultural Research Corporation. Recomendações Técnicas para a Cultura da Soja na Região Central do Brasil 1999/2000. Warta – PR. 2004.

[7] PRé Consultants. 2009. SimaPro, 7.0 – v. 7.2.4. Amersfoort, Netherlands.

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GHG emissions of organic and conventional blueberry orchards

GHG emissions of organic and conventional blueberry orchards

Abstract

A study was conducted to evaluate the GHG emission, in conventional and organic blueberry orchards, using a LCA evaluation system. Management data related to pests, diseases and weed control, and fertilization were collected from the beginning of the season until harvest. The impact category assessed was global warming (kg CO_2 equivalent), calculated using the software SimaPro 7.2. All the conventional orchards showed higher CO_2 emissions compared to the organic orchards.

Methodology

Three conventional and three organic blueberry orchards were studies. The functional unit used corresponded to 1t of final product. The studied stages were pests, diseases and weed control, and fertilization. The impacts of this management practices were assessed using the software SimaPro 7.2, using the 2007 IPCC methodology for estimating CO_2 eq kg (100 years). Inventory data were mainly collected through personals interviews with farmers and complemented with secondary sources.

Results and discussion

The three conventional orchards studied showed higher CO_2 emissions compared to the organic orchards, in relation to pests, diseases and weed control management (Figure 1), and fertilization (Figure 2).

One key factor contributing to this result is weed management. In organic orchards, the weed control is mainly manual, but conventional orchards also use herbicides. Pests and diseases control are also important contributors to CO_2 emissions. Both, pesticides and fungicides production, is intensive in carbon emissions, and their application should be minimized to avoid excessive and unnecessary emissions of greenhouse gases into the atmosphere.

Another factor that also shows differences is fertilization, due to the impact in terms of GHG emissions of synthetic fertilizers, which have high energy demand and high CO_2 emissions in its production and application process, in contrast to the organic fertilizers.

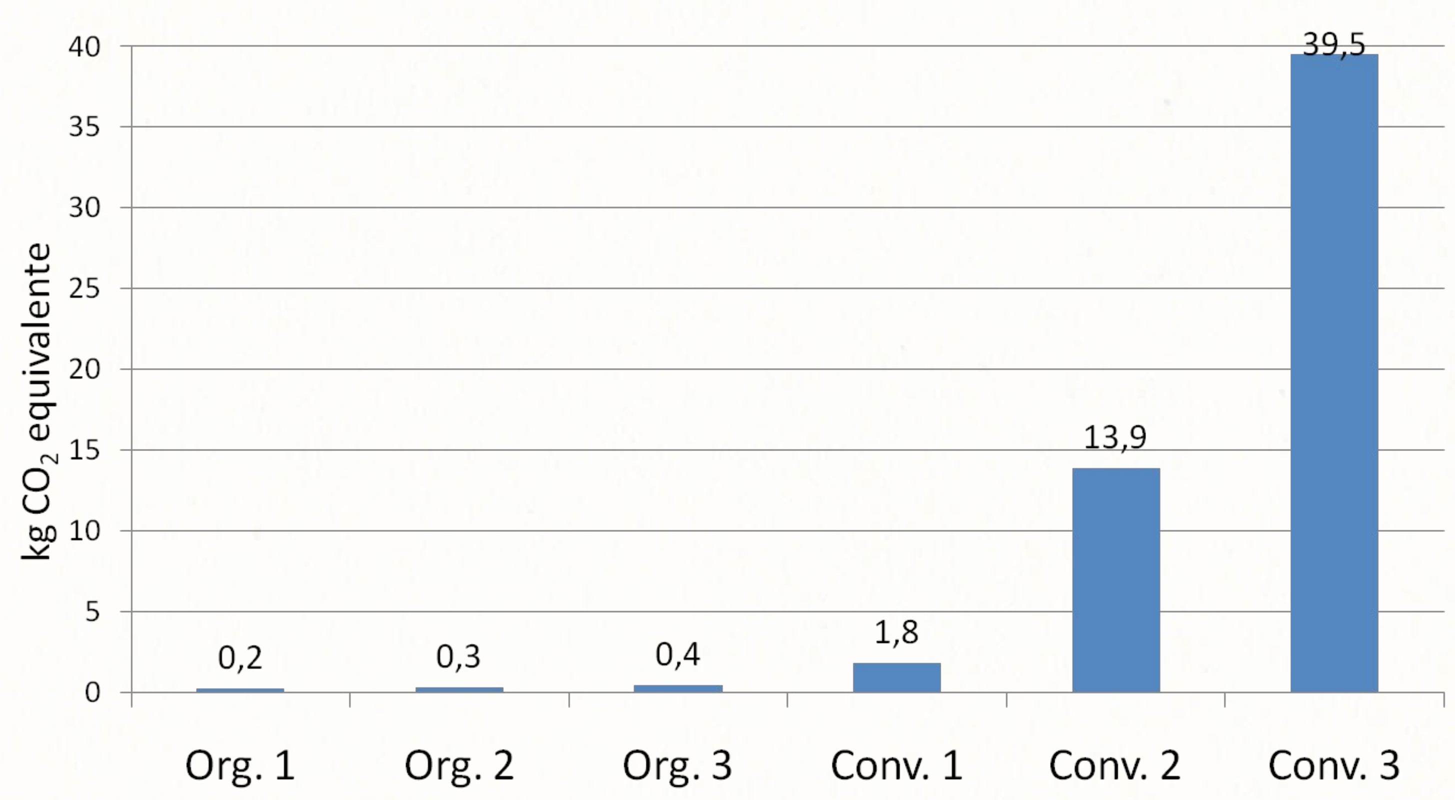

Figure 1. CO_2 equivalent emissions due to pests, diseases and weed control.

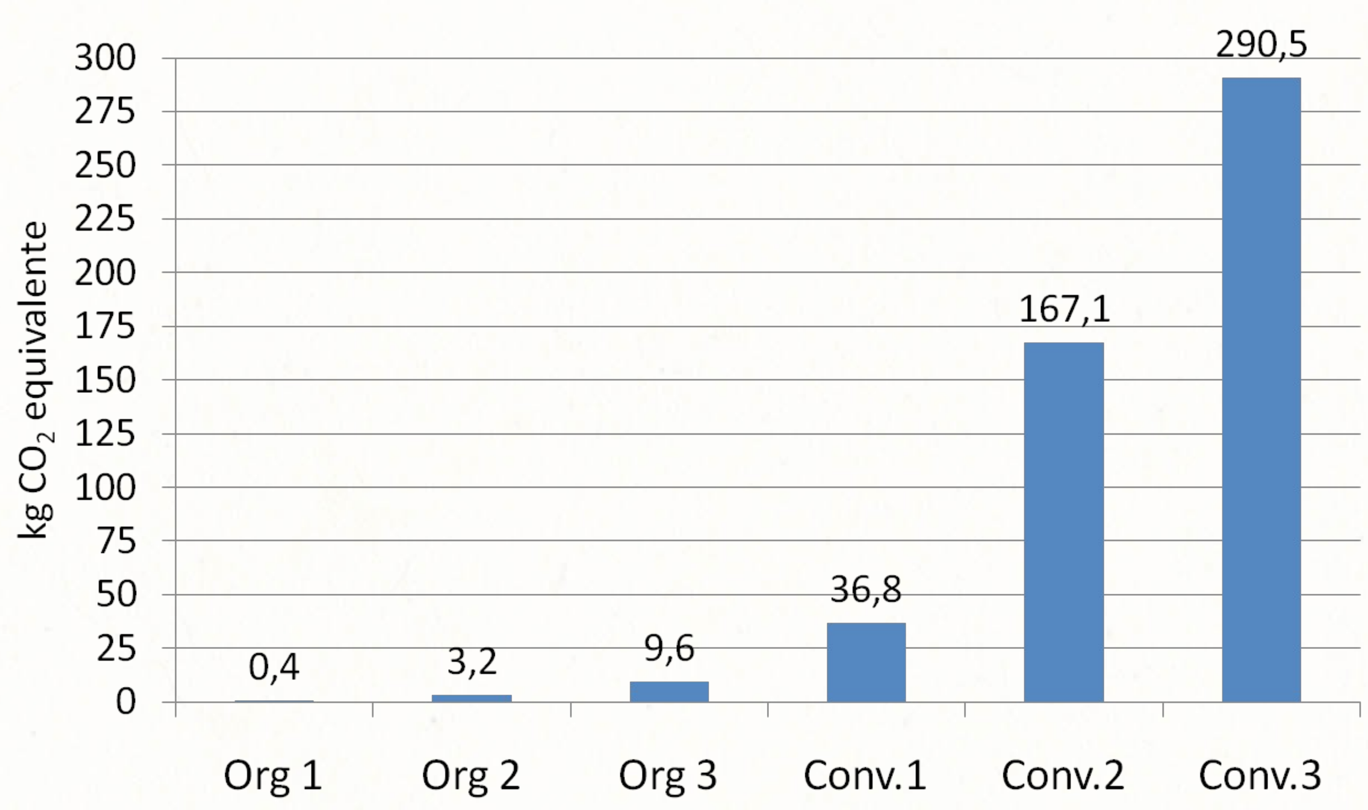

Figure 2. CO_2 equivalent emissions due to fertilization.

When comparing both figures, it is clear that fertilizers emit more GHG than pesticides, mainly due to the changes that they suffer in soil, especially nitrogen.

Conclusions

Conventional orchards increased greenhouse gases generated due to application of products that have high impact on their production and during the application process, with fertilizers which produce more emissions.

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Life Cycle Assessment and its relevance for community forest enterprises of Oaxaca, Mexico.

[1] Regino-Maldonado Patricia, [2] Regino Maldonado Juan, [3]Riba i Romeva Carles
[1]PhD student, Polytechnic University of Catalonia, Spain
[2] PhD, CIIDIR-IPN, Mexico
[3]PhD, Polytechnic University of Catalonia, Spain
E-mail contact: patricia.regino@upc.edu

ABSTRACT

These days the production activities of the forest industry; had contributed to the depletion of natural resources due to the environment impact and the contribution of greenhouse gases. By applying the methodology of Life Cycle Assessment (LCA), it is potential to assess potential environmental impacts and consequences of emissions throughout the life cycle of a product, from raw material acquisition to disposal, and identify potential improvements to reduce such impacts. The aim of this paper is to do systematically review the previous investigation of LCA in wood products in order to analyze the current situation and present the key challenges related to LCA in the forest industry. Identify details of LCA and its methodology, based on the International Standards Organization (ISO 14040). The systematic review explores the different ways of using LCA in various countries from 2005 to 2010, which identified 23 cases for this analysis, identifying that 35% of cases impact assessments on any part of the fabrication process and transportation of wood products (LCAWP), 30% evaluate the impacts of using energy from wood (EWP), plus 26% have generated data for the creation of inventories of wood products (LCIWP) and lastly 9% have been tracking the monitoring to implementation of LCA (MLCA). This study concludes there is insufficient research of LCA in Mexico of the forest industry so presents a discussion of the obvious advantages and limitations of LCA.

Topic: : LCA management: goods and services
Keywords: forest industry, LCA, environmental impacts, sustainability.

Introduction
Forests cover 31% of the whole land surface, there being a total area of forest in the world of just over 4 billion hectares (ha), which corresponds to an average of 0.6 ha per capita. [1]

Mexico has a land area of 196, 437.500 ha [2] with a forest area of 56, 698.067 ha. This represents 28.9% of the total land area [3]. It is noteworthy that Mexico has 80% of community forests, making it the second highest number of community-managed forests [4]. Therefore the state of Oaxaca plays an important role in forest resources, since 90% of woods and forests are in the hands of communities and *ejidos*, ranking fourth nationally in forest area of 5.1 million ha (53.7%) and forest management of 650 thousand ha of communities and *ejidos*. [5]

Oaxaca is located in an area of great natural wealth has encouraged the development of community forestry. [4] The community forestry generates social welfare projects, facilities, training, productive projects and direct distribution. The average annual production of 550 thousand m^3 of timber, an economic income of 450 million of pesos, accounts for 11% of national GDP and provides 42 000 jobs annually in the mainly rural communities. [5] Therefore it is important to address the production processes in a sustainable manner, to the best use of resources and impact assessments to identify critical parts of the process and identify possible improvements.

Life Cycle Assessment

LCA is the environmental aspects and potential impacts considering the use of resources and the environmental consequences of emissions throughout the life cycle of an output from raw materials acquisition, production, use, last treatment, recycling, to disposal [6]. The methodology consists of four phases:

a) Defining the purpose and scope, this specifies the purpose, scope and extent of the study.
b) Analysis of life cycle inventory (LCI), includes data collection and calculation procedures to quantify the inputs and main outputs of a system of a product or service.
c) Life Cycle Impact Assessment (LCIA) is to assess what significant are the potential impacts, based on the results obtained from the LCI.
d) Analysis and interpretation of the life cycle and evaluates the results to draw conclusions and make recommendations. The final report is the last item to complete phases of LCA according to ISO 14040. [7]

Initial assessments conducted in Latin American of wood-based products with this methodology, arising during the sixties in which the Consortium for Research on Renewable Industrial Materials (CORRIM) to study the wood like raw material emphasized energy consumption in manufacturing and the potential of wood as raw material for production of chemical energy. Nevertheless in the last 20 years at worldwide level the focus of analysis has shifted to environmental issues, a new scientific assessment was needed to examine the environmental assessment methodologies, focusing on the environmental impacts of wood and fiber wood products, and impact assessment.

Methodology

The research on multiple scientific data bases from 2005 to 2010. This review of the application of LCA to the forest sector took place at the macro level where they identified four ways of using LCA: impact assessments on any part of the production process and transportation of wood products (LCAWP), impacts assessments use of energy from wood (EWP), data generation for the creation of inventories of wood products (ILCWP) and monitoring to implementation of LCA (MLCA).

Results

23 cases were detected which were classified with respect to the application of LCA, with the following data: 35% of cases, environmental impact assessments on any part of the production process and transportation of wood (LCAWP), 30% evaluate impacts of using energy from wood (EWP), plus 26% have generated data for the creation of inventories of wood products (ILCWP) and finally 9% of cases have been monitoring to implementation LCA in forest industries (MLCA).

Life Cycle Analysis of Wood Products (LCAWP)

66% of cases conducted environmental impact assessments generated in the production process of wood that corresponds to building materials, where most analysis uses the "cradle to grave." According to the eight case studies analyzed, they were developed in Spain and the United States. The environmental loads considered are Global Warming (GW), Acidification (A), Eutrophication (E) Energy Consumption (EC), Depletion of the Ozone Layer (OD) and Fossil Fuels (FF).

One study detected is carried out in Spain [8] where the objective was analyze the environmental impact during the life cycle of the production process of a wooden panel. The analysis used is the "cradle to gate" where three subsystems are considered: wood preparation, shaped and finished on the board. The functional unit chosen was 1 m^3 of finished wood. Results of the evaluation show that the subsystem that generates greater impact is the preparation of wood and is the main contributor to the depletion of biotic resources, which is mainly due to diesel requirement for wood chipping stage (1.4 kg of oil per cubic meter of processed timber), also this subsystem is responsible for most greenhouse gases due to chemical production (phenol resin, mainly) and electricity production were responsible of 33% and 39% of total carbon dioxide (CO2), respectively. It found that biomass burning plays an important role in acidification and eutrophication (NO_x). The results provide valuable information that can help the wood panel plants to improve their environmental performance and sustainability.

Energy from wood products (EWP)

Seven cases were detected, which assessed the environmental impact of the use, processing and transport of biofuels. These studies were conducted in Norway, Sweden, France, Japan, Canada and the United States. The environmental loads considered were: Global Warming (GW), Acidification (A), Air Emissions (AE), Energy Consumption (EC) and Carcinogens (C).

A study in Norway [9] where the objective was to assess the environmental effects of the use of an ancient and a modern stove fueled with wood, where he established as a functional unit 1 Kw of heat supplied in a home by the stove. An analysis "gate to gate", and from the comparison of both stoves showed that new technologies contribute to a significant performance improvement for all types of impact study, as modern stoves improve the performance of 28 to 80%. Both stoves generate greenhouse gases and methane emissions in the use phase and were responsible for 60% impact. Usually housing heated by electricity generated around 210 g CO_2-eq/kwh and compared with CO_2 emissions than a modern stove built with the same heat (80 gCO_2-eq/Kwh) and an ancient stove (110gCO_2/Kwh) shows that stoves generate less emissions, because burning wood is regarded as neutral, it is important to consider that the use of local wood is of great importance, since otherwise it would have to consider transport, distance, and type of fuel used.

Formation of Life Cycle Inventory of Wood Products (LCIWP)

The 6 cases are detected in relation to building materials, where the analysis was considered "cradle to grave" and "cradle to gate". Five were done in U.S. and one in Spain. The environmental loads considered were: Global Warming (GW), Waste (W), Air Emissions (AE), Energy Consumption (LE), Respiratory Organs (RO) and Fossil Fuels (FF).

There is an analysis to generate data for the LCI, which analyzed the manufacture of plywood [10]. 1m^3 functional unit established as plywood, an analysis "gate to gate", includes all materials, fuel, electricity and supplies to produce plywood, by-products and emissions. Data were collected through surveys of manufacturing facilities (five plants) in the Pacific Northwest and Southeast United States. The production of these mills represented 26% and 14% of the total production of Pacific and Southeast, respectively. The data are assigned in bulk to plywood in terms of its contribution to the sum of the masses of all products and by-products. The input data consisted of fuel, electricity, wood, wood veneer and resin, while the outputs of products consist of plywood, a variety of wood by-products sold to other operations, and air emissions, water and land. It found that the energy used for plywood production from biomass is where 72% (Pacific) and 79% (Southeast) use this type of energy.

The data are useful for generating LCI "cradle to gate" of the product in combination with the LCI to produce the records of the factories and the impact of material and transport, and also serve as a benchmark to evaluate the performance of the process, for conducting life cycle assessment of walls, floors and roofs of plywood and other products, and residential structures.

Monitoring to implementation of LCA (MLCA)

Two cases were detected conducting the assessment to implementation and monitoring of the LCA methodology in business. These were conducted in Sweden and Venezuela. Where the impact categories were defined in general like emissions to air, water and human health.

One case in Sweden 2007 was done, which aims to analyze the development of the practice of LCA methodology in two companies, with the same characteristics as country, size, time with which they have been using the LCA [11]. Where fundamental differences in the practices of LCA (the number of studies and choice of methods and also in terms of organization and approach to task in LCA). By testing various theoretical explanations for these divergent practices LCA identified actions of persons and their understanding of the situation as important in the practice of LCA. This study indicates that companies use LCA differently despite having similar structural conditions such as company size or industry affiliation.

Conclusions

This paper reviews and reflects the major milestones in the implementation of the methodology of life cycle analysis in the forest industry over the past five years from 2005 to 2010. It addresses the different ways of applying the methodology in diverse phases of the system. LCA is recognized as an innovative methodology that helps to improve sustainability in various sectors, including the forest sector. It is noted that most cases of LCA studies have been conducted in developed countries in Europe and the U.S. and there are no comparable studies in the literature of the developing countries. Therefore, sustainability indicators in the forest sector should be developed and used to direct environmental indicators and energy to level worldwide. Because developing countries need to make these assessments in their production processes to identify environmental impacts in forest industries both wood and non wood products.

References

[1] FAO, 2010. Principales resultados. Evaluación de los recursos forestales mundiales. (Rome) Italy: FAO. Departamento Forestal. Organización de las Naciones Unidas para la Agricultura y la Alimentación.

[2] Valdés O, Negreros P. 2009. El manejo forestal comunitario en México. Universidad Veracruzana.

[3] SEMARNAT. 2002. Superficie forestal por ecosistema y tipo de vegetación. (D.F.) México. Subsecretaría de Gestión para la protección ambiental, Dirección General de Federalización y Descentralización de servicios forestales de suelo.

[4] Bray D, Merino L, Barry D. 2007. Los bosques comunitarios de México. (D.F.) Mexico: Instituto Nacional de Ecología. 149 p.

[5] Agroproduce. 2006. Información forestal del estado de Oaxaca. Fundación Produce. (Oaxaca) México.

[6] UNE-EN ISO. Normas ISO 14044. 2006. Gestión ambiental, Análisis del ciclo de vida, Requisitos y directrices. AENOR. (Md) España.

[7] UNE-EN ISO. Normas ISO 14040. 2006. Gestión ambiental, Análisis del ciclo de vida, Principios y marco de referencia. AENOR. (Madrid) España.

[8] González GS, Feijoo G, Widsten P, Kandelbauer A, Zikulnig RE, Moreira MT. 2009. Environmental performance assessment of hardboard manufacture. International Journal of life Cycle Assessment 14:456-466.

[9] Solli Ch, Reenaas M, Hammer A, Hertwich E. 2009. Life cycle assessment of wood based heating in Norway. International Journal of Life f Cycle Assessment 14:517-528.

[10] Wilson J, Sakimoto E. 2005. Gate to gate Life Cycle Inventory of softwood plywood production. Wood and Fiber Science, CORRIM special issue (37) 58-73.

[11] Rex E, Baumman H. 2007. Individual adaptation of industry Life Cycle Assessment practice: results from two case studies in the Swedish forest products. International Journal of life Cycle Assessment 266-271.

Applying the framework of Life Cycle Analysis to Forestry Social Sector in the Region of Bío Bío in Chile. First approaches and results.

Cofré, María José[87]
macofre@udec.cl

Abstract
Analysis of social life cycle (LCA-S), provide a research framework that integrates the multiplicity of stakeholders around a productive sector and contributes to complement the environmental and financial considerations. Due to this it is considering a new approach to solve environmental conflicts.
This article addresses a first approach to LCA-S for cellulose sector in the Bío Bío Region, Chile. And thanks to this perspective it was possible to analyze socio-environmentally the forest productive sector for the region.
Topic: LCA applications in industry, agribusiness, forestry and fishing.
Keywords: Social Life Cycle Assessment, Forestry, ISO 26.000.

1. Introduction

The forest sector contributes to 3.16% of GDP, we estimate that 65% of forest production is done in the Bío Bío region [2], contributing to generate about 130,000 direct jobs, and also a similar amount indirect jobs [3]. The forestry sector is the second largest exporter and the first based on a renewable natural resource, accounting for 47.5% of cellulose in 2009 [4]. In total, in 2008 in Chile were 4.94 million tons of pulp [5], 69% being generated in the region of Bío Bío [2] [3].
The country has 15.9 million hectares of forest cover, corresponding to 14.6% (2.3 million hectares) of forest plantations (CORMA, 2010), is estimated at 850,567 (37%) has the planting area for 2008 in the Bío Bío region [2]. This sector in the region, overall focus for 89.7% of the total workers in the forest area [6], concerned a national average of 52.9% direct recruitment and the remaining 47.1% indirect procurement [4]. It is important to emphasize that the explosion of forest sector development is accompanied by process outsourcing services market forest [7].
As part of the global trend and due to pressure from the international market, domestic enterprises linked to the forest area have incorporated policies and practices that go beyond the minimum that the law imposes [8]. Therefore it is important to note that sustainability of the productive sector, especially the dependence of the Bío Bío region has (be the main growth point of 2 of the 4 provinces of the region). Problems of was observed after the Subprime Crisis, where the Chilean forestry sector was the second most affected, resulting in a significant increase in unemployment.

The ACV-S has emerged as a viable alternative to include decisions to promote, to consider sustainable development not only of a product, or organization, but beyond that affects production sector, as in this case, all a region. The LCA-S comprises the social responsibility of organizations and aim to improve social and environmental performance along with a sustained profitability, because of this, this study tries to give a first approach to this issue [1].

2. Methodology

Information was collected primarily secondary and primary interviews with experts, using as the Guidelines for Life Cycle Analysis of Social (ACV-S) [1]. Due to the lack of information, such indicators were generated based on information provided by experts (weighted in some cases), and enriched by qualitative information. Functional unit was established as per tonne of pulp, the base year was 2008, and limits the system range from the cradle to the door and falls within the sub-forestry (nursery, planting, pruning and thinning, and harvesting), and industrial processing subsystem (manufacture of pulp, power generation), excluding transportation due to the scarcity of information.

3. Results and discussion

Based in 2008, the most negative impact is concentrated in the forestry sub-sector of forestry, aspects related to the Labour and Social, environmental and manufacturing subsector cellulose (linked to the age of the pulp mills as TRS emissions, etc.). Development and management plans on Occupational Safety and Health.

Forestry sub-sector gaps

Deepening the forestry subsector, environmental, heavy usage of pesticides in forestry subsector (nursery, planting and thinning), Pesticides (active agent) 3.28 to 07 per tonne of pulp and nutrients (NPK) with 36,43 per ton of pulp [9].

And from the perspective of LCA-S, Occupational aspects of Safety and Health (listed in the directices with the category of workers) are: a) high accident rate in the forestry sub-sector is 3.6 and is under the regional average of 4.2 [10], is less than 1.9 of the industrial sub-sector (manufacturing of cellulose), b) a high percentage of contractors (Responsibility) in the forestry subsector estimated at 95%, c) significant disparity in plans Occupational Safety and Health, with a sub-silvicultural development with minimum compliance with legal in Small and Medium Enterprises, and poor integration of health factors, occupational and psychosocial factors (linked to the determinants social stress and lack of control at work and home can have powerful effects on health and work, "work very demanding and in which people have little control carry special risk"), stressing the raw material, which are workers who support the sector [11].

The latter, which correspond to the main subjects of interest to the ISO 26000 Corporate Social Responsibility [12], framed: local community, with high levels of voluntary migration time in the forestry subsector 65% (Establishment of Planting, Pruning, Thinning and Crops) that generates potential decoupling family ties dysfunctional facilities, estimated at 4 workers per 1,000 tons of pulp (this subsector is primarily male). One important factor is the high inequality in the estimated average wage in the forestry subsector for $ 255,000 or 510 U.S. $ (as opposed to 900 U $ of Industrial Pulp Processing Subsystem). Relevant qualitative information, and segregation is the scarcity of information on local community outreach by the SMEs of the forestry subsector, the isolated and private initiatives in the areas of CSR, or generated only by large corporations, low investment in local patent (I + D + i), and the conflicts between indigenous (land rights and claims) mainly in the forestry subsector.

Table 1 - Summary of key indicators of forestry for the region of Bío Bío 2008.

Indicator LCA-S	Forestry Subsystem	Industrial Processing Subsystem Pulp
Migration and relocation of workers - Community	0,00418427	0,00141571
Conflicts of land rights to indigenous groups - Community	2,9321E-07	0
Number of conflicts with indigenous groups - Community	5,8641E-07	2,9321E-07
Hired labor locally - Community	1,466E-05	5,8641E-06
Local suppliers (percent) - Community	2,4981E-05	1,771E-05
Health and safety consumers / Fines (U$) - Consumers	2,8236E-05	0
Timely payments to suppliers - Players of the value chain	2,9321E-07	2,9321E-07
Prevention and Mitigation of armed conflict - Society	1,7592E-06	8,7962E-07
Average salary ($ chilean)- Society	0,07476745	0,13194256
Number of Workers - Society	0,00643733	0,00707857
Contribution to economic development (R & D costs relative to income) - Society	2,9321E-07	2,9321E-07
Plan Type Occupational Safety and Health - Workers	2,9321E-07	1,1728E-06
Accident rate (Health and Safety)- Workers	1,0555E-06	5,8055E-07

Social Footprint

The social construction of the trail primarily based on work such as the proposal of Doménech [13], that is as comprehensive social indicator, as some studies estimate that if unemployment is global social problems, through which unfold other major social problems. The author postulates that this indicator includes others such as education, health, poverty reduction, the decrease in migration rate, and facilitating the social fabric.

Based on these ideas is that conceived the concept of "sustainable global income" is meant as a hypothetical income (utopian) to GDP is calculated by dividing the world between the world's population capable of contributing to GDP (working-age population or population active, it personally it is important to incorporate the economically active population, as this excludes housewives, students and pensioners due to illness). From this, we extract the "overall employment," defined as the kind of jobs whose wages tends to total income, because if it complies with the principle of equity, there must be the tendency of nations to equalize wages with total income. Following these concepts, Doménech made to the Social Footprint Net (HSN) which is the difference between the Social Footprint Gross (HSB) and the Anti Social Footprint or real jobs generated by the product (CHS). Then we can understand the Net as Social Footprint:

HSN = HSB - CHS . … … … … … … … … ………. … … (1)

Where:

HSN = Number of total income of the company that could meet the total annual revenue.

HSB = Total income number that an entity or group (nation, region, institution, corporation or person) could meet with your total annual income.

CHS = Actual number of jobs generated during a period of time, usually one year. In business, excluding indirect employment.

Under the proposed Doménech, to extract the Social Footprint Gross (HSB), is calculated based on Forestry sector utilities in the region of Bio Bio to 2008 corresponding to U.S. $ 104,875,181, and the average compensation estimated for the sector which is $ 388,754, according to the estimated weight of experts. Then, the number of total income of the company that could meet the total annual revenue generated by the forest sector in the region of Bío Bío year 2008 was 140,948 jobs, which corresponds to the Gross Social Footprint. And real jobs generated by the forest sector in the Bío Bío region were 46,097 for 2008, which relates to the Anti Social Footprint. Both data obtained we applied a correction factor for the case of the Social Footprint Gross (HSB) was 0.97 which corresponds to the applicability of the concept of full employment, and the Anti Social Footprint, a contributing factor was calculated the proportion of indirect jobs (outsourcing percentage 0.63).

So we can conclude that the Social Footprint Net Forestry sector in the region of Bio Bio in 2008, up to 107,678 jobs, is therefore a difference of Gross Social Footprint (HSB) of 136,720 jobs and Anti Social Footprint that is 29,041 jobs. In summary, the sector could potentially generate 40 jobs per 1,000 tons of pulp (4 x 10-2 adt), actually generating the year 2008 13 for sector jobs per thousand tonnes of pulp, covering only 33.7%.

4. Preliminary findings and future challenges

The forestry sector has grown in recent decades by the forestry sub-sector outsourcing, which has characterized for a low income distribution and low participation of workers in the utilities (shown through the proposed Social Footprint), consistent with the phenomenon job insecurity that has accompanied economic development in Latin America over the last decade [14]. Therefore, both the commitment of senior management and the identification of Corporate Governance become fundamental at the time to improve the management of an organization, enterprise or productive sector [15].

A significant gap is the scarce or inexistent information mainly from the forestry subsector which is predominated by contractors (SMEs). This is needed to gradually conduct towards a sustainable development productive sector, as opposed to Industrial Processing Subsystem Pulp.

The disparity or different management methods of Occupational Safety and Health headed by the two great Oligopolies cause the re-consideration of those factors considered as "intangible value" as human capital, intellectual capital, management of variables such as knowledge, information, business ability, for the competitive positioning of businesses, forestry and regions [7].

At the macro level, one of the greatest challenges is to encourage investment as "responsible" in areas that have conflicts over indigenous land rights, it tends to be a highly vulnerable population, or where the local community has high degree of vulnerability and do not appear as social dumping.

Another challenge is how to ensure that social dimensions are relevant for decision making by large corporations? And how eco-labeling will generate social aspects that are meaningful and understandable to consumers?.

"Reflection is the quantum step, to consider the" workers "and" local communities "as a continuous resource renewable resource, which is likely to be over-exploited thereby altering the ecosystem that shelters the productive process pulping.

References

[1] Life Cycle Initiative. 2009. Guidelines for Social Life Cycle Assesment of Products.

UNEP, SETAC and Life Cycle Initiative cooperation CIRAIG, FAQDD and the Belgium Federal Public Planning Service Sustainable Development. http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf. Accessed 21/08/2010.

[2] INFOR. 2009. Forestry Yearbook 2009. Statistical Bulletin No. 125. Santiago. Chile. INFOR.

[3] ODEPA. 2010. Historical balance for agricultural and forestry products sector Chile - World (Thousands of dollars). http://www.odepa.gob.cl/. Accessed 21/08/2010.

[4] CORMA. 2010, Chilean Corporation of Wood. http://www.corma.cl. Accessed 21/08/2010.

[5] CMPC. 2010. Cellulose in Chile: Chile is a producer and exporter of world-class pulp. in Papelnet. The Pulp. http://www.papelnet.cl/celulosa/12.html. Accessed 21/08/2010.

[6] CORMABIOBIO. 2010. Chilean Corporation of Wood of region Bío Bío. http://www.cormabiobio.cl. Accessed 21/08/2010.

[7] Escobar. 2003. The comprehensive management of the forestry business. Days XVIII Forest Concordia Entre Rios. October 2003. Forest of Plata S.A. http://www.inta.gov.ar/concordia/info/Forestales/contenido/pdf/2003/193%20VIII%20JE%20def.pdf. Accessed 16/09/2010.

[8] Ackerknecht, Hildebrandt. 2009. Corporate Social Responsibility: Business Endeavors Forest Essentials. XIII World Forestry Congress. Buenos Aires. Argentina. 18 to 23 October 2009. http://www.cfm2009.org/es/programapost/trabajos/Responsabilidad_FD.pdf. Accessed 29/10/2010.

[9] González. 1999. Development of a conceptual model for decision making in environmental management of industry white kraft chemical pulp. Thesis for the degree of Doctor, University of Concepción. Concepción. Chile.

[10] ACHS. 2008. Yearbook of the Chilean Safety Association 2008. http://ww3.achs.cl/ws/wps/wcm/connect/7c4f270040f50396a0d2f0b370218de6/BIAN_AE10.pdf?MOD=AJPERES&CACHEID=7c4f270040f50396a0d2f0b370218de6. Accessed 19/08/2010.

[11] Wilkinson. 2003. Social determinants of health: the irrefutable facts. OMS. http://www.bvsde.paho.org/bvsacd/cd90/1008WILdet.pdf. Accessed 10/11/2010.

[12] Romero. 2010. New Social Responsibility Standard ISO 26000:2010. Model that provides guidelines for developing social responsibility in any organization. Social Responsibility Guide: First Edition 1 November 2010. http://www.gstandards.com/pdf/rs-iso26000-2010.pdf. Accessed 03/01/2011.

[13] Doménech. 2006. Social footprint and sustainable development. Paper, Second International Meeting on Poverty, Inequality and Convergence from 6 to 24 March 2006. http://www.huellasocial.com. Accessed 21/08/2010.

[14] Sotelo. 1998. The job insecurity: premises of globalization?. Papers on Population, Autonomous University of México. México. http://redalyc.uaemex.mx/pdf/112/11201804.pdf. Accessed 02/10/2010.

[15] Calafell. 2006. Governance and Corporate Social Responsibility. American Network of Universities for Corporate Social Responsibility, Presented to the International Congress Corporate Social Responsibility, University and Development. Buenos Aires, 4, 5 and 6 September 2006. http://www.redunirse.org/files/09%20-%202006%20-%20Gobernanza%20y%20RSE%20-%20Mario%20Calafell%20Loza.pdf. Accessed 21/11/2010.

EVALUACIÓN DE IMPACTO AMBIENTAL EN LA EMPRESA AZUCARERA PANCHITO GÓMEZ TORO MEDIANTE EL ANÁLISIS DEL CICLO DE VIDA.

LIFE CYCLE ASSESSMENT IN THE EVALUATION OF ENVIRONMENTAL IMPACT AT PANCHITO GOMEZ TORO SUGAR ENTERPRISE

MSc Ing. Dulce María Pérez Martínez[1]

[1]Grupo Empresarial Agroindustrial GEA Villa Clara.
Email: Direccion.Produccion@gea.vc.minaz.cu

RESUMEN

La industria azucarera genera un gran impacto en el medio ambiente. En la actualidad, uno de los métodos novedosos para evaluar cuantitativamente los impactos ambientales generados por productos y procesos es el Análisis del Ciclo de Vida (ACV), un método que es muy usado en los países desarrollados, pero aún es incipiente en América Latina. En el presente trabajo se aplica dicha metodología para cuantificar el impacto ambiental de la empresa azucarera "Panchito Gómez Toro". Los resultados muestran que la metodología utilizada constituye una herramienta valiosa para evaluar el desempeño ambiental de la producción de azúcar y se comprueba científicamente que la mayor contribución al impacto del proceso está dada por la etapa agrícola y en ésta, por el uso de la tierra y el uso de fertilizantes químicos y combustibles. El mayor impacto en la etapa industrial está dado por la cogeneración de electricidad con bagazo, producto de un incremento considerable en la emisión de material particulado, convirtiéndose en un punto caliente sobre el cual es necesario actuar con rapidez. La contribución del proceso a la categoría de Combustibles Fósiles muestra la alta eficiencia en la generación de energía que se logra en la empresa Panchito Gómez Toro. La combinación del uso del sistema de depuración de gases con otras medidas de P+L permite una reducción en el valor de la mayoría de las categorías de impacto consideradas, destacándose la de efectos respiratorios de compuestos inorgánicos y la de combustibles fósiles. Este trabajo constituye el punto de partida para la elaboración de los inventarios para esta industria y para la región de América Latina.

Palabras clave: *impacto ambiental, análisis de ciclo de vida, cogeneración con bagazo, depuración de gases, inventario de ciclo de vida*

ABSTRACT

The sugar industry generates a great impact in the environment. At present, one of the novel methods to quantitatively evaluate the environmental impacts generated by products and processes is the Life Cycle Assessment (LCA), a method that is widely used in developed countries, but still incipient in Latin America. In this paper such a method is applied to quantify the environmental impact of the 'Panchito Gomez Toro' Sugar Enterprise. The results obtained show that the methodology used constitutes a valuable tool to evaluate the environmental performance of sugar production and it is scientifically verified that the greatest contribution of this process to the impact is given by the agricultural stage and, therein, by the use of the land and chemical fertilizers and fuels. In the factory stage, the greatest impact is given by the bagasse-based power cogeneration resulting in a significant increase in particulate matter emission, thus becoming a hot point on which rapid action is required. The contribution of the process to the fossil fuels category shows the high efficiency in energy generation achieved at the "Panchito Gomez Toro" Sugar Mill. The combination of the use of a gas purification system with other cleaner production measures allows a reduction in the value of most of the impact categories considered, especially of that of the respiratory effects from inorganic compounds and of the Fossil Fuels category. This paper represents the starting point for the preparation of the Life Cycle Inventories for this industry and for the Latin American region.

Keywords*: environmental impact, life cycle assessment, cogeneration with bagasse, gas purification, life cycle inventory.*

INTRODUCCIÓN

La intervención del hombre en la naturaleza comenzó hace miles de años y el proceso de daños a causa de la actividad humana fue escaso y lento al inicio, sin embargo, hoy en día, el uso de sustancias químicas utilizadas en la agricultura y en la industria, el uso irracional de recursos y la contaminación, entre otros factores, destruyen en minutos lo que la naturaleza construyó en siglos o milenios.

A consecuencia del desequilibrio ecológico, el estudio del ambiente ha venido a ocupar un lugar necesario e importante en los foros nacionales e internacionales en los que se analizan y plantean orientaciones políticas, económicas y comerciales para lograr un desarrollo sustentable, que haga posible el crecimiento económico, sin poner en riesgo los recursos naturales que se han heredado de nuestros antepasados y preservarlos para las generaciones futuras.

En este contexto, la producción más limpia adquiere una gran relevancia, ya que es preciso prevenir las tendencias actuales que ponen en peligro de extinción de recursos invaluables y alteran las condiciones naturales del planeta. La conservación del ambiente configura un nuevo valor social, que exige un renovado compromiso, para identificar soluciones que respondan a las aspiraciones de la sociedad.

Para la nación cubana, la caña y el azúcar forman una parte integral de su historia, cultura y tradición. El azúcar de caña ha sido el producto principal en la economía cubana durante años. La caña se ha sembrado históricamente con el objetivo básico de producir y comercializar azúcar; es un cultivo con alta capacidad de producción, que en buenas condiciones, produce volúmenes por encima de las 100 t/ha de tallos. Si las hojas y topes (cogollo), que no se utilizan en la producción de azúcar, fueran incluidas, el volumen de biomasa ascendería un 20%. Se ha demostrado que el uso de la caña de azúcar, además de obtener energía renovable, es muy atractivo, ya que el proceso de combustión de la biomasa, como subproducto, es climáticamente neutral debido al ciclo de carbón cerrado de la planta (Suárez, 2005; Mesa, 2003; Villegas, 2005).

La industria azucarera utiliza grandes cantidades de agua e insumos en las etapas agrícola e industrial ya sea para la elaboración de sus productos o para el saneamiento de los equipos de producción. Aunque se ha demostrado el efecto positivo que tiene el uso de la biomasa cañera para la producción de energía, en el ahorro de combustibles fósiles, se pueden producir efectos nocivos por la respiración del material particulado generado en los procesos de combustión.

El Ministerio de la industria azucarera se ha manifestado a favor en la protección del medio ambiente y apoya las innovaciones en materia de metodologías de Evaluación de Impactos Ambiéntales y por esta razón ya se habla hoy en la Industria azucarera cubana de Análisis de Ciclo de Vida.

El objetivo del presente trabajo es determinar los procesos que más contribuyen al impacto ambiental considerando dos etapas: La Etapa Agrícola y la Etapa industrial, ambas muy importantes en la producción de Azúcar Crudo (producto final) y proponer un plan de medidas que contribuya a mitigar dichos procesos.

MATERIALES Y MÉTODOS

EL ACV hace posible calcular los impactos ambientales acumulativos resultantes de todas las etapas en el ciclo de vida del producto. En el presente trabajo se consideran las dos etapas del proceso de producción de azúcar: La Etapa Agrícola y la Etapa Industrial El estudio se realiza sobre la base de los requisitos establecidos en la Norma NC- ISO 14040 2005.

Alcance del estudio

Partiendo de una muestra representativa diaria de los parámetros fundamentales de la Industria y la Agricultura, se promediaron las entradas y salidas del proceso durante las tres últimas zafras (2006,2007 y 2008). El sistema de estudio considerado es una fábrica de azúcar crudo de caña: Empresa "Panchito Gómez Toro", con capacidad diaria de 2731 t de caña (promedio de las tres últimas zafras: 2006,2007y 2008), para las condiciones de producción convencional.

Unidad funcional

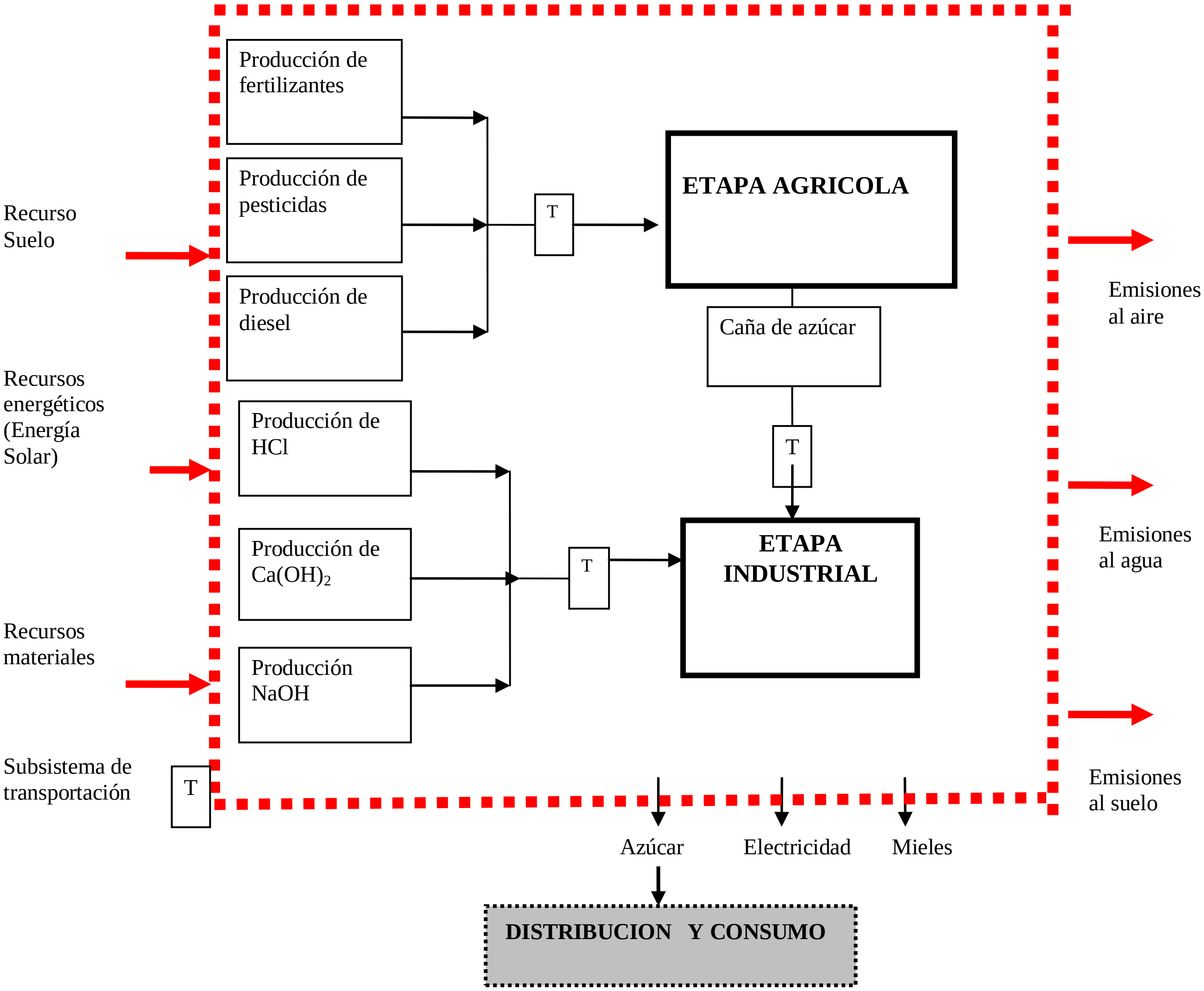
Es la unidad a la que se refieren todas las entradas (materias primas, energía,...) y salidas (productos, emisiones, residuos,...) del sistema en estudio. Debe estar claramente definida, ser medible y representativa de todos los flujos del proceso. La unidad más representativa de todas las entradas y salidas del proceso en estudio es la producción diaria de azúcar de la fábrica (282 t/d promedio de las tres últimas zafras: 2006,2007y 2008).

Consideraciones y Limitaciones:

A continuación se especifican las consideraciones hechas en cada etapa con respecto a las soluciones de los residuos:

- Se consideró el uso de Residuos Agrícolas de la Cosecha (RAC) y mieles finales como alimento animal, considerando el consumo de cantidades equivalentes de otros alimentos; además, en la literatura se plantea que dichos productos tienen entre sí un comportamiento comparable desde el punto de vista nutritivo (Valdés, 2005).
- Uso de Cachaza y Cenizas en organopónicos (compost); se consideró el ahorro de los fertilizantes químicos que comúnmente se emplean en la agricultura en Cuba (urea, cloruro de potasio y superfosfato triple), ya que los mismos proceden de procesos similares a los contenidos en la base de datos Ecoinvent.
- Uso de aguas residuales para fertirriego; se considera el ahorro de agua y fertilizantes equivalente a los contenidos de nitrógeno, fósforo y potasio del agua.
- La generación de electricidad satisface las necesidades en la industria, de acuerdo con el esquema tecnológico de cada alternativa y el resto se envía a la Red Nacional.

Figura 1. Límites del Sistema.



Para el análisis del ACV se utilizará el programa Simapro 7.1 (Goedkoop y Oele, 2004), utilizándose la base de datos Ecoinvent (2003) y los procesos creados para las condiciones de Cuba. Además, se usan datos de la documentación para fábricas de azúcar de la EPA. Se emplea el método del Eco-indicador 99 (PRé Consultans 2004) que tiene en cuenta 11 categorías de impacto y tres categorías de daños, para de esta forma demostrar cuáles son los productos y operaciones de mayor influencia en el impacto total del proceso.

Una vez propuestas las medidas de mitigación, se realizará la comparación de los impactos ambientales asociados al proceso antes y después de las mejoras, de forma tal que se pueda cuantificar su reducción.

Se realizó además un Análisis Estadístico de los Parámetros Primarios de la Industria y de la etapa Agrícola, para los cuales se calculó: la Media, la Desviación Estándar, la Varianza, el Coeficiente de Variación así cómo el Tipo de Distribución debido a que el análisis de incertidumbre resulta importante para definir el nivel de precisión de una evaluación de impacto ambiental. En el caso de estudio, los resultados estadísticos muestran la variabilidad de los datos para todas las variables estudiadas y por tanto, la incertidumbre en las condiciones de operación de esta industria.

Se utiliza el módulo de comparación de procesos para comparar los resultados de la evaluación ambiental con el uso o no de sistemas de depuración en el proceso de cogeneración de electricidad, considerando el uso de un sistema depurador mecánico (ciclón) con un 70 % de eficiencia. Los demás parámetros se mantienen constantes.

RESULTADOS Y DISCUSIÓN

Del proceso de evaluación de impactos se obtiene como resultado la Red del proceso donde se evidencia que la magnitud del impacto generado por la etapa agrícola es mayor que la del generado por la etapa industrial (producción de azúcar) y en esta última, la cogeneración de electricidad con bagazo representa la mayor contribución. Por otra parte, se destaca que el uso de los RAC genera un impacto ambiental beneficioso significativo. Este resultado se puede apreciar en la Tabla I que resume la contribución total del inventario para las etapas Agrícola e Industrial, según los procesos considerados en la base de datos Ecoinvent en combinación con los procesos típicos de la industria azucarera creados.

Tabla I: **Contribución Total del Proceso**.

Categoría de impacto	Unidad	Total	Etapa Agrícola	Etapa Industrial
Total	Pt	82571.603	45210.372	37361.232
Carcinogénesis	Pt	-1251.2142	-696.10857	-555.10568
Resp. orgánicos	Pt	2.0647863	1.8099239	0.25486249
Resp. inorgánicos	Pt	42956.52	703.75199	**42252.768**
Cambio Climático	Pt	424.94153	400.43374	24.507787
Radiación	Pt	7.7148743	11.584495	-3.8696209
Capa de Ozono	Pt	0.074764193	0.14387739	-0.069113199
Ecotoxicidad	Pt	-396.14201	-179.58196	-216.56005
Acidificación/ Eutrofización	Pt	1.1617132	-68.492926	**69.654639**
Uso del Terreno	Pt	39537.257	42745.067	-3207.8104
Minerales	Pt	76.338575	87.239276	-10.900701
Combustibles Fósiles	Pt	1212.8864	2204.5249	-991.63848

Se observa que en la etapa agrícola los valores numéricos de la tabla son, en la mayoría de las categorías de impacto, **positivos** (efecto perjudicial sobre el medio ambiente), no ocurriendo lo mismo en la etapa industrial, donde sólo se destaca por presentar impactos perjudiciales (**valores positivos**) en la categoría de efectos **respiratorios por compuestos inorgánicos y acidificación/eutrofización,** dados **fundamentalmente por la emisión indiscriminada de residuos en el proceso.**

Resulta significativo el hecho de que en ambas etapas, tanto en la agrícola como en la industrial, en la categoría de **Carcinogénesis** se obtienen resultados negativos (FAVORABLES) al impacto ambiental, lo cual está asociado con la reducción de emisiones de compuestos orgánicos al aire, al agua y al suelo. Las mayores contribuciones son debido al uso de las mieles finales y los RAC como alimento animal. La cogeneración de electricidad con bagazo contribuye de forma significativa a evitar la emisión de compuestos orgánicos que tiene lugar cuando la electricidad es generada a partir de combustibles fósiles. Se obtienen resultados favorables debido al uso de residuos líquidos y sólidos (cachaza, cenizas y agua residual que son usadas como fertilizantes e irrigación respectivamente), lo que evita el consumo de urea, superfosfato triple y cloruro de potasio.

De igual forma la **Ecotoxicidad** presenta resultados similares a la categoría de la **Carcinogénesis** y esto está asociado con la emisión al aire, al agua y al suelo de gran cantidad de compuestos orgánicos y de metales pesados, que contribuyen de manera significativa al impacto sobre el ecosistema. Ofrece valores favorables, ya que el uso de la electricidad a partir de bagazo, así como el uso de RAC y mieles como alimento animal, reducen el impacto de la industria azucarera en esta categoría.

Los resultados de la comparación de los procesos de cogeneración en esta industria con y sin depuración de gases se muestran en la **Tabla II.**

Tabla II: Comparación de los sistemas de cogeneración con y sin depuración de gases.

Categoría de Daño	Unidad	Cogeneración de electricidad sin depuración de gases	Cogeneración de electricidad con depuración de gases
Total	Pt	41131.646	12043.09
Daño a la Salud	Pt	41931.344	**12842.78**
Daño a la Calidad Ecosistema	Pt	87.036808	87.03681
Daño a los recursos	Pt	-886.7344	-886.734

Se observa que existe una disminución del impacto ambiental total generado, siendo el impacto usando sistemas de depuración (12043 Puntos) 3,4 veces menor que antes de usar estos sistemas (41131 Puntos), debido a la reducción de la emisión de material particulado.

Analizando las categorías de daño se aprecia que el impacto sobre la salud se ve notablemente beneficiado cuando se utilizan los sistemas de depuración de gases; el daño al ecosistema y a los recursos se mantiene en un mismo nivel.

Otras medidas que pueden contribuir a la disminución del impacto ambiental del proceso

Se analiza que el impacto ambiental del proceso puede ser disminuido aún más si se implementa una serie de medidas como las que se relacionan a continuación.

1. Chequear y controlar la efectividad del fertirriego y calidad de las aguas,
2. Planificar y asegurar la aplicación de compost y de otros residuales sólidos que se le incorporan al suelo,
3. Introducir en el Plan de Labores, las actividades agroecológicas no incluidas en el Programa de Suelos,
4. Independizar los residuos albañales de los del proceso fabril,
5. Construir trampas de grasa para la separación de aceites y lubricantes de las aguas residuales,
6. Establecer sistema para la extracción de cachaza en forma sólida y/o eliminación de derrames en el área de cargue,
7. Introducir sistema de laguna que permita desagregar el ácido clorhídrico de residuo de las limpiezas,

8. Asegurar la recuperación de la sosa (NaOH) agotada empleada en la limpieza de los evaporadores y calentadores y envío al enfriadero general,
9. Construir circuitos cerrados de enfriamiento y/o calentamiento en el tandem, máquinas de moler, turbogeneradores, bombas, cristalizadores, compresores,
10. Eliminar las causas que originan los retornos contaminados,
11. Tomar las medidas necesarias para la correcta operación de los sistemas de condensado y control analítico de las aguas condensadas,

Para corroborar el efecto de estas medidas se realizó la comparación de la etapa industrial del proceso actual con una nueva alternativa donde además de la instalación del equipo depurador de gases se cuantificaron los ahorros de sosa cáustica y de agua suavizada. Ver Tabla III.
En cuanto al resto de las medidas, aunque se conoce que deben producir una reducción del impacto, no se dispone en estos momentos de datos para su evaluación.

Figura 2: Comparación del Proceso Con y Sin Introducción de Medidas de P+L

Los resultados gráficos de la comparación del proceso actual con la alternativa considerando la introducción de medidas de Producción más Limpia se muestran en la figura 2.

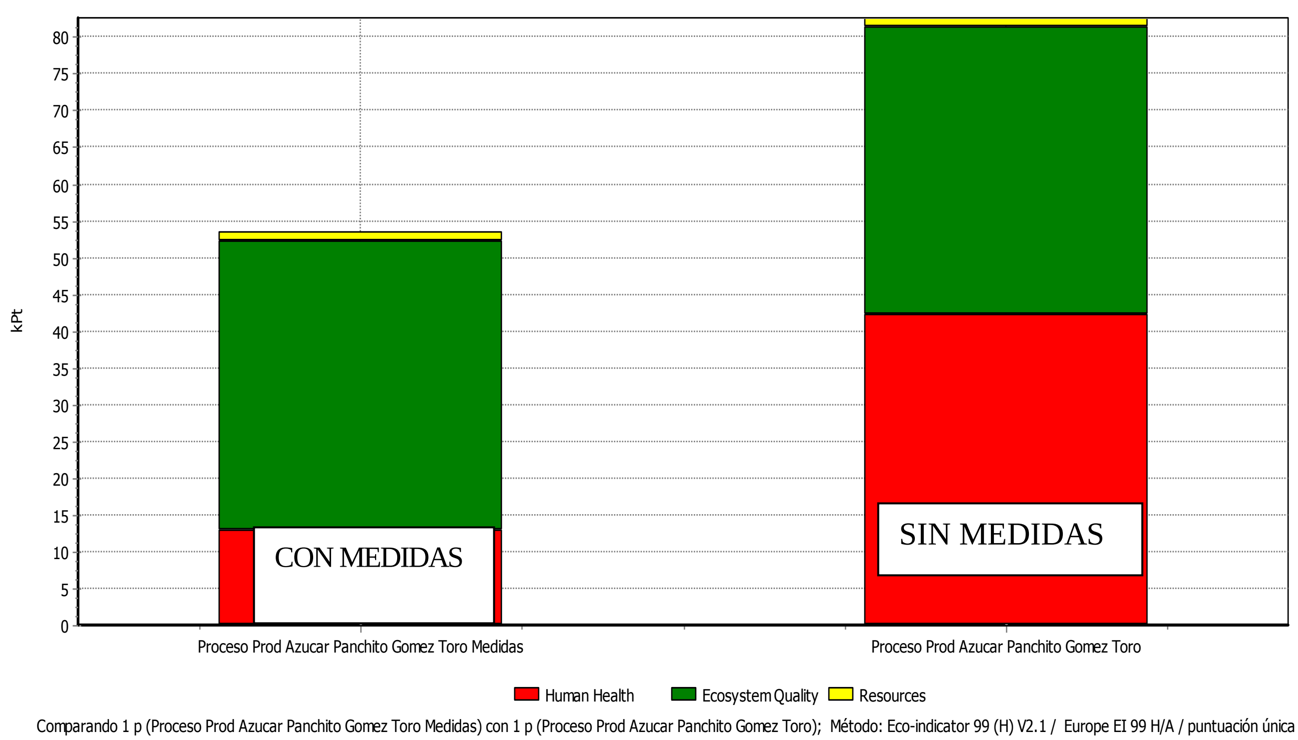


Tabla III Comparación del proceso con y sin Medidas de P+L. Caracterización.

Categoría de impacto	Unidad	Prod. Azúcar Panchito Gómez Toro	Prod. Azúcar con Medidas de P+L
Carcinogénesis	DALY	-0.048049702	-0.048057323
Resp. orgánicos	DALY	7.93E-05	7.93E-05
Resp. inorgánicos	DALY	1.649636	0.52918189
Cambio Climático	DALY	0.016318799	0.016304517
Radiación	DALY	0.00029627	0.000295
Capa de Ozono	DALY	2.87E-06	2.87E-06
Ecotoxicidad	PAF*m2yr	-50787.437	-50811.351
Acidificación/ Eutrofización	PDF*m2yr	14.893759	13.821605
Uso del Terreno	PDF*m2yr	506887.9	506887.24
Minerales	MJ surplus	3207.5032	3203.8633
Combustibles Fósiles	MJ surplus	50961.613	50908.819

En la Tabla III, por categorías de impacto, se observa la mayor disminución en la categoría de efectos respiratorios por compuestos inorgánicos, debido a la instalación del depurador de gases, seguido por las categorías de Acidificación/Eutrofización y combustibles fósiles, debido a la reducción de los consumos de sosa cáustica y agua suavizada. Se observan disminuciones menos significativas en las categorías Cambio climático, Radiación, Ecotoxicidad y Minerales.

CONCLUSIONES

1. El ACV realizado aporta el Inventario de Ciclo de Vida que constituye el punto de partida para la elaboración de los inventarios para esta industria y para la región de América Latina.
2. La mayor contribución al impacto del proceso (efecto perjudicial al medio) está dada por la etapa agrícola y en ésta, por el uso de la tierra, la producción y el uso de fertilizantes químicos y combustibles.
3. El mayor impacto en la etapa industrial está dado por la cogeneración de electricidad con bagazo, producto de la emisión de material particulado, lo que destaca la necesidad de instalación de separadores de partículas en estas instalaciones.
4. La contribución del proceso a la categoría de Combustibles Fósiles muestra la alta eficiencia en la generación de energía que se logra en la Empresa Panchito Gómez Toro.
5. El uso de sistemas de tratamiento para la remoción de material particulado disminuye en un 70% el impacto ambiental generado por el proceso de cogeneración.
6. La combinación del uso del sistema de depuración de gases con otras medidas de P+L produce una reducción en el valor de la mayoría de las categorías de impacto consideradas, destacándose la de efectos respiratorios de compuestos inorgánicos, Acidificación/ Eutrofización y combustibles fósiles.
7. La metodología utilizada constituye una herramienta útil para la cuantificación de los impactos ambientales de la producción de azúcar de caña en Cuba.
8. Los resultados alcanzados en materia de ACV nos han dado la posibilidad de que especialistas de nuestro sector formemos parte de la RED Cubana de CV y tengamos participación en actividades de la RED Latinoamericana de ACV.

BIBLIOGRAFÍA

- Ecoinvent Centre: The Life Cycle Inventory Data Version 1.01. (Ecoinvent data V1.01), December 2003, © Swiss Centre for Life Cycle Inventories/2003.
- Goedkoop, M. and M. D. Oele: Introduction to LCA (Life Cycle Assessment) with SimaPro, PRé Consultants, Sept. 2004, sitio web: www.pre.nl. Consultado: 15 de septiembre 2006.
- Mesa, J Y González, L.2003. La agroindustria de la caña de azúcar en un marco de Desarrollo sostenible, Revista Ciencias.com, 12 de agosto de 2003.
- National Office Normalization. NC ISO14041. 2000. Environmental management. LCA, Cuba, 2000.
- National Office Normalization. NC ISO14040. 2005: Environmental management. LCA, Cuba, 2005
- Suárez R, Morin R. Caña de Azúcar y sostenibilidad: enfoque y sostenibilidad, Cuba, 2005
- Valdés, A.2005 Combustibles y energías renovables a partir de la biomasa, Reunión Regional sobre Biomasa para la producción de energía, CITMA, Revisado Dic. 2005
- Villegas PJ, Cruz O.2005, Evaluación del impacto ambiental del uso de la biomasa en fábricas de azúcar en Cuba.

LCI & LCIA

CILCA 2011
MÉXICO

The Importance of Normalization of Normalization References in Interpreting LCA Results
United States

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Life Cycle Assessment on Catalonia coast: Integration of urban water cycle
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Social subcategories and indicators of SLCA inventories adapted to informal labour and self-employment: a case of Brazilian work market
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Life Cycle Greenhouse Gases in a Power Plant
Mexico

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Mexico

The Importance of Normalization References in Interpreting LCA Results

Junbeum Kim, Yi Yang, Junghan Bae, Sangwon Suh

Junbeum Kim , Bren School of Environmental Science and Management, University of California, Santa Barbara
Yi Yang, Department of Bioproducts and Biosystems Engineering, University of Minnesota
Junghan Bae, Department of Bioproducts and Biosystems Engineering, University of Minnesota
Sangwon Suh, Bren School of Environmental Science and Management, University of California, Santa Barbara

Normalization is a step connecting characterization and weighting within Life Cycle Impact Assessment (LCIA), a process which translates Life Cycle Inventory (LCI) results into more comprehensible and comparable metrics. Normalization References (NRs) are the characterized results of a reference system, typically a national or regional economy. Normalization is widely practiced in LCA-based decision support and policy analysis. Compilation of NRs demands significant effort and time as well as intimate knowledge of data availability and quality. Consequently, only one set of NRs published in 2006 is available for the U.S., and has been adopted by various studies. In this study, completeness of the previous NRs was evaluated, and significant data gaps were identified. Filling in these data gaps increased the magnitude of NRs for 'human health cancer' 'human health non-cancer', 'ecotoxicity', and 'eutrophication' by 639,544%, 106,688%, 6,311% and 101%, respectively. Such changes can alter or even reverse the outcome of an LCA study. We applied the previous and updated NRs to conventional gasoline and corn ethanol LCAs. Using previous NRs, corn ethanol showed weighted environmental impact an order of magnitude higher than gasoline, while applying updated NRs showed comparable impacts between the two. The results demonstrate that NRs play a decisive role in LCA interpretation. The updated normalization references are made available to the public.

Development of the parameterized inventories of life cycle and modelling of environmental profiles for the production of crude sugar in Cuba

Pérez Gil, Maylier; Contreras Moya, Ana; Rosa Domínguez, Elena; Espinosa Rodríguez, Vianka; Kumar Karna, Nabin

Central University "Marta Abreu" of Las Villas. Faculty of Chemistry and Pharmacy. Highway to Camajuaní, km 5 ½, Santa Clara, Villa Clara, Cuba. Postal Code: 54830 100. Fax: 53-42-281608. Telephone: 53-42- 281164. E-mail: maylier@uclv.edu.cu

Abstract

In the work being presented, the parameterized inventories for the life cycle of the crude sugar production in the Cuban Sugar Industry through a detailed record of all input and output currents involved in the process has been modeled, with appropriate statistical processing of the same. This allows the assessment of the environmental impacts associated with the process in different scenarios of operation and operational variables to detect the greatest impact on each of the impact categories analyzed. The system limits are defined for the industrial stage and the process of cogeneration as an auxiliary system is evaluated.

By means the process tree, all input and output currents for each unitary operation are analyzed. The editing and configuration of parameters are done using the SimaPro software, through material and energy balances, the hierarchy to level of unit-processes for building and comparing different stages is identified.

The environment profiles from any sugar industry of our country can be obtained by combination of the parameterized Inventories, with the existing methodology of this industry. In this paper a generic process of crude sugar production has been evaluated, using the eco-indicator 99 methodology and the parameters that major impact produce are identified.

Topic: Life Cycle Assessment: inventories and impact evaluation.

Key words: LCA, Eco-indicator 99, inventory modeling, databases.

Introduction

To quantify the sustainability of technologies various tools like Life Cycle Assessment (LCA) has been implemented. The LCA methodology provides all the occurred environmental impacts through out the life cycle of the product and relates them with the specific environmental problems; moreover, it permits to establish priorities to define the preventive strategies of improvement of the environmental actions [1-7].

For the application of a LCA are define four stages, in correspondence to ISO standards specially designated, in Cuba are correspond since CN ISO 14040 up to 14043: definition the goal and scope of the study, inventory analysis, impacts environmental assessment and interpretation [1, 4, 6, 8, 9].

For the implementation of this methodology, many computational programs like SimaPro have been designed, that demonstrates the advances in the facility and efficiency of the method, being the most used software in the LCA. [10-12].

The presented work has the following objectives: to model the inventory of the sugar industry, define and configure the parameters of the inventory and to evaluate different scenarios in function of the variability of the conditions of the operation.

Methods

The analysis of the Life Cycle Inventory (LCI) is the most exacting stage in the LCA, this includes data collection and calculation procedures to quantify the inputs (resource use) and outputs (products, co-products and emissions to air, water and soil) of a production system. For this data of the use of resources and emissions of all the processes is collected, using different data sources (LCA database, reports, papers, investigations in the place, knowledge of experts); construct a system model and calculate the use of the resources and emissions of the studies product. Through the calculations can be detected at what stage of life cycle of the product under study, are given the largest inputs, outputs and impacts [6, 9, 13-15].

For the modelation of the LCI the following actions must be undertaken:

1. Collect data in a format corresponding to the same collection.
2. Parameterize the data to be modeled.
3. To make the fluid diagram identifying all the inputs (raw materials and energy) and outputs (products, co-products and emissions) currents.
4. Identify all the rules of calculation used for the variable parameters (mass and energy balances).

5. Allocation the environmental charges in correspondence to the co-products that exist in the process.
6. Analyze the sensibility of the LCI data to identify the uncertainty obtained by LCA due to the accumulative effects of the imprecision in the input data.

Through the parameterization the necessary parameters for a complete specification of a model or geometric object are defined, various types of data are used and permit to apply the same algorithm to the different data.

When using parameters to model a process, calculation rules are used in place of fixed data to construct the model, which can be used in different stages and processes. It makes possible to construct models varying the inputs and outputs parameters of the process, moreover helps to compare between two or more scenarios.

Results and Discussion

Generally, a process of production of crude sugar starts from the entry of the sugarcane to the industry and is discharged into the rocker. The cane comes from different units of production due to which there is a great variability of the quality of the raw material in function of the cultivating conditions, harvesting, cleaning and time elapsed from reaping process till its arrival to the reception in the industry which has impacts in its processing. A generic process of the crude sugar production can be grouped in five stages: juice extraction, purification (heating, alkalization and clarification), concentration (evaporation and cooking of the sugar), crystallization and centrifugation of the sugar. The difference between the crude sugar industries in our country is given in the operation mode, in each of the stages of the process. In this work, triple effect has been considered in the evaporation stage (with a pre-evaporator) and a system of two cooked masses (A and B); moreover the bagasse produced in the extraction stage is used as combustible to cogenerate energy, technique that is implemented in most of the crude sugar industries of our countrie [16].

In Figure 1 the process tree to obtain sugar is represented which is no more than the model for the inventory of the data.

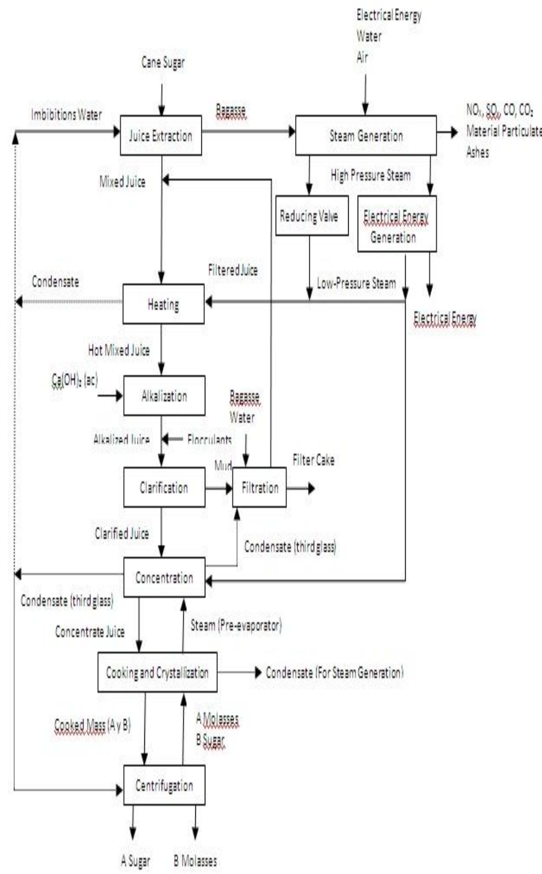

Figure 1. Model of life cycle of a generic process of crude sugar in Cuba

In accordance with the classification of the parameters that is used in the literature, the data of LCI is defined in:

Fixed parameters: fixed data and it refers to the reports of harvest time in the industry. They are directly related with the involved currents in each of the steps of the process.

Calculated parameters: it is determined through materials and energy balances, using the input parameters and can be input data too.

In this study were published 33 fixed parameters and 38 calculated parameters.

After editing the parameters are evaluated environmental impacts to a generic process of crude sugar through the Eco-indicator 99 which allowed us to determine which variables have the greatest impact on each category of impact.

Figure 2 shows that the impact categories that were negative (beneficial) are associated with emissions to air, water and soil organic compounds (mainly benzene, dioxins, toluene, dichloroethane, methylene chloride, tetrachloroethylene, hydrofluoric acid, phenol) and heavy metals (arsenic, cadmium, nickel, chromium, mercury, copper, lead) which are reduced by the concept of avoided products (electricity and ash for composting).

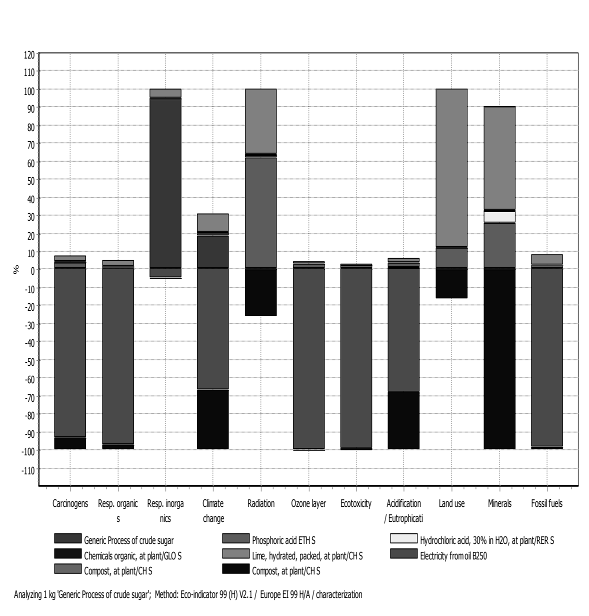

Figure 2. Environmental profile for the impact categories/characterization

In Figure 3, it is observed that the impact category, respiratory effects of the inorganic compounds present higher prejudicial values to the environment, justified with the emission of the particulate material (PM-10, PM-2.5), oxides of nitrogen and sulphur dioxide as the principal contributors produced in the steam generation from bagasse.

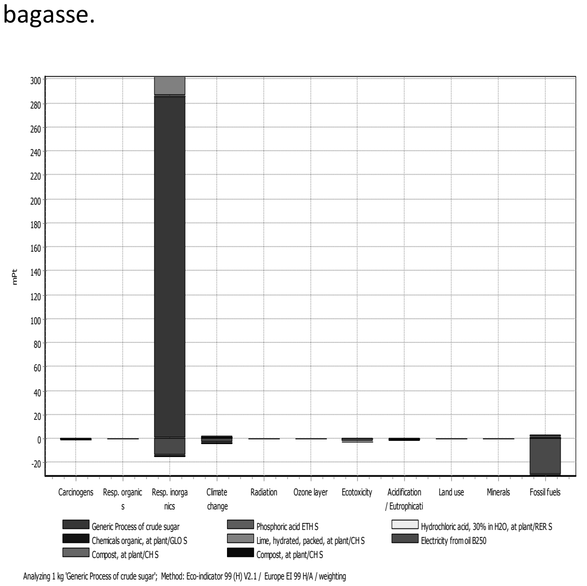

Figure 3. Environmental profile for the impact categories/weighting

If the impact is analyzed as damage category it is proved, in the Figure 4, that the major prejudicial effect is on the Human Health, in correspondence with the results of the category of respiratory effects by inorganic compounds explained previously. The less effects is produced on the resources, due to the consumption of the electricity generated by the own production process.

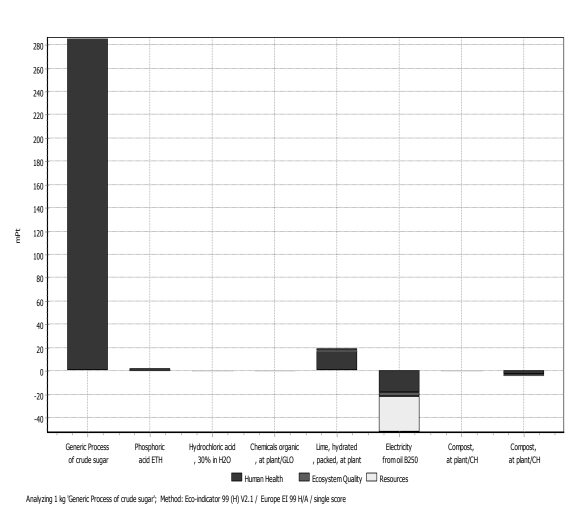

Figure 4. Environmental profile by damage categories/single score

Conclusions

1. Results shown that the environmental profiles of crude sugar production can be modeled by using parameterized inventories of life cycle.
2. The parameterization of the life cycle inventory of the crude sugar permits to model different scenarios varying the input and output parameters of the process.
3. The impact assessment phase reported the major prejudicial effects on the category of the respiratory effects by the inorganic compounds due to the emission of the particulate material and therefore for the category of damage to the Human Health.
4. The beneficial impacts on the different categories of impacts are given by the concept of the avoided product.

References

1. Fullana, P. (2002) "Análisis del Ciclo de Vida". Editorial Rubes. España.
2. PNUMA (2003) (Programa de las Naciones Unidas para el Medio Ambiente). "Life Cycle Iniciative". Disponible en: http://www.uneptie.org/sustain/1cinitiative
3. Iglesias, D. (2005) "Relevamiento exploratorio del análisis del ciclo de vida de productos y su aplicación en el sistema agroalimentario. Contribuciones a la Economía", ISSN 1696-8360. Disponible en: http://www.eumed.net/ce/
4. NC ISO 14040 (2005) "Environmental management. Life Cycle Assessment. Principles and framework". National Office of Normalization. Havana City. Cuba.
5. Gaudreault, C.; Samson, R.; Stuart, P. R. (2006) "Survey of LCA applications in the pulp and paper industry". Conference Proceedings. 17th International Congress of Chemical and Process Engineering, CHISA 2006. Prague, Czech Republic. ISBN: 80-86059-45-6.
6. Sánchez, O. J. y col. (2007) "Análisis de ciclo de vida y su aplicación a la producción de bioetanol: Una aproximación cualitativa". Revista Universidad EAFIT, Vol. 43, № 146. Abril-Junio, 2007. Disponible en: http://www.redalyc.uaemex.mx
7. Althaus, J. H. et. al. (2007). "Overview and Methodology. Data v2.0 (2007)". Swiss Centre for Life Cycle Inventories. Ecoinvent report No. 1. Dübendorf, December 2007.
8. Sáenz, M. y Zufía, J. (1999) "Análisis de Ciclo de Vida para la reducción de impactos medioambientales generados por el sector agroalimentario Vasco". Sociedad pública de gestión ambiental del país Vasco (IHOBE), 1999. Disponible en: http://www.nasdap.ejgv.euskadi.net/r50-468/es/contenidos
9. SAIC (Scientific Applications International Corporation). (2006) "Life Cycle Assessment: principles and practice". National Risk Management Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268. Mayo, 2006. Disponible en: http://www.epa.gov/ORD/NRMRL/lcaccess/pdfs/chapter1_frontmatter_lca101.pdf
10. Goedkoop, M and Oele, M. (2004) "Introduction to LCA (Life Cycle Assessment) with SimaPro". PRé Consultants. Disponible en: http://www.pre.nl/download/manuals/UserManual.pdf
11. PRé Consultants. (2006) "Life cycle tools to improve environmental performance and sustainability". Amersfoort, The Netherlands. Revisado en Enero, 2006a. Disponible en: http://www.pre.nl/pre
12. PRé Consultants. (2006) "SimaPro 6.0. LCA software: the powerful life cycle solution". The Netherlands. Revisado en Enero, 2006b. Disponible en: http://www.pre.nl
13. Llanes, E. y col. (2005) "Propuesta de aplicación de herramienta de gestión ambiental. Análisis de Ciclo de Vida a la actividad agrícola". Revista Ciencias. Código ISPN de la Publicación: EEEykVlFZuXyoXnEbj. Publicado el 16 de Mayo, 2005. Disponible en: http://www.revistaciencias.com
14. Björklund, A. and Finnveden, G. (2006) "Welcome to a course in Life Cycle Assessment, Center for Environmental Strategies research". Revisado en Abril, 2006. Disponible en: http://www.infra.kth.se/fms/utbildning/lca/1N1800_F1.pdf
15. Contreras, A. M. (2007) "Metodología para el análisis del ciclo de vida combinado con el análisis energético en la industria azucarera cubana". Tesis presentada en opción al grado de Doctor en Ciencias Técnicas. Universidad Central "Marta Abreu" de Las Villas. Cuba.
16. Pérez, M. (2009) "Evaluación ambiental del proceso de cogeneración con bagazo en la Industria Azucarera Cubana mediante el Análisis del Ciclo de Vida" Tesis presentada en opción al grado científico de Máster en Ingeniería en Saneamiento Ambiental. Universidad Central "Marta Abreu" de Las Villas. Cuba.

State of the art and Life Cycle Inventory of packaging waste incineration in Spain and Portugal

Margallo, María [(1)], Aldaco, Rubén[(1)], Bala, A[(2)], Fullana, Pere [(2)], Irabien, Ángel [(1)]
[(1)] Departamento de Ingeniería Química y Química Inorgánica,
Universidad de Cantabria, ETSIIT, Avda. de Los Castros s/n, 39005, Santander, Spain.
Tel. +34 942200870, Fax. +34 942201591, e-mail: margallom@unican.es
[(2)] Escola Superior de Comerç Internacional (ESCI-UPF),
Pg. Pujades, 1. 08003 Barcelona, Spain Tel. +34 932954710, e-mail: giga@admi.esci.es

ABSTRACT
This work is part of the "FENIX-Giving Packaging a New life" project, a 3-year European LIFE+ funded project. The main objective of this project is to develop a flexible software tool for the Spanish and Portuguese municipalities to obtain the environmental impact of the packaging waste management system using the LCA methodology. This paper is the first part of the study focused in the stage of packaging waste incineration. According to this, a review of the main treatment and technologies applied in waste incineration and the inventory data of the incineration plants sited in Spain and Portugal has been done.

Topic: Life Cycle Assessment Management Trends: LCA methodology and LCIA.

Keywords: Packaging waste, incineration, Life Cycle Inventory.

1. INTRODUCTION

This work is part of the "FENIX-Giving Packaging a New life" project, a 3-year European LIFE+ funded project. The main objective of this project is to develop a flexible software tool for the Spanish and Portuguese municipalities and other organisation to obtain the environmental impact of the packaging waste management system using the LCA methodology. Specifically this paper is focused in the incineration process, which main objective is to treat waste so as to reduce its volume and hazard, while capturing or destroying potentially harmful substances. Incineration processes may also allow recovery of the energy, mineral and/or chemical content from waste [1]. Basically incineration process includes the pretreatment, thermal treatment and energy recovery and flue-gases treatment.

1.1 Pretreatment, handling and storage

This is previous preparation stage to the thermal treatment.

1.2 Thermal treatment

This treatment comprises basically the combustion of the Municipal Solid Waste (MSW) in a furnace. In this process, slag is generated as solid residue while the flue-gases are used in the energy production through a turbine. Different types of thermal treatments are applied to the different types of wastes, however not all thermal treatments are suited to all wastes. Specifically the most common technologies are grate incinerators, rotary kilns, fluidised beds and pyrolysis and gasification systems. However in Spain and Portugal just the grate incinerators and fluidised beds are used.

1.2.1 Grate incinerators

This type of incinerators is widely applied for the incineration of mixed municipal wastes. Grates usually have as main components:

- Waste feeder.
- Incineration grate: rocking, reciprocating, travelling, roller and cooled grates are the main types of grates.
- Bottom ash discharger.
- Incineration air duct system.
- Incineration chamber.
- Auxiliary burners.

1.2.2 Fluidised bed

Fluidised bed incinerator is a lined combustion camber in the form of a vertical cylinder. In the lower section, a bed of inert material (such as sand or ash) on a grate is fluidised with air. Normally this type of incineration requires a preparatory process step which makes raise the process costs. The main types of fluidised bed are stationary or bubbling fluidised bed, spreader-stoker furnace and rotating fluidised bed.

1.3 Flue-gases treatment

Gases generated in the combustion before be emitted must be treated using different treatment system depending on the type of pollutant to be removed.

- *Reduction of particulate emissions:* electrostatic precipitators, ionisation wet scrubbers, bag filters and cyclones and multi-cyclones are used to removed these pollutants.
- *Reduction of acid gases (HCl, HF and SO_x)*: usually this reduction is carry out by dry, semi-wet and wet processes adding CaO or $Ca(OH)_2$.
- *Reduction of emissions of nitrogen oxides (NO_x)*: in this case two process are applied, the Selective Non-Catalytic Reduction (SNCR) process where NO_X are removed using ammonia or urea as reducing agent and the Selective Catalytic Reduction (SCR) process where the flue-gas passed over a catalyst.
- *Reduction of Dioxins and Furans:* most usual treatment is adsorption on activated carbon but also bag filters and SCR could be applied.

1.4 Waste treatment

In the incineration process bottom, boiler and fly ashes and slag are the main waste generated. Ashes are usually disposed of, but could be used as a filling material in civil construction. On the other hand slag is disposed of by landfill without further treatment, or may be recycled.

2. RESULT AND DISCUSSION

According to the European Pollutant Release and Transfer Register E-PRTR, in Spain and Portugal there are respectively 10 and 3 installations of incineration of non-hazardous waste (capacity 3 tons/h) [2]. Figure 1 shows incinerators location.

Figure 1- Location of Spanish and Portuguese incinerators.

2.1 Planta de Valortització Energética Sant Adrià de Besòs (TERSA)

The energy valorisation plant sited in Barcelona (Catalonia, Spain) serves out to 750,000 inhabitants. In 2008, 321,728 tons of wastes were incinerated, producing 167,504 MWh, of electricity. In relation to waste, 12,039 tons of ashes were generated, 55,642 of usable slag and 7,002 tons of scrap. Some technical data are given in the Table 1.

Table 1- Technical data of TERSA [3].

Incineration capacity	14.5 t/h
Type of furnace	Von Roll grate
Combustible LHV	1,900-2,200 kcal/kg
Flue-gases treatment	Electro filter, SNCR, scrubbers, activated carbon, bag filter

2.2 Tractament i Revaloritzaió de Residus del Maresme, S.A. (UTETEM)

The incineration plant gives service to 407,000 inhabitants of Barcelona. In 2009, 170,274 tons of wastes were incinerated; generating 86,104,879 kWh of electricity. Regarding to waste, 24.65% in weight of waste were slag and 4.25% ashes, being stabilized 7,213 tons. Likewise 854 tons of scarps were generated. Some technical data of the plant are given in the Table 2.

Table 2. Technical data of UTETEM [3].

Incineration capacity	10 ton/h
Type of furnace	Travelling grate of bar
Combustible LHV	2,100 kcal/kg
Auxiliary combustible	Natural gas
Flue-gases treatment	SNCR, semidry and dry system, activated carbon, bag filter

2.3 TRARGISA

This plant serves out to 125,000 inhabitants of Girona (Catalonia, Spain). In 2009, 30,179.68 tons were incinerated producing 7,595,100 kWh of electricity. About waste, 21% in weight of the waste were slag, 650 tons ashes and 1,073.55 tons scrap were obtained. In the Table 3 some technical data are shown.

Table 3. Technical data of TRARGISA [3].

Incineration capacity	2.5 ton/h
Type of furnace	MARTIN reverse acting grate
Combustible LHV	≈1,800 kcal/kg
Electricity production	7,595,100 kWh
Flue-gases treatment	Electro filter, bag filter injection activated carbon and $Ca(OH)_2$,

2.4 TIRMADRID

The incineration plant serves out to 1,000,000 inhabitants of Madrid (Spain). In 2009, 311,205 tons of wastes were incinerated generating 234,840,800 kWh of electricity. In relation to the waste, 7,035 tons of scraps were recovery from the slag. Some technical data are given in Table 4.

Table 4. Technical data of TIRMADRID [3].

Incineration capacity	9.17 ton/h
Type of furnace	Bubbling fluidised bed
Combustible LHV	3,500 kcal/kg
Auxiliary combustible	Gasoil C
Flue-gases treatment	Cyclones, scrubbers, bag filters, activated carbon

2.5 Zabalgarri, S.A.

The energy recovery plant serves out to 700,000 inhabitants of 10 municipalities of Vizcaya, (Basque Country, Spain). In 2009, 223,933 tons were incinerated and 661,160,000 kWh of electricity were generated. In relation to the waste, 3.74% in weight of the MSW were ashes, 19% slag and 2% recovery scrap. In the Table 5 some technical data are shown.

Table 5. Technical data of Zabalgarri [3].

Incineration capacity	30 ton/h
Type of furnace	Reciprocating grate
Combustible LHV	2,000 kcal/kg
Auxiliary combustible	Natural Gas
Flue-gases treatment	Bag filter, SNCR, activated carbon

2.6 Incineradora de Tarragona (SIRUSA)

The incinerator of Tarragona (Catalonia, Spain) serves out to 350,000 inhabitants. In 2009, 142,418 tons of MSW were incinerated, obtaining 44,552 MWh of electricity. In Table 6 some technical data are shown.

Table 6. Technical data of SIRUSA [3].

Incineration capacity	9.6 ton/h
Type of furnace	Roller grate with Dusseldorf system
Combustible LHV	1,900-2,200kcal/kg
Auxiliary combustible	Gasoil
Flue-gases treatment	Semidry system, bag filter, activated carbon

2.7 PIR Melilla (REMESA)

The incineration plant of Melilla (Spain) gives service to 74,000 inhabitants. 39,155.9 tons of MSW were incinerated in the plant in 2009. In this year 8,044 MW of energy were consumed being selling 11,298 MWh of energy. In relation to waste, 2.66% of the MSW were ashes (1043 ton/year) and 24% slag from which 1,043 t/year of scrap were recovered. Some technical data of the plant are shown in the Table 7.

Table 7. Technical data of REMESA [3].

Incineration capacity	4.5 – 6 ton/h
Type of furnace	Serrated grate
Combustible LHV	1,700
Auxiliary combustible	Gasoil
Flue-gases treatment	Semidry system with bag filter, activated carbon

2.8 Complejo medioambiental de Cerceda (SOGAMA)

The incineration plant serves out to 211,708 inhabitants of Galicia (Spain). In 2009, the plant had a nominal capacity of 550,000 tons/year, with an electricity production of 335.078.400 kWh. In relation to waste, 33,239.74 tons of wastes were ashes, 69,037.55 slag, 8,334.1 iron scrap and 213.94 tons aluminium scrap. Some technical data of the plant are shown in Table 8.

Table 8. Technical data of SOGAMA [3].

Type of furnace	Circulating fluidised bed
Combustible LHV	3,500 kcal/kg
Tons incinerated/year	533,742 (2007)
Auxiliary combustible	Natural Gas
Flue-gases treatment	Semidry system, bag filters, hydrate lime and activated carbon

2.9 TIRME, S.A.

The incineration plant serves out to approximately 846,210 inhabitants of Mallorca (Balearic Islands, Spain). In 2009, 294,185 tons were incinerated obtaining 152,389 MWh of electricity were produced, being selling 119,759,000 kWh of energy. In relation to waste, 9.6% of wastes were ashes, 23.5% slag and 28,345 tons of scrap were recovered. In the Table 9 some technical data are given.

Table 9. Technical data of TIRME [3].

Type of furnace	2 Roller grate and 2 cooled grates
Combustible LHV	1,800 kcal/kg
Auxiliary combustible	Gasoil C
Flue-gases treatment	Semydry scrubber, SCR bag filter, activated carbon

2.10 Planta de Tratamiento Integral de RSU de Cantabria (URBASER)

The incineration plant of Cantabria (Spain) gives service to 580,000 inhabitants. In 2009, 113,338 tons of MSW were incinerated in the plant producing 82,800 MWh/year of electricity. About waste, 4.01% of wastes were ashes and 13.21% slag. In Table 10 some technical data are shown.

Table 10. Technical data of URBASER [3].

Type of furnace	12 ton/h
Type of furnace	Roller grate
Combustible LHV	2,800 kcal/kg
Auxiliary combustible	Natural gas
Flue-gases treatment	Scrubber, bag filter, activated carbon

2.11 VALORSUL

The incineration plant of Valorsul sited in the municipality of Loures, (Lisboa, Portugal) has an incineration capacity of 662,000 ton/year. Wastes (LHV 7,820 kJ/kg) are incinerated in a Detroit stocker, reciprocating grate generating 30 kg/Mg MSW of ashes and 200 kg/Mg MSW of slag. To the flue gas treatment a semidry process with lime injection, a SNCR, and activated carbon injection are applied [4].

2.12 Valor Ambiente - Gestão e Administração de Resíduos da Madeira

The incineration plant sited in Madeira (Portugal) has an incineration capacity of 16 ton/year and an electricity production of 473 kW/t. Wastes received in the plant have a LVH 2,800 kcal/kg and are treated in a roll grate. About waste, 160 kg/t MSW of slag and 59 kg/t MSW of waste from FGT are generated [5].

2.13 LIPOR - Serviço Intermunicipalizado de Gestão de Resíduos do Grande Porto

The Energy Recovery Plant located in Maia (Oporto, Portugal) has an incineration capacity of 400,000 ton/day, producing 200,000 MWh/year of electricity. Wastes received in the plant with a LVH of 7,700 kJ/kg are treated in combustion grids 26º inclination [6].

3. CONCLUSIONS

The most relevant technologies applied in the MSW incineration in Spain and Portugal have been reviewed and will be included in the future model based on LCA. About thermal stage, grate incinerator, rotatory kilns and fluidised bed could be applied. However in Spain and Portugal just grate incinerators and fluidised bed are used.

Different cleaning systems are applied depending on the pollutants contained in the gases. In Spain and Portugal electrostatic precipitators, electrofilters, bag filters and cyclones are the main techniques used for reducing particulate emissions. Acid gases are treated through dry, semi-dry and wet processes, while NO_x are eliminated by means of Selective Non Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR) processes. About dioxins and furans, these substances are usually treated by absorption on activated carbon.

REFERENCES

[1] [EC] European Commission. 2006. Reference Document on the Best Available Techniques for Waste Incineration.

[2] AEVERSU, Asociación empresarial de Valorización de RSU. http://www.aeversu.com/ Accessed 15.10.2010.

[3] European Pollutant and Release Transference Register http://prtr.ec.europa.eu/ Accessed 22.10.2010.

[4] Valorsul, S.A. http://www.valorsul.pt/ Accessed 22.10.2010.

[5] A Valor Ambiente - Gestão e Administração de Resíduos da Madeira, S.A. http://www.valorambiente.pt/ Accessed 25.10.2010.

[6] LIPOR- Serviçio Intermunicipalizado de Gestão do Grande Porto. http://www.lipor.pt/ Accessed 22.10.2010.

Environmental profile of irrigated and non-irrigated soybean in central Argentina. Its application in bioenergy.

Piastrellini, Roxana[1,2] Arena, Pablo[1,2] and Civit, Bárbara[1,2]
[1]Universidad Tecnológica Nacional Facultad Regional Mendoza – Cnel. Rodríguez 273 (5500) Mendoza, Argentina - ++54 261 5243001
[2]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
roxana.ppp@gmail.com

ABSTRACT

Key words: bioenergy – water use – water consumption - soybean

Topic: LCA Management Trends – LCA methodology: LCI and LCIA

Introduction

The major soybean producer region as feedstock for biodiesel production in Argentina is the Pampas. However, in recent years the crop has spread to other regions of the country that have different climate, soil type and availability of water resources. In many of these regions is needed to enable irrigation systems to complement the crop water requirement. But in others, irrigation is used to increase the yield. The purpose of this study is to compare the environmental profile obtained by analyzing the production cycle of soybean when applied artificial irrigation and when production is obtained from rainfed agriculture.

Material and Methods

The case study is located in the province of Córdoba in central Argentina. Production processes are considered for soybean under till farming system. The analysis accounted for the manufacture and transportation of chemicals and transport of RR soybean seeds, machinery manufacturing and delivery process of diesel used as fuel. It is not considered the impact of the use of GMOs. Life Cycle Impact Assessment phase contemplates the impact categories included in the EDIP method / PICU 97 v2.04, using the software tool SimaPro V. 7.1. To them, it is added the quantification of water use making a water balance considering the availability of the watersheds and the water withdrawal for irrigating.

Results and Conclusion

While adoption of a supplemental irrigation system (IS) reduces considerably the impact of eutrophication and toxicity in soil, seriously increases other impact categories like global warming potential. On the other hand, the use of irrigation makes a significant increase in yield of about 32% compared with the one obtained with rainfed agriculture (Non-IS). Water use per unit area in the IS is 8215 m^3 while it is 5705.9 m^3 in Non-IS.
In general terms, the benefit of applying an IS for soybean in central Argentina is doubtful form the environmental point of view. It should be analyzed deeply to determine if the economic benefit compensates the negative environmental aspects.

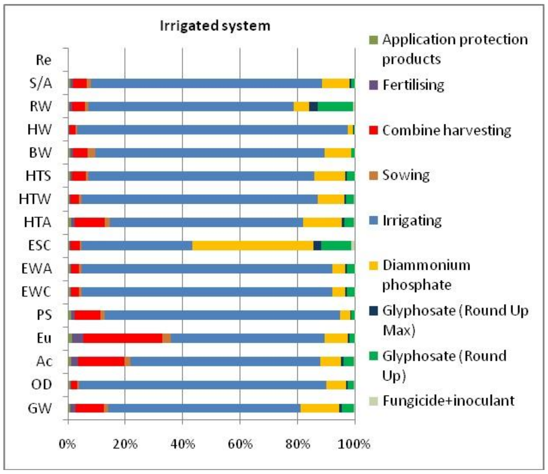

Figure 1: Environmental profile, irrigation system

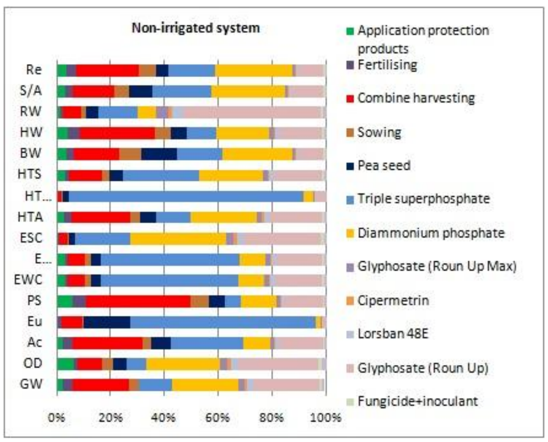

Figure 2: Environmental profile, non-irrigation system

Table I: Water use for irrigated and non-irrigated systems

Water use	IS	Non-IS
Rainfall (mm)	436.1	454.0
Irrigation (mm)	269.7	-----
Efficiency	0.90	-----
Applied irrigation (mm)	299.7	-----
Soil water content (mm)	77.9	109.1
Crop water content (mm)	7.8	7.5
Total water use (m^3/ha)	**8215.0**	**5705.9**
Total water use (m^3/kg soybean)	**2.16**	**2.04**

Life Cycle Assessment on Catalonia coast: Integration of urban water cycle

Maria José Amores[1], Jorgelina Pasqualino[1], Montse Meneses[1], Isabela Butnar[1], Francesc Castells[1] , Josep Flores[2], Raquel Céspedes[2]

[1]Departament d'Enginyeria Química, Universitat Rovira i Virgili, Campus Sescelades, Avda Països Catalans N26, 43007 Tarragona, Spain
[2]Aguas de Barcelona (Agbar), Proyecto Sostaqua, General Batet 1-7, Pl5, 08028 Barcelona, Spain
francesc.castells@urv.cat

Abstract

Given the increasing demand of urban water for both potable and non-potable applications, in many countries urban water authorities are struggling to satisfy the demand meanwhile improving the environmental profile of the urban water system.
The main goal of this study is the environmental analysis of the whole urban water cycle, taking into account all its elements: potable water treatment plants, water distribution system, water use, wastewater treatment plants (WWTP), and sewage systems. Based on the methodology of Life Cycle Assessment (LCA), we assessed the current urban water systems on the Spanish coast of the Mediterranean Sea and proposed possible scenarios for improving their environmental performance in order to find out the best scenario for the urban water management.
Urban Water Cycle here considered includes potabilization, distribution, collection, treatment and optional wastewater reclamation. Inventory analysis was performed based on local operation data complemented with Ecoinvent Database whenever the local data were missing.

Topic: LCA Methodology: LCI and LCIA

Keywords: Life cycle assessment (LCA); urban water cycle; Environmental assessment; Waste Water Treatment, Desalination Plants.

Introduction

Water covers $^2/_3$ parts of the earth's surface, which creates a perception of abundance. However, of the total, 97% is salty, the 2,24% is fresh water frozen in ice, glaciers and deep groundwater, and only 0,26% is fresh water available for human consumption [1]. No doubt it is a very small quantity of fresh water to supply all the natural cycles dependent on it. Thus, water is one of the most important substances on our planet, so much so that without it life would not be possible. It is an indispensable resource for all human activity and a key factor in the ecological balance and in health.

Proper management of the water cycle in the city should adopt environmental criteria, to respect the natural environment and return the water to the environment in an acceptable condition. In addition, the potable water should have an adequate quality and meet the needs of the population.

Water conservation requires action across the whole water cycle. A large number of methods and tools have been developed to describe the environmental implications of urban water systems. In this study, we use Life Cycle Assessment (LCA) to assess impacts of urban water cycle in a Mediterranean city which includes all the different elements of the Urban Water

Cycle: collection, purification, distribution, collection, wastewater treatment, reuse and disposal.
This work has considered the urban water cycle as a whole as illustrated in Figure 1. Integration of Water Cycle from collection to return to the environment will allow a comprehensive analysis of the system, which guarantees to global improvement. For example, improved water quality will imply less intensive and therefore cheaper treatment, and with guarantees for consumers health. Or, improving the operation of a wastewater treatment plant will reduce costs and make easier tertiary treatment for reuse. The use of treated wastewater for non-potable uses (irrigation, cleaning, aquifers ...) represents a net saving of water, always a scarce resource.

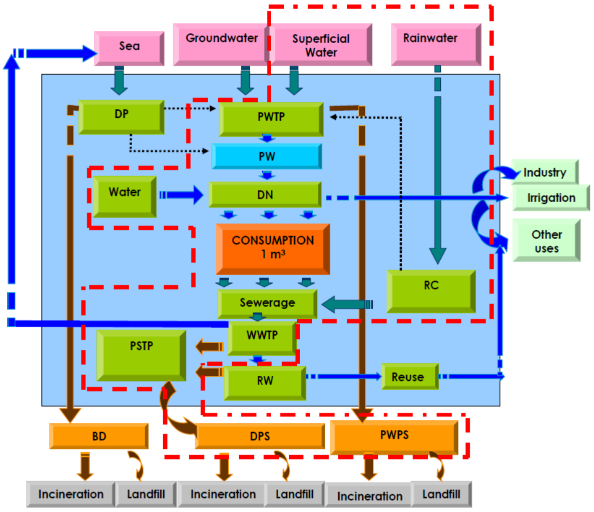

Figure 1. Urban Water Cycle in Mediterranean city. [*Abreviations: Potable Water Treatment Plant (PWTP), Potable Water (PW), Distribution Net (DN), Waste Water Treatment Plant (WWTP), Processing Sludges of Treatment Plant (PSTP), Reclaimed Water (RW), Rainwater Collection (RC), Desalination Plant (DP), Depuration Plant Sludges (DPS), Potable Water Plant Sludges (PWPS), Brine disposal (BD)]*.

Hence, the model presented below meets a comprehensive consideration of the whole urban water cycle. Considering the path of 1m^3 of water from collection to return to the environment, we can determine the environmental effects generated at each stage of its life cycle path and then analyze which stages are those that generate more emissions and consume more energy.

Methodology

Life Cycle Assessment

The environmental assessment method applied in this study is Life Cycle Assessment (LCA) which is an ISO 14040-14044 [2] normalized method for the environmental assessment of industrial systems from "cradle-to-grave" which begins with the extraction of raw materials from the earth, continues with product development and manufacturing, and finally ends when all materials are returned to earth [3].

Impacts are assessed with LCM Manager, one of the most complete LCIA method to date. The studied impacts are:

- Acidification potencial [kg SO_2-Eq]
- Climate change [kg CO_2-Eq]
- Eutrophication potencial [kg PO_4-Eq]
- Photochemical oxidation [kg formed ozone]
- Depletion of abiotic resources [kg antimony-Eq]
- Strathospheric ozone depletion [kg CFC-11-Eq]
- Ecotoxicity [kg 1,4-DCB-Eq]
- Water consumption [m^3]
- Cumulative Energy Demand [MJ]

We followed the methodology indicated by international standards (ISO), conducting LCA with four steps:

- Definition of goal and scope.
- Inventory analysis.
- Impact assessment.
- Interpretation of results.

Definition of Goal and Scope

The goal of this study is to assess the environmental profile of a typical urban water cycle in a Mediterranean city and propose solutions for its improvement.

The challenge of this work has been to obtain a tool for analyzing the environmental profile of the various elements of the urban water cycle. Based on the application of LCA, we obtained a tool which allows the calculation of an integral and modular environmental impact of the various components of the Urban Water Cycle. The tool generates an impact matrix and a table of results and graphics for each of the selected environmental indicators. It also allows identifying the source of the impacts at each stage of a particular process and thus be an instrument to improve it. The advantage of this tool is that it can be used to assess any urban water cycle.

In addition to the current urban water cycle (superficial water intake pumping, potable water treatment, distribution, collection, wastewater treatment and purification), this tool assessed two other cases studies. The first one has set a stage for improvement which includes a tertiary treatment at the wastewater treatment plant with a water reuse. These results follow the other cases studies obtained before [4]. The second has assumed on hypothetical scenario of drought in which, in addition to superficial water intake pumping, it was supplied sea water in a percentage 25% to 50%. For this case study it has considered the Desalination plants data [5].

The considered functional unit was $1m^3$ of potable water supplied to the consumers. So, all data and results are reported here referring to this functional unit. We considered within the system boundaries all of the processes included, from the water collection to the final treatment (see Figure 1). For all the plants we considered only the operation stage because previous studies indicate that the environmental impact of the construction, dismantling, and infrastructure materials is negligible when compared to the operation phase [6].

Inventory Analysis

We performed the LCA inventory and calculated the environmental loads by adapting the data from the Ecoinvent V2.1 database (Swiss Centre for Life-Cycle Inventories 2009) [7] to the Spanish energy mix [8] and the European model for transport and water. When performing the LCA in the case study, we considered all the energy and mass input and output flows. We therefore considered all of the reagents used at the different treatment stages, their packaging, and their transport. The amount of waste generated by the water treatment plants, its treatment or final disposal weren't taken into account. However transport of this final waste to the treatment plants was also taken into account. The consumption of energy and the services and materials required for maintenance were considered at each stage of treatment.

Impact Assessment

Environmental impact was assessed with SiSOSTAQUA, an environmental management tool adapted from the LCAmanager tool developed by SIMPPLE SL, a spin-off of the University Rovira i Virgili. CML2000 method (Centre for Environmental Studies 2001) [9] was used in this study, the most widely applied midpoint life cycle impact assessment (LCIA) method. CML2000 was chosen because it presents the results with the indicators units, giving an idea of impact magnitude, which is especially helpful for the non-specialized audience.

Results and Discussion

The evaluation of the different environmental indicators for the steps considered in the Urban Water Cycle is presented in Table 1 and their relative contributions are ploted in Figure 2.

This case study has been assessed taking into account some considerations in the Urban Water Cycle which includes five stages. The first stage is Intake Pumping of the surface water to Potable Water Treatment Plant (PWTP). The second stage considers water and sludge treatment in PWTP. The third one is the final pumping and distribution of the potable water from the PTWP to the urban zone. Fourth stage considers the Distribution Net (DN) and sewerage. The last one is the water and sludge treatment in Waste Water Treatment Plant (WWTP).

Table 1. Main results of current Urban Water Cycle in Mediterranean city.

Categ.	IP	PWTP	FP	DN	WWTP	Total
AP	1,17E-03	6,72E-04	8,64E-04	1,61E-03	1,58E-03	5,89E-03
GWP	1,48E-01	1,01E-01	1,28E-01	2,62E-01	1,19E-01	7,58E-01
EP	8,96E-05	6,87E-05	6,68E-05	1,35E-04	1,27E-03	1,63E-03
PHO	8,77E-06	1,17E-05	9,14E-06	3,80E-05	2,16E-05	8,93E-05
DAR	1,11E-03	7,20E-04	7,84E-04	1,70E-03	1,74E-03	6,05E-03
ODP	1,29E-08	2,68E-08	8,12E-09	2,38E-08	3,64E-08	1,08E-07
TE	2,54E-01	2,44E-01	2,10E-01	7,14E-01	6,29E-01	2,05E+00
WU	1,88E+00	5,73E-01	3,66E-01	6,87E-01	2,35E+00	5,85E+00
CED	1,88E+00	5,73E-01	3,66E-01	6,87E-01	2,35E+00	5,85E+00

[*Considerations: AP (kg SO2-Eq), GWP (kg CO2-Eq), EP (kg PO4-Eq), PHO (kg O3), DAR (kg Antimony-Eq), ODP (kg CFC-11-Eq), TE (kg 1,4-DCB-Eq), WU (m3) and CED (MJ)]*.

It is observed that the main environmental impacts are generated by Distribution Net and Waste Water Treatment Plant.

The main impact of the Distribution Net, 25-35% in almost categories is due to the energy consumption of pumping. Considering the infrastructure materials, we observed that ductile cast iron pipes contributed the most to the impact in the Distribution.

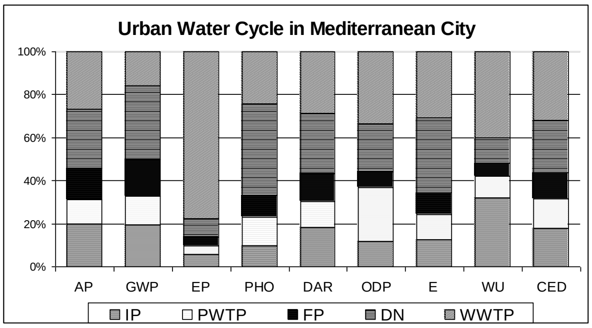

Figure 2. Relative contribution of Urban Water Cycle in Mediterranean city.

The Waste Water Treatment Plant has the highest environmental impact in eutrophication (78%), depletion of abiotic resources (34%) and Cumulative Energy Demand (32%). This is due to the water line because of its high energy consumption [10] which is assigned to the aerobic reactor. The high impacts in eutrophication categories are due to excess nutrients and heavy metals, respectively, caused by the final disposal of sludge (application in soil). The depletion of stratospheric ozone and cumulative energy demand is caused by the reagent used in the mix chamber.

In the other scenarios it can be observed that when water reuse is included, the GWP of the water system remains practically unchanged because the inclusion of an obligatory tertiary treatment is balanced by the credits obtained by the fertilizers saving in agricultural uses. The study also considered a hypothetical situation of drought conditions, when a new desalination plant has to be included in order to cover the water requirements. Results show that this solution would imply an increase of about 30% of the environmental impact of the global water system and therefore, it should be used only to complement the purification process already existing.

Conclusions

The analysis of the overall urban water cycle has allowed us to check scenarios or combinations of elements of the cycle in order to select the best option from economical and environmental point of view.
This study demonstrates the usefulness of LCA for the assessment of the urban water systems enabling the identification of critical processes and the potential improvements of the system. SiSOSTAQUA is a valid tool to calculate the environmental profiles of the proposed combinations and select the most appropriate option. In general, it was observed that energy consumption is the main cause of the measured impacts of the various elements of the cycle. Consequently, any energy saving measure will increase environmental and economic benefits.

However, in times of drought or water shortage will be necessary to supply the population with water from desalination, despite the high energy consumption of these plants.
Given that the purification of surface water and seawater, requires complex and expensive treatments compared to that of groundwater, the most viable option is to supply the population mainly from groundwater from wells and mines.

For future works is considered necessary to promote the optimization of the water supply chain taking into account the needs of the population, current and future availability of resources and economic and environmental costs of the various stages of the Urban Water Cycle. Based on the elements of the cycle and the integrated model of urban water cycle developed in the project, the proposed optimization process would provide a tool to obtain for each situation, the optimal mix of supply sources and water treatment techniques.

References

[1] Gencat, 2009. Generalitat de Catalunya. Departament de Mediambient i Habitatge.
Environmental Sustainability Report of the Catalan Water Reuse Programme (PRAC). Document of Public Information, According to the Official Journal of the Government of Catalonia (DOGC) No. 5428 of 24/07/2009 (in Catalan).
[2] International standardisation organisation. 2009. Environmental Management- Life cycle assessment – Principles and Framework. ISO 14040 and Requirements and guidelines. ISO 14044.
[3] Vince F., Aoustin E., Bréant P., Marechal F., 2008. LCA tool for the environmental evaluation of potable water production. Desalination, Volume 220, Issues 1-3, 1 March 2008, Pages 37-56.
[4] Meneses M., Pasqualino J., Castells F. Environmental assessment of urban wastewater reuse: Treatment alternatives and applications, 2010. Chemosphere 81 266–272.
[5] Meneses M., Pasqualino J., Cespedes M., Castells F. Alternatives for reducing the Environmental Impact of the main residue from a desalination plant. Applications And Implementation, Volume 14, Number 3 Journal of Industrial Ecology.
[6] Muñoz, I., Rodríguez Fernández-Alba, A., 2008. Reducing the environmental impacts of reverse osmosis desalination by using brackish groundwater resources. Water Res. 42, 801–811.
[7] Swiss Centre for Life-Cycle Inventories, 2009. Ecoinvent database, Dübendorf, Switzerland. <http://www.ecoinvent.org>.
[8] Red Eléctrica de España (REE). Production mix electricity 2008 in Spain. www.ree.es
[9] Centre for Environmental Studies, 2001. University of Leiden, CML 2 baseline
method 2000.
[10] Pasqualino J., Meneses M., Abella M., Castells F. LCA as a Decision Support Tool for the Environmental Improvement of the Operation of a Municipal Wastewater Treatment Plant. Environ. Sci. Technol. 2009, 43, 3300–3307.

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Introducing new characterisation factors for depletion of abiotic resources: anthropogenic stock extended abiotic depletion potentials

Markus Berger
Laura Schneider
Matthias Finkbeiner

Technische Universität Berlin
Department of Environmental Technology / Chair of Sustainable Engineering
Office Z1 / Strasse des 17. Juni 135 / 10623 Berlin, Germany
E-mail contact: markus.berger@tu-berlin.de

Abstract
Resource scarcity is a matter of concern for many industrial sectors but is not sufficiently reflected in current life cycle impact assessment methods. Tackling this shortcoming a new characterisation model for the impact category depletion of abiotic resources is introduced aiming at a more realistic assessment of resource use in terms of material availability for human usage. The method is based on the abiotic depletion potential (ADP) developed by Guinée and colleagues but modifies the extraction-reserve-ratio used for expressing raw material scarcity in two steps. First, ultimate reserves reflecting the total material availability in the earth crust are replaced by resources as they represent a deposit which can be mined with today's technolo–gies now or in the near future. Since large material amounts are also available within the technosphere, which have the potential to increase material availability drastically, these "anthropogenic stocks" are added to resources. By putting updated extraction rates in relation to the sum of resources and anthropogenic stocks, new characterisation factors were derived termed as anthropogenic stock extended abiotic depletion potentials (AADP). Using data from the United States Geological Survey a set of characterisation factors was calculated for ten relevant metals. A theoretical case study revealed that metals which are perceived as scarce but did not contribute significantly in the conventional ADP now dominate the AADP category indicator result. Hence, the new characterisation model enables a more realistic assessment of depletion of abiotic resources and can even allow for a basic material availability analysis within life cycle assessment.

Key words: resource use, depletion of abiotic resources, anthropogenic stock, life cycle impact assessment

Introduction
Raw materials are important for most industrial sectors and a potential scarcity is a matter of concern for many stakeholders. In current life cycle impact assessment [1] practice, resource use is evaluated by means of indicators based on (surplus) energy [2, 3], exergy [4], or extraction-reserve-ratios denoting scarcity like the abiotic depletion potential (ADP) [5]. However, all characterisation models presently available share a deficiency as they neglect great amounts of raw materials stored in material cycles within the technosphere which has an influence on actual material availability. This paper aims at developing a methodology for including these anthropogenic stocks into the current abiotic depletion potential [5]. Thus, the "anthropogenic stock extended abiotic depletion potential" (AADP) is introduced as a new characterisation model for the impact category depletion of abiotic resources. After determining a set of characterisation factors for relevant metals the new method is applied and tested in a theoretical case study. The results are evaluated and compared to results obtained by means of the conventional ADP [5] underlining the relevance of this enhancement.

Methodology
In their default characterisation model Guinee and colleagues [5] determine characterisation factors for depletion of abiotic resources as shown in the following equation.

$$ADP_i = \frac{ER_i}{(UR_i)^2} \cdot \frac{(UR_{Sb})^2}{ER_{Sb}} \qquad (1)$$

First, the extraction rate (ER) of raw material i is divided by the square of the ultimate reserves (UR), denoting the total availability of raw material i in the earth's crust. Second, this ratio is put in relation to the extraction-ultimate-reserve-ratio of the referen-ce resource antimony (Sb). In order to enable a more realistic material availability assessment, the model of Guinee and colleagues [5] was modified in two steps. First, ultimate reserves were substituted by resources (R) as they reflect the presently identified share of ultimate reserves whose economic extraction is currently or potentially feasible [6].

$$ADP_i = \frac{ER_i}{(R_i)^2} \cdot \frac{(R_{Sb})^2}{ER_{Sb}} \quad (2)$$

Second, anthropogenic stocks (AS) available in the technosphere are added to lithospheric stocks as the sum of these two deposits reflects the total material amount available for human uses.

$$AADP_i = \frac{ER_i}{(R_i + AS_i)^2} \cdot \frac{(R_{Sb} + AS_{Sb})^2}{ER_{Sb}} \quad (3)$$

When adding anthropogenic material stocks to lithospheric deposits, stocks with similar concentrations and extraction availabilities have to be combined. As shown in Figure 1, lithospheric stocks range from ultimate reserves, which comprise the total amount of a material in the earth crust, to reserves denoting only a small fraction that can be mined with today's technology in an economic way [6]. In a similar way, anthropogenic stocks can be divided into in-use, hibernating, deposited, and dissipated stocks [7] which provide different material concentrations and availabilities, too.

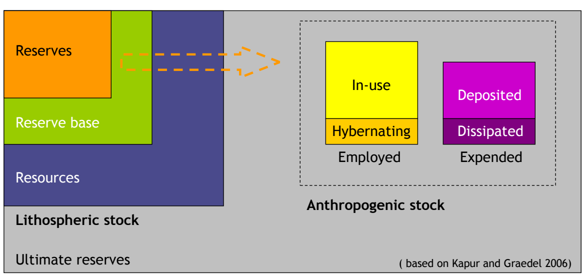

Figure 1 Types of lithospheric and anthropogenic material stocks

Considering similar material extraction possibilities it seems consistent to combine resources and the total anthropogenic stock, as both sources stand for deposits for which extraction is currently or potentially feasible. It should however be noted that the dissipated stock, which comprises the fraction of anthropogenic stocks that is lost due to e.g. leaching or chemical reactions [6], and should actually be subtracted from the total anthropogenic stock in the calculation. However, detailed material flow analyses of copper have shown, that the dissipated stock accounts for less than 1 % [7] and can thus be neglected in this study. However, it has to be acknowledged that materials have different characteristics that will also have an influence on the amount of dissipation. For a more accurate analysis a close assessment of individual materials should be conducted.

Based on the characterisation model shown in Equation 3 characterisation factors for a range of relevant metals are calculated. Since data for anthropogenic stocks is available for a limited number of materials only [8], it was determined as the accumulated extraction rate since the beginning of records in approximately 1900 until 2008. It is assumed that the amount of materials extracted before is negligibly low in comparison to the large quantities that have been mined since 1900. The material extracted until today is present in the technosphere as either in-use, hibernating, deposited, or dissipated anthropogenic stock. All data for extraction rates and resources were derived from the United States Geological Survey (USGS) [6]. After determining a set of characterisation factors for relevant metals, the new model is tested by evaluating a fictional life cycle inventory. The impact assessment for the category depletion of abiotic resources was accomplished by applying the conventional abiotic depletion potential (ADP) [5] and the anthropogenic stock extended abiotic depletion potential (AADP). For simplicity the fictional inventory contains the elementary input flows of 1 kg of each material for which AADP characterisation factors were calculated.

Results & Discussion

Based on the characterisation model described in the previous section, anthropogenic stock extended abiotic depletion potentials (AADP) were calculated for ten metals using USGS data for extraction rates, resources, and anthropogenic stocks (calculated based on cumulated extraction rates). Table 1 shows the AADP characterisation and factors derived from the conventional ADP characterisation model [5].

Table 1 Conventional ADP according to Guinee et al. [5] and AADP characterisation factors

Raw mate -rial	Extraction rate [t/a] [6]	Resour-ces [t] [6]	Anthro-pogenic stock [t]	ADP [kg Sb-e. /kg] [5]	AADP [kg Sb-e. /kg]
Al	3.90E+07	7.50E+10	8.73E+08	1.00E-08	5.34E-06
Cd	2.01E+04	6.00E+06	1.04E+06	3.30E-01	3.19E-01
Co	7.59E+04	1.50E+07	1.94E+06	2.62E-05	2.08E-01
Cu	1.57E+07	2.30E+09	5.11E+08	1.94E-03	1.57E-03
Fe	2.22E+09	8.00E+11	5.71E+10	8.43E-08	2.38E-06
Hg	1.32E+03	6.00E+05	5.46E+05	4.95E-01	7.92E-01
Ni	1.57E+06	1.30E+08	4.78E+07	1.08E-04	3.91E-02
Pb	3.80E+06	1.50E+09	2.17E+08	1.35E-02	1.02E-03
Sb	1.65E+05	5.50E+06	5.90E+06	1.00E+00	1.00E+00
Zn	1.16E+07	1.90E+09	4.18E+08	9.92E-04	1.70E-03

One might assume that AADP factors should be larger than ADP factors as the availability decreases when resources and anthropogenic material stocks are used instead of ultimate reserves to determine the extraction-reserve-ratio. However, this is not necessarily the case as the factor expresses the result in relation to the reference resource antimony, which itself has a rather large anthropogenic stock. Hence, the characterisation factors ADP_i and $AADP_i$ can hardly be compared directly. Only the ratio of e.g. ADP_{Cu} to ADP_{Ni} can be compared to the ratio of $AADP_{Cu}$ and $AADP_{Ni}$. For the AADP, the difference between the ratios is dependent on the anthropogenic stock-resource-relation of the materials. Hence, materials with relatively large anthropogenic stocks will contribute comparatively less to abiotic depletion than materials with relatively low anthropogenic stocks.

This rather theoretical discussion is illustrated by means of the case study in which a fictional life cycle inventory, consisting of 1 kg of each metal for which characterisation factors are available, was evaluated using ADP and AADP. The results on the inventory level and for the impact category depletion of abiotic resources when using either ADP or AADP characterisation factors are shown in Figure 2 below.

As it can be seen only cadmium, mercury, and antimony contribute to the impact assessment results in a noticeable manner while the remaining metals cause minor impacts only. Comparing the results of ADP and AADP, it appears that no big differences are obtained by means of the new characterisation model. In both cases the result is dominated by the impacts resulting from the abiotic depletion of antimony, mercury, and cadmium – even with a similar percental contribution.

Considering the equally distributed inventory containing 1 kg of each metal, Figure 1 also reflects a direct comparison of the characterisation factors shown in Table 1. As characterisation factors for cadmium, mercury, and antimony are largest and similar in ADP and AADP it is logical that they dominate the results and lead to similar findings. Hence, one should not generalize that no differences are obtained when applying AADP.

In a second case study shown in Figure 3, the dominating metals were excluded from the analysis and the results are again displayed for the inventory and impact assessment levels using ADP and AADP characterisation models.

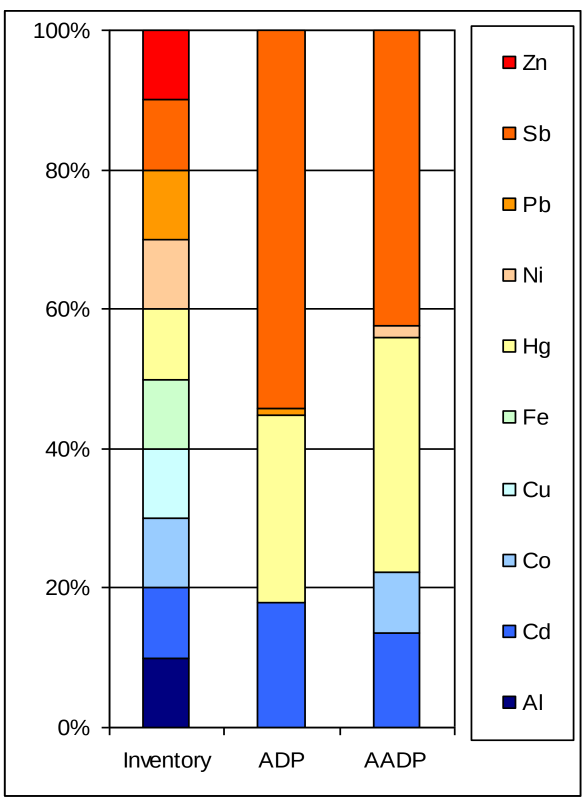

Figure 2 **Contribution of individual metals to the impact category depletion of abiotic resources when using ADP and AADP characterisation models**

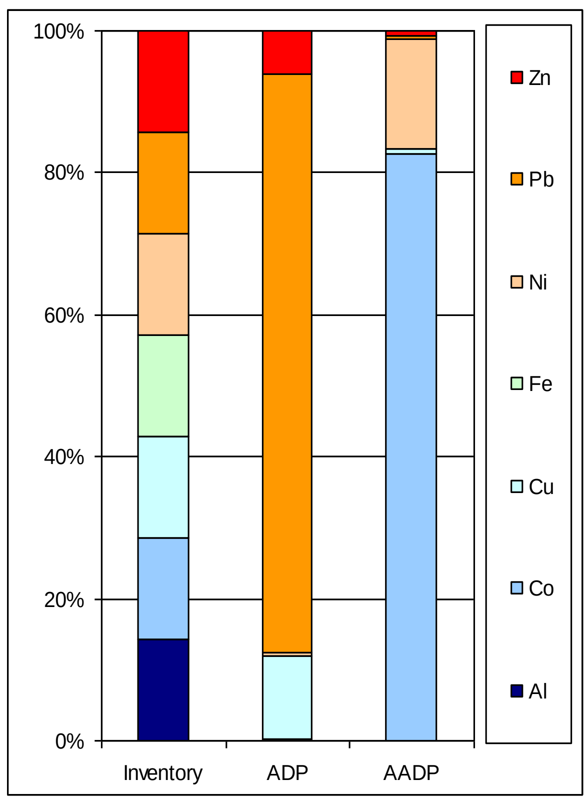

Figure 3 **Contribution of selected individual metals to the impact category depletion of abiotic resources when using ADP and AADP characterisation models**

While the ADP result is dominated by the abiotic depletion of lead, cobalt and nickel contribute most to the AADP category indicator result. Hence, in ADP lead is regarded as the scarcest metal in the inventory when computing characterisation factors based on the ratio of extraction-rate to ultimate reserves. In contrast, when calculating extraction-reserve-ratios by means of the sum of resources and anthropogenic stocks, lead is of less importance and cobalt is regarded as the most critical metal.

By taking into account real lithospheric and anthropogenic material deposits available for human usage, it seems that the new AADP characterisation model can enable a more realistic assessment of depletion of abiotic resources. It may therefore even allow for a basic material availability analysis within LCA studies to identify potentially scarce materials.

However, there are still challenges which currently remain unsolved. The lack of data concerning resources and anthropogenic stocks inhibits the calculation of a larger set of characterisation factors. From a methodological point of view it is still unclear how anthropogenic stocks can be calculated for mineral substances or fossil fuels, for which plastics available in the technosphere might serve as anthropogenic deposit.

Conclusions

In order to allow for a more realistic material availability assessment, a new characterisation model for depletion of abiotic resources was introduced. The new method is based on the conventional abiotic depletion potential (ADP) developed by Guinée and colleagues [5] but uses resources and anthropogenic material stocks rather than ultimate reserves for the calculation of extraction-reserve-ratios. So called anthropogenic stock extended abiotic depletion potentials (AADP) serve as characterisation factors and have been calculated for ten relevant metals. A case study in which a fictional life cycle inventory was assessed using ADP and AADP revealed different results. If the inventory contains cadmium, mercury, and antimony no big differences between the two methods are detected as characterisation factors for these metals are largest and similar in both models. If these dominating materials are excluded large differences in the category indicator results can be seen. Metals like cobalt and nickel, which are perceived as critical, do not influence the ADP result at all. As these metals contribute most to the AADP category indicator result, the new characterisation model seems to enable a more realistic assessment of resources use in LCA. However, a larger set of characterisation factors and further research are needed to make the concept applicable in LCA practice.

References

[1] ISO 14044. 2006. Environmental management - Life cycle assessment - Requirements and guidelines, European Committee for Standardisation, Brussels, Belgium.

[2] Goedkoop M, Spriensma R. 2001. The Eco-indicator 99 - A damage oriented method for Life Cycle Impact Assessment. Amersfoort, The Netherlands.

[3] PE International. 2010. http://www.gabi-software.com. Accessed 20 December 2010.

[4] Bösch ME, Hellweg S, Huijbregts MAJ, Frischknecht R. 2007. Applying Cumulative Exergy Demand (CExD) Indicators to the ecoinvent Database, Int. J. LCA. 12, no. 181-190.

[5] Guinee JB, Gorree M, Heijungs R, Huppes G, Kleijn R, de Koning A, van Oers L, Sleeswijk AW, Suh S, Udo de Haes HA, de Bruijn H, van Duin R, Huijbregts MAJ. 2002. Life cycle assessment - An operational guide to the ISO standards. Dordrecht, The Netherlands,

[6] USGS. 2010. Mineral Commodity Summaries 2010. Washington, D.C., USA.

[7] Kapur A, Graedel TE. 2006. Copper mines above and below the ground, Environmental Science & Technology. 3135-3141.

[8] UNEP - International Panel for Sustainable Resource Management. 2010. Metal Stocks in Society. Paris, France.

Proposal for the information structure for the Brazilian Industry LCI data network management

ABSTRACT

This proposal aims establishing a framework for LCI data management of the Brazilian industry, using a national network. This database will provide, for different economic sectors, a development environment with international recognition of Life Cycle Inventories of the Brazilian industry, based on a globally integrated information structure. This is defined as Inventory Management Life cycle preparation, provision and maintenance of data LCI with quality, consistency, coherency and reliability as governed by the International Lifecycle Platform - ILCD.

Topic-Life Cycle Management - Life Cycle Analysis: Inventories and Impact Assessment
Key words : LCI management, database network, Brazilian economy, information network

Introduction and justification

LCA is an environmental management tool that allows organizations to understand the environmental impacts of materials, processes and products, and information obtained lead to the development of new products and the detection of improvements to be implemented, and formulate specific marketing strategies (Chehebar, 1997).

The interest of economic organizations by LCA has grown sharply, after the publication in 2006 of ISO 14025 which sets the requirements for obtaining the type III environmental label, and among them is the requirement to undertake a study LCA.

It appears that LCA methodology is made possible only from the internationally available databases containing Cycle Inventory (LCI), supporting the implementation of an LCA study. Within the inventories are identified and characterized the main components of the flows of matter and energy involved in the generation of a particular product and the technologies associated with them.

In this context, the Brazilian Institute of Information Science and Technology (Ibict), supported by the Ministry of Science and Technology and the Financier of Studies and Research (FINEP), has been developing since 2007, the project " Life Cycle Inventory for Environmental Competitiveness of Brazilian Industry" the goal of providing a system of national databases containing Life cycle Inventories of inputs needed for the LCA of products relevant to the Brazilian export.

Since the database storage of inventory is being tested and the methodology for preparing inventories of Brazilians in final review for publication, the main tool needed to structure the System Life Cycle Inventory of Brazilian Industry (SICV Brazil), are in their final stage of development, the next step is the implementation of the database system and the development of inventories.

Also, as studies of various institutions mobilize inventories and generate large volumes of data, it means that the network management will facilitate the entire development process from collection of inventory data to supply, maintenance and sustainability of SICV Brazil.

Furthermore it is intended with the creation and the implementation of this network to improve the infrastructure of communication between partners, to create centers of industry inventories, to promote the integration of projects, to contribute to the improvement of professional qualification in the subject through distance education and to support the development of collaborative research and innovation.

Method

The structure of the Network is composed of two levels (Figure 1):

The first is directly associated with the management of the bases in the production of inventories. At this level, the information generated at the process level as a result of inventory is organized by industrial sectors and coordinated by the nucleus sector commission namely encompassing a National Association of that sector, academics or researchers (familiar with the industry) and a government representative. The information available at this level will be the responsibility of these nucleus data quality and security.

It is interesting that these nuclei have an initial government support during the elaboration of the main inventory, ie, during the development of the Brazilian industry database background. These nuclei will therefore be in charge to maintain and keep the quality of LCI data generated for that sector.

The second level is associated with the validation and availability of data to become public inventories, and will be a central decision-making point. The validation of these inventories will take into account the guidelines defined by ILCD documents, namely completeness, quality and consistency. This center will consist of representatives from the database, specialists in LCA and government representatives.

In order to standardize the sectors LCI information, generated as partial inventories to be combined to built up the Brazilian databasel, we suggest the following infrastructure provision for each nuclei:

- Capacity building on the Brazilian LCI methodology;
- provision of LCA ontology; and,
- access to main LCA database to common information organization.

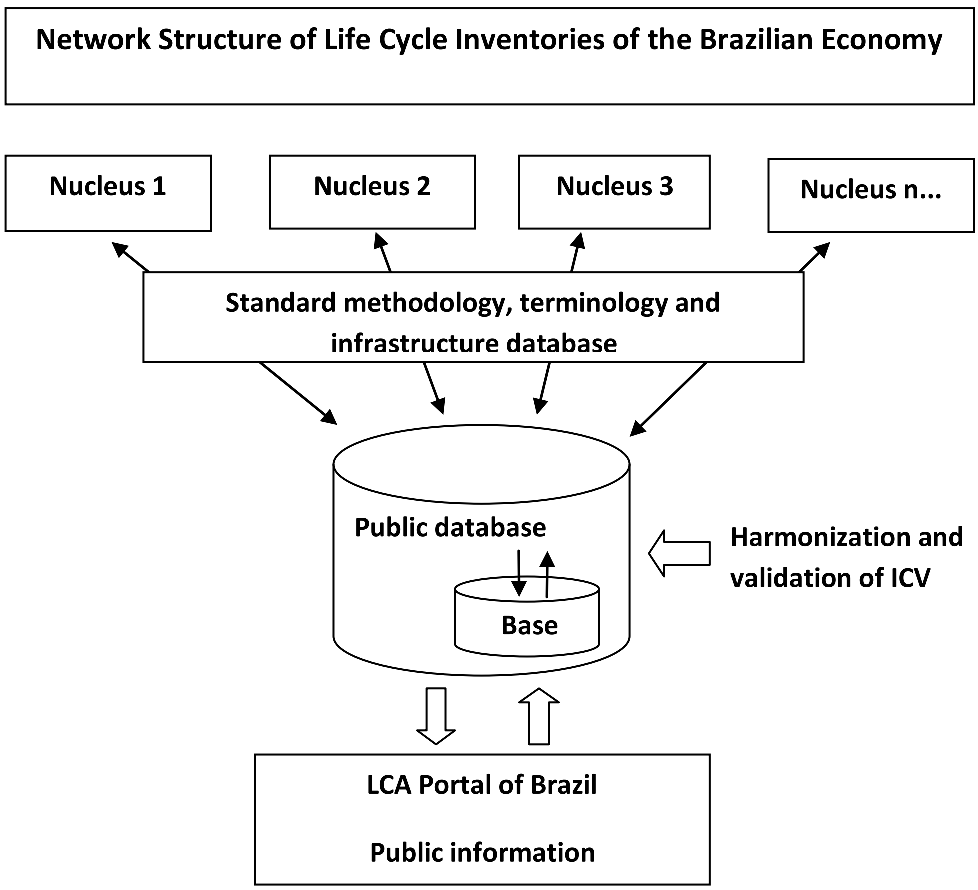

Figure 1 - Network Structure of Life Cycle Inventories of the Brazilian Economy

Discussion and results

One goal on establishing this LCI network is to undertake surveillance and policies monitoring on the issue and initiatives of the various entities involved, and its repercussions throughout the Brazilian territory, seeking the adequacy and direction under international standards.

The Brazilian Network LCI aims to promote coordination between regional and local initiatives, and is emerging around the need to share knowledge and information and coordinate on a national level, people and institutions working in the area of ICV, to expedite and strengthen the power of the national database.

The idea of the network is to be very operative, performing and integrating actions and concrete work on the subject, providing the prospect of performing enterprises based on solid and consolidated management information, having as main objectives the dissemination of the culture of life cycle thinking in networking standard and support the development of studies of the Life Cycle Assessment within organizations and industries in Brazil.

REFERENCES

1 - CHEHEBE, J. R. B. Life Cycle Analysis of Products: ISO14000 (In Portuguese). Rio de Janeiro: Qualitymark.

2 - COLTRO, Leda, Life Cycle Assessment as Management Tool. 2007. Campinas:CETEA.

3 - ILCD, 2008 Recommended LCA Practice-Series of TECHNICAL Gdance Handbooks based on ISO 14040 and 14044 – Main Gdance Document for all applications and corp. situations (draft), JRCIE, Italy.

4 - PARAMESWARAN, M. et al.: *P2P Networking: Na Information-Sharing Alternative, Computer*, vol. 34, pp 31-38, julho de 2001.

5 - TANENBAUM, A.S. 2003. Computers Networks (In Portuguese), Elsevier, Rio de Janeiro.

Process on "Global Guidance for LCA Databases"

Sonnemann, Guido[1] & Vigon, Bruce[2] & Broadbent, Clare[3] & Curran, Mary Ann[4] & Finkbeiner, Matthias[5] & Frischknecht, Rolf[6] & Inaba, Atsushi[7] & Schanssema, Aafko[8] & Stevenson, Martha[9] & Ugaya, Cássia Maria Lie[10] & Wang, Hongtao[11] & Wolf, Marc-Andree[12] & Valdivia, Sonia[1]

[1]SCP Branch, UNEP DTIE Paris,
15 rue de Milan,
75441 Paris Cedex 09, France
e-mail: guido.sonnemann@unep.org

[2]SETAC North America,
1010 North 12th Avenue,
Pensacola, FL 32501-3367, USA

[3]World Steel Association,
Rue Colonel Bourg 120,
1140 Brussels, Belgium

[4]US Environmental Protection Agency,
Office of Research and Development,
26 West-Martin-Luther-King-Drive,
Cincinnati, OH 45268, USA

[5]Department of Environmental Technology,
Technical University Berlin,
Straße des 17. Juni 135,
10623 Berlin, Germany

[6]ESU-Services Ltd,
Kanzleistrasse 4,
8610 Uster, Switzerland

[7]Research Center for Life Cycle Assessment,
Nat. Inst. of Adv. Indust. Science a. Technol. (AIST),
16-1 Onogawa,
Tsukuba, Ibaraki 305-8569, Japan

[8]Plastics Europe
Rue Colonel Bourg 122,
1140 Evere, Belgique,
Brussels, Belgium

[9]752 Ridge St, #2
Charlottesville, VA 229902 USA

[10]Federal Center of Technologic Education,
Parana, Brazil
[11]College of Architecture and Environment,
Sichuan University,
R306, No.99, Kehuabei Road,
Chengdu, 610065, China

[12]European Platform on Life Cycle Assessment,
European Commission, JRC, IES, Sustainability Assessment Unit,
TP 270, Via E. Fermi 2749,
21027 Ispra, Varese, Italy

Abstract

UNEP and the Society of Environmental Toxicology and Chemistry (SETAC) are collaborating within the Life Cycle Initiative to address the need for global guidance on life cycle inventory (LCI) data collection and processing into databases for widespread use. The process was launched at the first Stakeholder Engagement Meeting, "Towards Global Guidance for LCA Databases", in Boston on the 30th of September in 2009, where the high attendance confirmed the international interest in the UNEP/SETAC proposal and a majority of the participants agreed with the vision.

The vision is to help provide global guidance on the establishment and maintenance of life cycle assessment (LCA) databases, as an input for improved interlinkages of databases worldwide. The vision is expected to contribute to increasing the credibility of existing LCA data, to further foster the generation of more data (also for applications such as carbon and water footprint) and to enhance their overall accessibility.

It is therefore expected to help provide a sound scientific basis for product stewardship in business and industry and life cycle based policies in governments, and ultimately, aid in the advancement of the sustainability of products. This work will complement that of other initiatives.

The importance of the project is highlighted by the fact that a global network of data is required for managing supply and production chains in a global economy. To develop credible LCAs across such a scale, it is essential that databases have uniform data requirements to allow consistent modeling and reliable decision support. Additional disclosure of the information on a single operation or gate to gate level is seen as beneficial.

The seven stakeholder meetings following the launch in 2009 have informed stakeholders about this plan for the global guidance development. The central upcoming activity is the 5-day Pellston-type Workshop in 2011, which is being organized by the Secretariat of the Life Cycle Initiative on behalf of UNEP and SETAC. A Steering Committee (SC) of the process has been established and is co-authoring this paper.

Keywords: Global guidance, Life cycle database, Life cycle inventory, Pellston workshop

Background

There is a need for global guidance to guarantee an efficient allocation of resources and to help ensure reliable quality data. To address this need, a decision was made in 2007 to produce a manual on developing national LCA data for energy systems, especially targeting the needs of developing and emerging economies. However, the manual has not yet been finalized due to the significant amount of diverging comments. Moreover, it was understood that the demand of such a manual existed in many other countries. Discussions have indicated that there are a number of contentious methodological issues concerning the way in which an LCA database can be developed. It was therefore decided to organize a workshop, which will address methodological and, as far as possible in this type of event, also organizational issues related to LCA database guidance. The methodological issues include aligning data development with the goal statement, modeling, quality, and data documentation and review, while the organizational issues could go as far as to formulate suggestions on how to set up and govern LCA databases.

Most LCAs are developed using a combination of data sources. LCI data covering the product or service may be generic or specific and averaged data sets. They can come from consultants and researchers or—as key primary data sources—from specific suppliers, supply chains, or trade organizations. Data sets may be for free, purchased from stand-alone vendors, or supplied as a package with LCA computational software. Data may have transparent inventories, i.e., showing the single operation or gate to gate material and energy flows, or they may be aggregated cradle-to-gate or cradle-to-grave data sets. Data from specific suppliers or supply chains are in some cases considered business sensitive and subject to confidential disclosure agreements. Review of the underlying data and LCI models may help to assure users about the quality and unbiased nature of both unit process and aggregated data.

The requirements for performing and disclosing information and results from an LCA study have been codified in a series of international voluntary standards through the International Organization for Standardization (ISO). The current ISO standards for LCA (14040 and 14044) do not provide explicit guidance on creating, maintaining and/or updating LCI databases. As a result, a range of guidelines have been developed over the past two decades on which data should be collected and how data should be modeled and reported to achieve the compatibility and consistency needed by LCA modelers. Having commonly applied guidelines for appropriate data collection, data processing and combining, transparent data reporting, and periodic updating would benefit both data collectors and users. The workshop aims to contribute to this process.

Workshop scope and aims

A 5-day Pellston-style workshop will take place 30th January to 4th February 2011 in Shonan Village Center in Japan. The setting was chosen based on the need for a neutral venue, oriented toward an atmosphere of focused work.

SETAC Pellston workshops convene about 40–50 invited experts, who, through a combination of working groups and plenary sessions, address and write about specific goals in a highly structured, intensive week. The "Pellston" approach has been used successfully for over 30 years and more than 50 publications demonstrate how these workshops have advanced the state of environmental science (http://www.setac.org/node/104). Previous Pellston workshops have produced practical recommendations to LCA practitioners and policymakers. Despite previous efforts steered by UNEP to develop guidance on this critical area of LCA practice, there remain a number of challenges, which this workshop will aim to address, striving towards consensus.

The workshop participants include selected experts from ongoing regional and national as well as industry database initiatives in OECD countries, emerging economies and developing countries. Moreover, a few key consultants developing databases as well as experienced SETAC and regional life cycle network experts are also attending together with UNEP staff and relevant users of LCA databases. The participation is strictly by invitation only. All existing database formats are mutually accepted by all participants in the 2011 workshop since the focus of the workshop is not on format but on data development.

The workshop starts with an annotated table of contents as an initial document on "Global Guidance for LCA Databases". A comprehensive list of existing LCA guidance documents is used as a reference. The Steering Committee is developing discussion-initiation papers prior to the meeting in order to facilitate the discussions during the workshop. The objectives of the workshop are to provide recommendations:

- For internationally acceptable guidance on the establishment of LCI data. The recommendations could also serve as the basis for future compatibility of databases worldwide and the development of national/regional databases in developing countries and emerging economies.
- To facilitate additional data generation, including applications such as carbon and water footprints, and to enhance overall data accessibility.
- To increase the credibility of existing LCI data, as well as the collection of new data. Improving databases of background data (energy, materials, transport, and waste treatment) and industrial processes, both unit and aggregated data sets, are areas of high interest.
- To support a sound scientific basis for product stewardship in industry and life cycle based policies in governments. Ultimately, to help the advancement of more sustainable products and processes.

The output from the workshop will be a report that captures the current thinking and discussions by the attendees at the meeting on the issues that were identified in the initiation papers. Outcomes of the workshop, among others, are expected to include:

- Best practice guidelines to assist LCI users in better understanding the issues of setting system boundaries, allocation rules, etc., and the influence on LCI data.

Follow-up activities (i.e., a second workshop or other activities considered as appropriate to address issues that were not covered, or not sufficiently covered) may be organized by the UNEP/SETAC Life Cycle Initiative.

Disclaimer Involvement in the process towards a "Global Guidance for LCA Databases" does not imply an agreement or endorsement of the outcomes of the workshop or subsequent scientific reports.

Environmental assessment of feed consumption for milk production in semi intensive system in Southern Brazil

Léis, Cristiane Maria de[1]; Prudêncio da Silva, Vamilson[1,2]; Olszensvski, Francieli Tatiana[1]; Zanghelini, Guilherme Marcelo[1]; Decker, Morgana[1]; Soares, Sebastião Roberto[1].

[1]Universidade Federal de Santa Catarina, Dep. de Eng. Ambiental, CEP: 88040-970, Florianópolis, Brasil
[2] INRA, UMR 1069 Sol Agro et hydrosystème Spatialisation, F-35000 Rennes, France
E-mail: cristiane_leis@ens.ufsc.br

ABSTRACT
The models of agricultural production more widespread in the world in the last four decades have given priority to technical and economic efficiency, where the physical productivity increased dramatically, with the objective of supplying the market demand and maximizing profits, but without proper concern for its sustainability in the long run. We performed an LCA of the semi intensive system farms, using the SimaPro® software and data from Ecoinvent® database. The functional unit adopted was 1 liter of cooled milk at the farm gate, without energy correction. Although the data in this study are still preliminary, we find that in the semi intensive system the categories of greatest environmental impact are global warming and energy demand. Changes in breeding system are needed to reduce environmental impacts and to increase the productivity per animal.

Keywords: Environmental impact, dairy system, Life Cycle Assessment.

Introduction
The cattle may be an environmental risk factor when the necessary actions to prevent pollution are not taken into account [1]. The production of cattle is characterized by its extensive practices or by integrated it into the farm practices, supplemented with crop or forestry productions which are not objects of great environmental concern. Conversely, production systems with high concentration of animals have a high risk of pollution and consequent environmental degradation [1]. The characterization of dairy cattle production systems is important for the identification of hotspots in the productive system and for the implementation of regional development projects. In Brazil there is a great diversity of milk production systems. The genetic variability and consequently the feeding management are important variables of the current production models characterization [2]. The authors point out that in Brazil the dairy farming has two distinct characteristics: a national coverage and a large variability of production systems practices. This heterogeneity of the system characteristics contributes to the environmental, social and economic impacts. Dairy production is a practice carried out throughout Brazil. In Brazil, about 85% of the whole cattle could be considered household production and generate about 16 million jobs in rural areas [3]. The climatic conditions of the country allow the adaptation of the regional peculiarities. Thus, there are many models of milk production. There are systems with different degrees of specialization, since properties of subsistence, using rudimentary techniques and daily production of less than ten liters over the entire farm and producers with daily production of 50,000 liters [4]. Due to the diversity of dairy farming in space and the existing production systems, have lack of informations, this would facilitate the planning of its activities, identification of research problems and more appropriate strategies to transfer technology for each productive sector and region [5]. The LCA is a methodology that provides qualitative and quantitative factors of environmental impacts caused by products. However, not only during production processes, but also throughout the other stages of product life, as in obtaining raw materials and basic production of energy needed to supply the product system [6]. Environmental assessment of dairy farming with this approach has been the focus of studies in some European countries like Sweden [7], Germany [8], Norway [9], Spain [10] and Portugal [11]. The aim of this study was assess the influence of environmental impact of the stage in a milk production system in southern Brazil.

Methodology
Region of study
We used data from a dairy farm located in Mandaguari, North-Central region of Paraná State (23° 32'52"S and 51° 40' 15"W). The climate is subtropical and the region's average temperature is 20 º C. The property has a total

area of 48.4 ha, of which 17 ha are occupied by dairy cattle. The feed system is based on commercial feed and silage. The system is semi intensive, and the animals only come out of the stable for milking.

Goal and scope

The objective of the study was to assess the environmental impacts associated with the production of milk in the winter season in a dairy farm with handling system semi intensive to the year 2009. The supply chain under study is described as for fresh milk production. The functional unit (FU) was set to produce 1 liter of cooled milk in the farm gate. For this study, the system limits considered were: production and use of agricultural machinery, production and combustion of diesel, transport of agricultural harvest at an average distance of 250 km, production and use of chemical inputs, pesticides and organic fertilizers, electricity and materials for cleaning and disinfection consumption, production of pasture, fodder and grain in the farm (and part of the food from outside the farm) with its emissions to air and emissions from enteric fermentation. It was not considered the buildings due to unavailability of data.

Inventory analysis

Data were collected directly at the property with the help of the farmer. We used the program SimaPro® and the database used was Ecoinvent®. Although this database is specific to Europe, it was considered that most of the production processes are similar. However, for food production, grain drying, burning diesel and electricity, the processes have been adapted to the Brazilian situation.

Environmental Impact Assessment

In this study the impact assessment covered all the steps recommended in ISO 14040, except the normalization and weighting. The impact assessment method was the CML 2001 (baseline) and added the land occupation category and Total Cumulative Energy Demand (CED). For this paper we present results for the following impact categories: acidification, eutrophication, global warming, land occupation and total cumulative energy demand. This modified method was chosen since it contains the impact categories usually related to the impacts of the agricultural products' supply chain.

Results and discussion

In this study we present partial results, since the research project is still running. The data collected by now were used in the LCA and we show the general results in Table 01 for each impact category analyzed.

Table 1: Environmental impacts of dairy farm in the Paraná State, Brazil, per liter of fresh milk.

Impact category	Unit	Total
Acidification	Kg SO_2 eq	0.0013
Eutrophication	Kg PO_4 eq	0.0020
Global warming (GWP100)	Kg CO_2 eq	1.1474
Land occupation	m^2a	0.1273
Total cumulative energy demand	MJ eq	3.0673

Results shows that about 22% of CED (Fig 1) come from electricity used in farm, use of milking, milk cooling and cleaning, etc. However, the greatest demand occurs in the process of silage (48.4%) and dairy concentrate production (30%), because processing of fertilizers used in the production chain requires a high consumption of fossil energy.

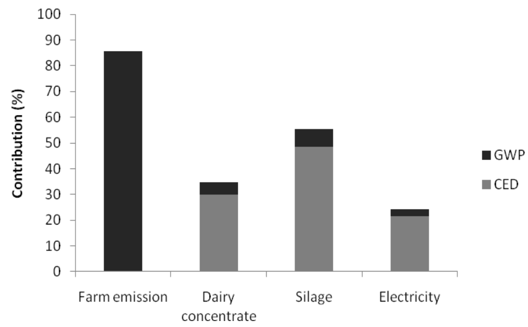

Figure 1: Contribution (%) of some life cycle stages in CED and GWP for 1 liter of cooled milk at the farm gate.

For the category of Global warming is observed that 66% of emissions come from activities of bovine enteric, 18 % comes from N_2O emissions and 15% from CO_2 corresponding emissions of the manufacturing processes of feed and silage (Table 2).

Table 2: Greenhouse gases (%) contribution of dairy farm per liter of cooled milk.

Substance	%
CH_4	66
N_2O	18
CO_2	15
Other	1

Figure 1 shows that the largest emission of gases that contribute to the greenhouse effect occurs on the farm, from enteric emissions, mainly. After that we can mention the dairy silage and concentrate. In the intensive system of cattle feedlot, high feed intake and enteric fermentation lead to hight emissions per liter of milk produced. However, in Brazil, the lack of adequate management makes the productivity per animal not so efficient as in other countries, even when the creation system is intensive The two main sources of CO_2 eq. are emissions from the animals and the use of fossil fuels in transport and processing steps of inputs. However, to estimate emissions of GHGs, we use the formulas proposed by the IPCC [12], but the investigation is still ongoing. Evaluating two regions of Santa Catarina State, we find that the use of fossil fuels in food production represented the higher contribution of non-renewable energy demand in this impact category. The difference for now-renewable energy demand is connected to the lower system productivity and consequently the larger use of food per kg of milk [13]. However, in another study in Sweden, was founded the range of 2.1 to 2.7 MJ per kg of milk of energy demand in dairy systems with higher level of technology [14], while we found 3 MJ eq. per liter. In the evaluation system in Santa Catarina State semi extensive values were superior to global warming [13] to found in this study (1.14 kg of CO_2 eq per liter), getting very close to that found in studies conducted in Sweden in systems with higher technology [14, 15]. These comparisons must be taken into account with caution, because of differences in functional units.

Conclusion

In the semi intensive production system, the largest contribution of GWP comes from enteric emissions. For CED, the mainly contribution comes from feed production stages. To improve the use of energy in the system of milk production, one should optimize the use of concentrated feed, looking for dosing according to the curve of milk production. The higher input of feed and fertilizers leads to large emissions of CO_2 eq., due to the use of fossil fuels. In this study, probably the most important factor that affects the impacts, is the amount of concentrated feed consumed per liter of milk produced, together with the enteric fermentation. Therefore improvements in these factors may represent a better environmental performance for system semi intensive studied. However, the data used in this study are still preliminary, the results should be carefully analyzed, and should not be considered as a final conclusion of this research.

References

[1] GTAA – Grupo de Trabalho Agro-Ambiental. 2001: Plano de Acção 2000-2002. Ministério das Cidades, do Ordenamento do Território e do Ambiente; Ministério da Agricultura, Desenvolvimento Rural e Pescas. Relatório Final. p. 87.

[2] Assis A.G. de, Stock L.A., Campos O.F. de, Gomes A.T., Zoccal R., Silva M.R. 2005. Sistemas de produção de Leite no Brasil. Circular Técnica 85. Embrapa Gado de Leite, Juiz de Fora, p. 6.

[3] Instituto Brasileiro de Geografia e Estatística. 2008. Censo Agropecuário. Disponível em < http://www.sidra.ibge.gov.br/bda/pecua/default.asp?t=3&z=t&o=23&u1=1&u2=1&u3=1&u4=1&u5=1&u6=1&u7=1> Acesso em 20 de Dez de 2010.

[4] Zoccal, R.; Gomes, A. T. Zoneamento da produção de leite. 2005. In: Zoccal, R. et al. A inserção do Brasil no mercado internacional de lácteos. 1. ed. Juiz de Fora: Embrapa Gado de Leite, Cap. 13, p. 163 – 180.

[5] Fernandes, E. N.; Bressan, M.; Verneque, R. da S. 2004. Zoneamento da pecuária leiteira da região sul do Brasil. Ciência Rural, Santa Maria, v.34, n.2, p.485-491.

[6]Carlsson-Kanyama, 1998. A. Climate change and dietary choices – how can emissions of greenhouse gases from food consumption be reduced? J. of Food Policy, 23(3–4), 277–293.

[7] Cederberg, C.; Mattsson, B. 2000. Life cycle assessment of milk production: acomparison of conventional and organic farming. J. of Cleaner Production, Oxford, v. 8, n. 1, p. 49-60.

[8] Haas, G.; Wetterich, F.; Köpke, U. 2001. Comparing organic, intensive and extensive grassland farming in southern Germany by process life cycle assessment. Agri., Ecosystems & Environment, Oxford, v. 83, n. 1/2, p. 43-53.

[9] Hogaas, M. 2002. Life Cycle Assessment (LCA) of Industrial Milk Production. The International J. of Life Cycle Assessment, 7: 115-126.

[10] Hospido, A.; Moreira, M.T., Feijoo, G. 2003. Simplified life cycle assessment of galician milk production. Int. Dairy Journal, 13: 783–796.

[11] Castanheira, E. G. 2008. Avaliação do Ciclo de Vida dos produtos lácteos fabricados em Portugal Continental. Aveiro. 169f. Dissertação (Mestrado) - Universidade de Aveiro.

Departamento de Ambiente e Ordenamento.

[12] IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

[13] Léis, C. M. de; Silva JR., V. P.; Meireles, S. ; Olszensvski, F. T. ; Soares, S. R. 2010. Environment assessment of two dairy systems in Brazil South. In: VII International Conference on Life Cycle Assessment in the Agri-food Sector, Bari/Itália. Anais VII International Conference on Life Cycle Assessment in the Agri-food Sector.

[14] Cederberg, C.; Flysjö, A. 2004. Life cycle inventory of 23 dairy farms in South-Western Sweden. ISBN: 91-7290-237-x. SIK, Report the Swedish Institute of Food and Biotechnology.

[15] Cederberg, C.; Sonesson, M. H.; Sund, V. and Davis, J. 2009. Greenhouse gas emissions from Swedish production of meat, milk and eggs 1990 and 2005. ISBN: 978-91-7290-284-8. SIK, Report the Swedish Institute of Food and Biotechnology.

Life Cycle Inventory Modeling: The appropriate LCI approach for decision support

Palma-Rojas, Silvia[1,2]
Caldeira-Pires, Armando[3]
Nogueira, Jorge[1]
[1] University of Brasilia, FACE, Department of economics, Brasilia, Brazil
[2]Brazilian Institute of Information in Science and Technology (IBICT), Brasilia, Brazil
[3] University of Brasilia, Faculty of Technology, Department of Mechanical Engineering, Brasilia, Brazil
E-mail: spalmarojas@unb.br

The life cycle inventory modeling (LCIM) principle and method approach is an important decision that must be made in the first stage of an LCA study. Thus, according with EC (2010), the life cycle inventory phase is to be done in line with the goal definition and meet the requirements derived in the scope phase.
Currently, the LCIM is referred to two main categories: attributional LCA (ALCA) and consequential LCA (CLCA). Where, ALCA aims at describing a product system and the potential environmental impacts that can be attributed to its life cycle. And, CLCA aims at describing the expected consequences of a change in demand, and it basically uses a market oriented approach to identify the affected process ou marginal process that will be assessed.
Some authors point out that the methodologies used for these two modeling approaches are different specifically regarding system delimitation definition and inventory data compilation. Others state that one of the major differences between ALCA and CLCA focuses on the choice between average and marginal data in the modeling of systems. Thus, the interest of the LCA community in having rules defining the most appropriate LCIM approach according to each application case emerges from the difficulty for LCA practitioners to distinguish them for their applications.
From this perspective, this paper aims to present a proposal guinding scheme that help to identify the apropriated LCIM approach according to each application, as well as to identify the marginal processes in consequential applications. This proposal scheme is the conjunction of the main proposal schemes found in the LCA literature. Thus, this paper tries also to draw attetion to LCIM issues in Latin American researches and start a discussion of its applications in the region.

Topic: LCA methodology: LCA and LCIA
Keywords: LCI modeling, Consequential LCA, Attributional LCA, General Equilibrium Analysis

Introduction

The system boundaries decision is an important step for starting any LCI work, however for this decision to be taken, it is necessary to define the LCI modeling approach to be used. Lundie, et al (2007) proposed a recommended application scheme for guiding to LCA practitioners toward ALCA or CLCA. The proposed application scheme is based on three guiding questions that try to help to LCA practitioners to decide on which modeling category would reflect the reality better conforming to the current application case. Those subsequent three questions are: Is product related to decision support goal & scope of the study?; Will a change that is induced by the decision change the overall status quo considerably? e; Can the induced change be modeled in a rather correct manner that does not outweigh the gained insight?. In case that "Yes" is the answers of the questions, a CLCA must be carried out. If any answer is negative, an ALCA study must be carried out.
EC (2010) proposes three different decision-context situations. The first decision-context situation – *i.e.* situation A – considers a micro-level decision support – *e.g.* environmental reporting and product labeling and declaration; the second situation – *i.e.* situation B – considers a meso/macro-level decision support – *e.g.* policy support; and the last situation – *i.e.* situation C – considers both micro and macro level and it is a descriptive accounting or documentation of the analyzed system of the past, present or forecast future and without accounting any potential influence or consequences on other systems. For situation A and C, an attributional LCA is considered appropriate (EC, 2010; Frischknecht. R,

Stucki. M, 2010). However, for cases of processes that are affected by large-scale consequences in situation B, and in assumption scenarios of situation B the most appropriate model is consequential LCA (EC, 2010).
Another LCI modeling definition framework is presented by Frischknecht, R and Stucki, M (2010). Their proposal defines the LCI modeling principle by the economic size of the object of investigation. They point out that the economic size of the object of investigation is an important aspect to take into consideration inside the selection of the appropriate LCI modeling, where the economic size of a company or product would be assessed by monetary indicators; the indicators proposed by the authors are: annual consolidate turnover; monetary purchase volume from relevant economic sectors and; physical purchases volume from relevant economic sectors.
Subsequetly, after identifying the LCI modeling principle, the following step is the definition of the system delimitation. It is important to highlight that the way how the system boundaries are defined differs considerably between ALCA and CLCA because each modeling approach is interested in different processes and data. For example, in an ALCA all processes that contribute relevantly to the overall environmental impacts of the life cycle must be considered. Differently, the processes included into a CLCA are those that are expected to be most affected by the decision. It is important to denote that for a consequential approach not matter whether the affected processes are located within or outside the life cycle of the object of investigation. For example, all processes that are most sensitive to a change in demand or that are able to increase their production due to capacity constraints must be considered (Frischknecht R and Stucki M, 2010; EC, 2010).
When is carried out a CLCA, the LCA practitioner ou researcher faces the necessity of identifying the affected processes by a change in demand, also known as marginal processes, instead the processes of the product's life cycle. There are different methods or procedures for identifying those processes, among the most used are the five step procedure proposed by Weidema (2003) (Weidema, B. *et al* (1999), Weidema, Bo P (2003), Ekvall, T and Weidema, Bo P (2004)), and the methods used in economics for analyzing policy changes or decision support. Those economics methods are Partial Equilibrium analysis and General Equilibrium analysis. The difference between partial and general equilibrium model is that the former analyzes the impact of changes for one market at the time, in contrast to the latter that analyzes the complete economic system.
Weidema, B. P (1999), Weidema, Bo P (2003), Ekvall, T and Weidema, Bo P (2004) present an assisting procedure for identifying marginal technologies or processes – *i.e.* the processes or suppliers affected by a change in demand. They proposed a five-step procedure that aims to answers two different questions, one is related to know the situation in which the studied change occurs – *i.e.* short term or long term effects of the change, the change effect to specific processes or overall market, and the trend of the relevant market segment – and aims to define the type of LCI modeling approach, and the second point try to indentify the specific technologies affected by the change – *i.e.* capacity of production of a technology is flexible or fixed, changes affect the constraints.
Consequently, this paper aims to present a proposal guinding scheme that help to identify the apropriated LCIM approach according to each application, as well as to identify the marginal processes in consequential applications. This proposal scheme is the conjunction of the main proposal schemes found in the LCA literature. Thus, this paper tries also to draw attetion to LCIM issues in Latin American researches and start a discussion of its applications in the region.

Results and discussions

In this paper were analyzed many of the most recent publications about life cycle modeling approach to identify the procedures used by the authors to differetiate the two main LCIM approaches and the marginal processes, when a CLCA is carried out.
Those publications carried out different study case and they are divided in two groups. The first group analyzes and compares the results of both ALCA and CLCA modeling approach (Ekvall, T. and Andræ, A.S.G. (2006), Lesage, P; Ekvall, T; Deschênes, L. and Samson, R. (2007a, 2007b), Thomassen, M.A; Dalgaard, R; Heijungs, R; Boer, I. de (2008) and Gaudreault, C; Samson, R. and Stuart, P. R. (2010)) and the second group analyzes, exclusively, the results of consequential modelling approach (Schmidt, J. and Weidema, Bo P. (2008), Schmidt, J. (2008), Dalgaard, et al (2008), Schmidth, J. (2010), Kløverpris, J; et al (2008) and Kløverpris, J; et al (2010)).

It was obseved that the five step procedure proposed by Weidema (2003) (Weidema, B. *et al* (1999), Weidema, Bo P (2003), Ekvall, T and Weidema, Bo P (2004)) was the procedure more used by LCA practitioners to identify marginal processes in CLCA, despite some authors claim the necessity of general equilibrium experts to participate in CLCA studies. According to procedures to define the more appropriate LCI modeling approach to be used in a specific study was not identify the used of any procedure. From this perspective, it is despited, in figure 1, the proposal of a complete LCIM identification procedure that is a combined scheme to identify the more appropriate LCIM approach and the marginal processes when the more appropriate is a CLCA. This proposal is the conjunction of two procedures; the simple scheme proposed by Lundie, et al (2007) known as "the recommended application scheme", and the five step procedure proposed by Weidema (2003).

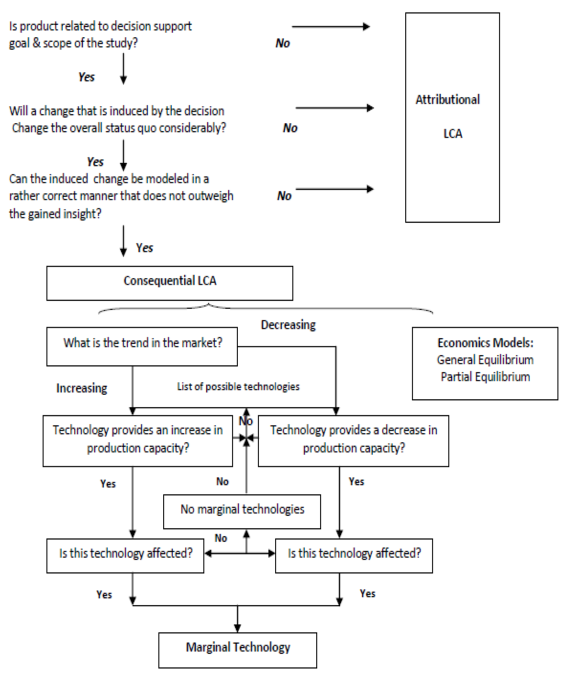

Figure 1. Proposal of a LCIM identification procedure
Source: Weidema (2003) & Lundie, et al (2007)

Also, in table 1, it is shown an overview of main characteristics of and differences between ALCA and CLCA based, mainly, on the interpretation of results and conclusions of Ekvall. T and Andræ. ASG (2006); Lesage. P et al (2007a, 2007b); Thomassen. M A et al (2008); and Gaudreault. C et al (2010).
And, in table 2 are described the main properties of a CLCA based, mainly, on the interpretation of the results and conclusion of the following papers: Schmidt. J and Weidema. Bo P (2008); Schmidt. J (2008); Dalgaard et al (2008); Schmidth. J (2010); Kløverpris. J et al (2008); and Kløverpris. J et al (2010).

Description	ALCA	CLCA
Type of research question	Status quo, descriptive	Assessing consequences of changes
Type of database	Average	marginal; average
Knowledge required	Physical mechanisms	Physical, market mechanisms
Functional unit	Represent static situation	Represent change in volume
Functional unit in LCI modeling comparative studies	Represent static situation	as ALCA
System boundary	Static process	Affected processes by a change in demand
Considered process	Inside the life cycle investigated	Inside and/or outside the life cycle investigated
Identification of the processes	Average	Marginal
System expansion	Not used	used
Allocation	used	Avoided
Hotspot identification	identification	Difficult identification
Data available	Databases, IO^6 table	Not always
Quality of data used	sensitive to uncertainties	Higher sensitive to uncertainties

Table 1. Overview of ALCA and CLCA

Properties	Consequential approach
Type of study	Analyze environmental impact due to change in demand
Size of the change	Large-scale consequences or changes
Reason for carrying out a study	Decision support
Target audience	Policy makers, decision makers
Data use	marginal
Relevance phase	System delimitation and system expansion
Identification points	Identification of marginal technologies, suppliers, products, co-products, such as relevant market segment, flexible suppliers and substitutable suppliers
Methods of identification	Weidema (2003), partial equilibrium model, general equilibrium model.
advantages	Completeness, accuracy, more realistic
disadvantages	High uncertainties in identifying marginal information
Main challenges of the method	Creation of a marginal database

Table 2. Main characteristics of CLCA

Conclusions

This paper proposes a combined scheme that identifies the appropriate LCI modeling and the marginal processes for crrying out a CLCA study. This scheme is a conjunction of two important procedures in LCI modeling literature, Lundie et al (2007) and Weidema (2003).
Discussions about LCIM approaches are not wide discussed in Latin American region. This paper presents the main characteristcs of each approach, according to the more recent publications in LCIM.

Reference

Dalgaard. R, Schmidt. J, Halberg. N, Thrane. M, Pengue. W.A. 2008. LCA of Soybean Meal. Int J LCA 13 (3): 240-258.

Ekvall, T and Andræ, A.S.G. 2006. Attributional and Consequential Envriomental Assessment of the Shift to Lead-free Solders. Int J LCA 11 (5): 344-353.

Ekvall. T, Weidema. Bo P. 2004. System Boundaries and Input Data in Consequential Life Cycle Inventory Analysis. Int J LCA 9 (3): 161-171.

European Commision (EC). 2010. ILCD Handbook (International Reference Life Cycle Data System Handbook). General Guide for Life Cycle Assessment – Detailed guidance. European Union, 414pp.

Finnveden, G. 2008. A world with CO_2 caps: Electricity production in consequential assessments. Int J Life Cycle Assess 13: 365-367.

Frischknecht. R, and Stucki. 2010. Scope-dependent modeling of electricity supply in life cycle assessments. Int J Life Cycle Assess 15:806-816.

Gaudreault. C, Samson. R, and Stuart. P R. 2010. Energy decision making in a pulp and paper mill: selection of LCA system boundary. Int J Life Cycle Assess 15: 198-211.

International Organization for Standardization (ISO). 2006. Environmental management – life cycle assessment – principles and framework. ISO 14040:2006, 2nd edn 2006-06.

Kløverpris. J, Baltzer. K, Nielsen. P H. 2010. Life Cycle Modelling of Land use Induced by Crop Consumption. Part 2: Example of Wheat consumption in Brazil, China, Denmark and the USA. Int J Life Cycle Assess 15: 90-103.

Kløverpris. J, Wenzel. H, Nielsen. P H. 2008. Life Cycle Modelling of Land use Induced by Crop Consumption. Part 1: Conceptual Analysis and Methodological Proposal. Int J LCA 13 (1): 13-21.

Lesage. P, Ekvall. T, Deschênes. L, and Samson. R. 2007a. Environmental Assessment of Brownfield Rehabilitation Using Two Different Life Cycle Inventory Models: Methodological Approach. Int J LCA 12 (6): 391-398.

Lesage. P, Ekvall. T, Deschênes. L, and Samson. R. 2007b. Environmental Assessment of Brownfield Rehabilitation Using Two Different Life Cycle Inventory Models: Case Study. Int J LCA 12 (7): 497-513.

Lundie, S; Ciroth, A; Huppes, G. (2007). Inventory methods in LCA: towards consistency and improvement. Final report. UNEP-SETAC LIFE CYCLE INITIATIVE – LIFE CYCLE INVENTORY (LCI) PROGRAMME.

Schmidt, JH. 2008. System delimitation in agricultural consequential LCA. Int J Life Cycle Assess 13: 350-364.

Schmidt, JH. 2010. Comparative life cycle assessment of rapeseed oil and palm oil. Int J Life Cycle Assess 15: 183-197.

Schmidt. JH and Weidema. Bo P. 2008. Shift in the Marginal Supply of Vegetable Oil. Int J LCA 13 (3): 235-239.

Thomassen. MA, Dalgaard. R, Heijungs. R, Boer. I de. 2008. Attributional and Consequential LCA of Milk Production. Int J Life Cycle Assess 13: 339-349.

Weidema Bo P. 2003. Market Information in life cycle assessment. Danish Environment Protection Agency, Copenhagen, Denmark, pp 1-147.

Eco-Speed, a new Life Cycle Assessment methodology for Latin American countries.

Keywords: Life Cycle Assessment Methodology, Eco-Speed, Water Use and Quality Category, Land Use and productivity, USEtox Characterization Factors

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Rodriguez-Pérez, B.[1*]

Rosa-Dominguez E.[2]

Contreras, Ana[3]

[1] Berlan Rodríguez-Pérez, University of Cienfuegos, Industrial Engineering Department , Carretera a Rodas 4 Caminos, Cienfuegos, Cuba. ZP: 55200. E-mail: brguez@ucf.edu.cu

[2]Elena Rosa Domínguez, Central University "Marta Abreu" de Las Villas. Chemistry- PharmacyFaculty. Camajuaní Road km 5½, Santa Clara, Villa Clara, Cuba. ZP: 54 830. Phone: 53-42- 281100. E-mail: erosa@uclv.edu.cu

[3]Ana M. Contreras, Central University "Marta Abreu" de Las Villas. Chemistry- PharmacyFaculty. Camajuaní Road km 5½, Santa Clara, Villa Clara, Cuba. ZP: 54 830. Phone: 53-42- 281100. E-mail: erosa@uclv.edu.cu

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Abstract

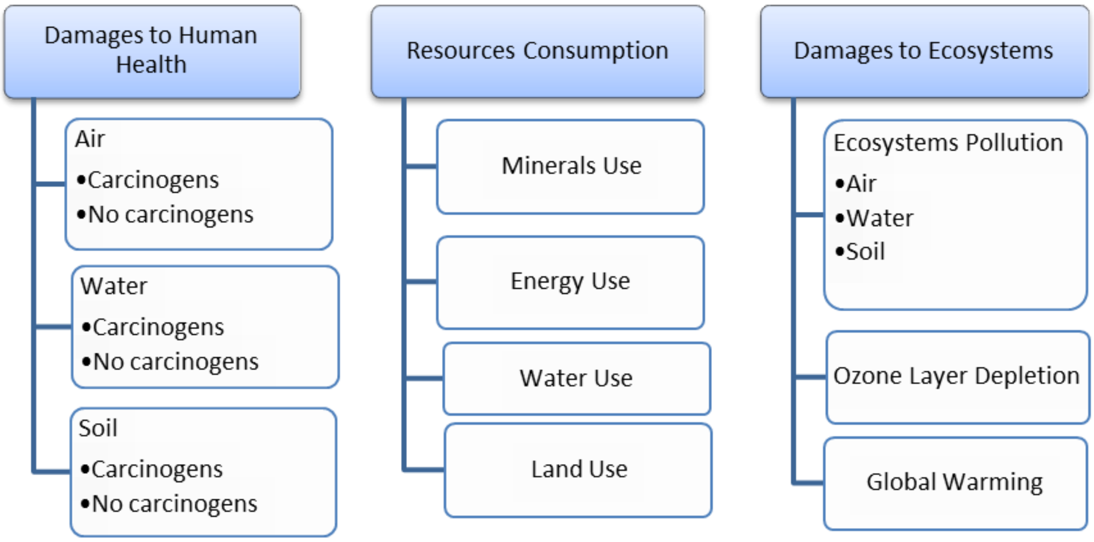
"Eco-Speed" is a new life cycle impact assessment methodology that proposes 3 damage and 15 impact categories. USEtox the newest method reported for assessment toxicity of chemicals is used for the assessment of Human Health and Damage to Ecosystems. This Factors are calculated for carcinogens and non-carcinogens and ecosystems, including more than 3000 substances, employing the particularly data of Cuba, Centro-America and the Caribbean, South-America and the Word; using the USEtox Spreadsheet provided by (M. Hauschild et al. 2008). The same regions have its specific normalization factors, in order to make Eco-Speed applicable for its. There is a new category, Water Use, which is prepared for assessing the water consumption and quality. The water quality is expressed as water consumption, considering as the quantity of water needed for diluting the pollution charge as Biological Oxygen Demand, emitted to a water body. The category Land Use is developed for considering the change of use impacts and the relation of land used and land productivity, bearing in mind the waste land fill. All categories are expressed as rate functions, interpreted as the velocity components of consuming a resource, from that the name Eco-Speed. The idea of incorporate the time component to the damage assessment provides an improved form for calculating overall points, which have to be obtained from all different damage categories since all categories are expressed as dimensionless rates once normalized.

1.1 Introduction

This presented method uses functions of speed of exhaustion in most of its impact categories, of there the name of Eco-speed. Another of the distinctive characteristics of the method is the application of technical of estimate for the compliment of the impact categories, including in them the biggest quantity possible of identified substances as that affect the environmental mechanism.

1.2 Characterization

Eco-Speed bill with 3 categories of damage, those that are affected by 13 impact categories, the form in that you/they are related represents in the figure 1.1. In general the basement of the method is to use functions of exhaustion, where the results are dimensionless, using a fractional relationship, where the numerator represents the element to analyze and the denominator represents the available quantity of that element, this way they will be considered the potential impacts of each analyzed element then, like they are presented next for each one of the categories of damage and of impact.



Figures 1.1: Relations between the Impact and of damage of categories in Eco-Speed method

1.3 Damages to Human Health

This category of damage represents the quantity of health problems cases that are probably presented in the defined time horizon. It is determined by the sum of the potential impacts that you/they are generated by the emission of carcinogenic and not carcinogenic substances to the air, it dilutes or floor. Their calculation form is represented in the equation 1.1

$$HE = CA + NCA + CW + NCW + CS + NCS \qquad (0.1)$$

Where:

- HE: Indicator of damages to people in function of the exhaustion
- CA: Indicator of potential damages for the presence of Carcinogenic in the air.
- NCA: Indicator of potential damages for the presence of not carcinogenic in the air.
- CW: Indicator of potential damages for the presence of Carcinogenic in the water.
- NCW: Indicator of potential damages for the presence of not carcinogenic in the water.
- CS: Indicator of potential damages for the presence of Carcinogenic in the floor.
- NCS: Indicator of potential damages for the presence of not carcinogenic in the floor.

Impact categories included in this damage category are follows the same way of calculations including the potential impacts from the emissions of carcinogenic or not carcinogenic substances to the air water or soil. The used factors are composed initially of those calculated by the pattern USETox for the substances included in (Rosenbaum, et al 2008), to those that the other substances were added contained in similar categories of the methods: Eco-indicator 99 (in their three versions), Impact 2002+, TRACI and EDIP, of which estimates of their characterization factors could settle down for the pattern USETox. The work of the estimate carried out for (Rodríguez et al 2010) it facilitated the use of the biggest quantity in substances for this category.

The characterization factors for each substance represent the potential cases of health problems caused for each Kg of the substances emitted to the air, their measure unit it is given by Cases/Kg and these factors are comparative units that allow relating the importance of a substance with another.

The form of calculation of the indicator of the category is represented next in the equation 1.2.

$$CA = \sum_{i=1}^{n} (CF_i * m_i) \tag{0.2}$$

Where:

- CA: Indicator of potential damages for the presence of Carcinogenic in the air, water or soil.
- FC: Factor of Characterization for the substance " i " for this category.
- mi: Emitted mass of the substance " i ".
- n: quantity of substances included in category.

1.4 Resources Consumption.

For the development of this category the information were used provided by several international organisms, dedicated to the manipulation of related statistical data, among them the most important consulted they are: (United Nations 2010), (DOE/EIA 2009), (National Office of Statistical, Cuba 2009) and (EUROSTAT, European commission 2008).

1.4.1 Water Use.

For the impact calculation in the use of the water, they are kept in mind the entrances and exits to the system of analyzed product, starting from each one of the possible origins, or supply sources, since the calculation of the category is based on dividing this volume of water for the available total quantity of that same resource type, like it is shown in the following equations:

$$WA = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{v_i + m_j * f_j}{V_i} K_i \tag{1.3}$$

Considering K_i as the following Equation:

$$K_i = 1 - \frac{V_i}{T} \tag{1.4}$$

Were:

- WA: Category Indicator for Water Availability.
- v_i: used volume from reservoir “i”
- m_i: mass emitted of substance “j” that contributes to eutrophication
- f_i: Factor of water volume required for diluting the mass of “j” emitted
- V_i: Total volume available 95 % of time from reservoir “i”
- T: Total volume of available water (sum of all reservoirs)
- K: Correction Factor
- n: quantity of reservoirs

1.4.2 Category Land Use.

For the impact of the Land Use it has been considered to propose a weighting in dependence of the use change that is carried out when using the floor. It is based on the classifications of their productivity, where 4 classifications are used, very productive, productive, not very productive and very not very productive; these classifications are those used by the agencies that provide the data used for the calculation of the indicator of the category (National Office of Statistical, Cuba 2009),(EUROSTAT, European commission 2008), for that reason they stay as such. Their calculation formula is defined as:

$$LU = \sum_{i=1}^{n} \frac{a_i * \prod_{j=1}^{m} P_j C_{ij}}{A_i} K_i \tag{1.5}$$

Considering K_i as:

$$K_i = 1 - \frac{A_i}{T} \tag{1.6}$$

Where:

- LU: Land Use Impact Category Indicator
- a_i: Used Area of land variety "i"
- A_i: Available Area of land variety "i"
- C_i: correspondent Factor for Change of Land use
- P_i: Correspondent Factor for relation of Land variety and type of use.
- K: Correction Factor
- T: Total Land Available

The factors for change of use and relation of variety-type of use are presented in table 1 and the factors for land change of use are presented in table 2. For interpreting tables, we have to take into account that negative values imply positive emissions to environment.

Table 1: Factors for weighting relation between land Use and Land Variety.

Soil Variety / Type of Use	Very poor productive	Poor productive	Productive	Very productive
Waste landfill	0.25	0.5	0.75	1
Industrial, construction, highways, mining	0.2	0.5	0.7	0.9
Grassland	-0,4	-0.2	0.75	0.25
Agriculture	-0,8	-0.6	-0.4	-0.25
Reforestation, fruits trees plantations	-1	-0.6	-0.4	-0.2

Table 2: Factors for weighting Land Use change.

To / From	Waste landfill	Industrial, construction, highways, mining	Grassland	Agriculture	Reforestation, fruits trees plantations
Waste landfill	0.2	-0.5	-0.75	-1	-1
Industrial, construction, highways, mining	0.5	0.2	-0.5	-0.75	-1
Grassland	0.75	0.5	-0.2	-0.5	-0.75
Agriculture	1	0.75	0.5	-0.2	-0.5
Reforestation, fruits trees plantations	1	1	0.75	0.5	-0.2

1.4.3 Energy Use

The use of the energy is based on the division of the mass of the used energy resources, dividing them for the mass of the available resources, according to the following equation, which will represent the speed of exhaustion of the analyzed resource.

$$EU = \sum_{i=1}^{n} \left(\frac{e_i}{E_i} \right) \quad (1.7)$$

Where:

- e_i: It represents the mass of the energy resource "i" that is used in the analyzed system.
- E_i: It is the available mass in proven reservations of the energy resource "i".

1.4.3 Minerals Use

The use of the minerals is based on the division of the mass of the used resources, dividing them for the mass of the available resources, according to the following equation, which will represent the speed of exhaustion of the analyzed resource.

$$MU = \sum_{i=1}^{n} \left(\frac{m_i}{M_i} \right) \quad (1.8)$$

Where:

- m_i: It represents the mass of the resource " i " that is used in the analyzed system.
- M_i: It is the available mass in proven reservations of the resource "i".

1.5 Eco-toxicity

This category includes the potential impacts of the substances included in the pattern USETox (Rosenbaum, et al 2008), to those that the other substances were added contained in similar categories of the methods: Eco-indicator 99 (in their three versions), Impact 2002+, TRACI and EDIP, of which estimates of their characterization factors could settle down for the pattern USETox.

The characterization factors for each substance represent the fraction potentially affected that caused by each Kg of the substances emitted to the air, their measure unit is given by PAF/Kg and these factors are comparative units that allow relating the importance of a substance with another.
The form of calculation of the indicator of the category is represented next in the equation:

$$EA = \sum_{i=1}^{n} (CF_i * m_i) \quad (1.9)$$

Where:

- EA: Indicator of potential damages for the presence of dangerous substances in the air, soil or water.
- FC: Factor of Characterization for the substance " i " for this category.
- m_i: Emitted mass of the substance " i ".
- n: quantity of substances included in this category.

Conclusions

Eco-speed pretends to be a suitable methodology for assessing environmental Life Cycle of product, parting from the necessity of countries in Latin American region to apply regionalized methods, in order to avoid the uncertainties produced for applying European or developed countries methodologies. In this way Eco-Speed is presented in different formats, like SimaPro and OpenLCA, or a simple edition for Excel or OpenOffice spreadsheet; allowing many as possible user to work with it.

The need of including water categories on Life Cycle Assessment Methodologies is presented by the UNEP SETAC LCA initiative as a priority for developers and experts of LCA in all over the world. With this work is pretend to make a first approach to this category that will be updated with the criteria showed in the presentation of the present paper on CILCA 2011.

USEtox Toxicity model is used for calculating the specific region characterization factors for toxicity of chemicals in Latin American Conditions, employing the particularly data of Cuba, Centro-America and the Caribbean, South-America and the Word.

The second steep for using properly and adapted methodology for Latin American countries must be a creation of a region databases, with the aim of allow the publications of LCA studies and analyze the process impacts correctly in all the real Life cycle. The first processes to include may be basic industries like electric generation, agricultural products and mining.

References

Hauschild, M., T. M Bachmann, M. Huijbregts, O. Jolliet, A. Köhler, H. F Larsen, M. Margni, et al. 2008. International consensus model for comparative assessment of chemical emissions in LCA. In *LCE 2008: 15th CIRP International Conference on Life Cycle Engineering: Conference Proceedings*, 291.

Huijbregts, M. A.J, J Struijs, M. Goedkoop, R. Heijungs, AJ Hendriks, and D Van De Meent. 2005. Human population intake
fractions and environmental fate factors of toxic pollutants in Life Cycle Impact Assessment. *Chemosphere* 61, no. 10: 1495-1504.

Ingwersen, W. W. 2010. Advances in life cycle assessment and emergy evaluation with case studies in gold mining and pineapple production. University of Florida.

Mckone, Thomas, Michael Z. Hauschild, Olivier Jolliet, Matt Macleod, Manuele Margni, Dik Van De Meent, and Ralph K . Rosenbaum. 2008. Building a Model Based on Scientific Consensus for Life Cycle Impact Assessment of Chemicals: The Search for Harmony and Parsimony. *American Chemical Society* 42, no. 19: 42.

Park, J. H, and K. K Seo. 2006. A knowledge-based approximate life cycle assessment system for evaluating environmental impacts of product design alternatives in a collaborative design environment. *Advanced Engineering Informatics* 20, no. 2: 147–154.

Reap, J., F. Roman, S. Duncan, and B. Bras. 2008a. A survey of unresolved problems in life cycle assessment. Part 1: impact assessment and interpretation. *International Journal of Life Cycle Assessment* 13, no. 5: 374–388.

———. 2008b. A survey of unresolved problems in life cycle assessment. Part 2: impact assessment and interpretation. *International Journal of Life Cycle Assessment* 13, no. 5: 374–388.

Rosenbaum, R. K, and Q. S Assessment. Model comparison for toxicity characterization models.

Rosenbaum, R. K, T. M Bachmann, L. S Gold, M. A.J Huijbregts, O. Jolliet, R. Juraske, A. Koehler, et al. 2008. USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. *The International Journal of Life Cycle Assessment* 13, no. 7: 532–546.

Rosenbaum, Ralph, Till Bachmann, Lois Gold, Mark Huijbregts, Olivier Jolliet, Ronnie Juraske, Annette Koehler, et al. 2008. USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. *The International Journal of Life Cycle Assessment* 13: 532-546.

Zamagni, A., P. Buttol, P. L. Porta, R. Buonamici, P. Masoni, J. Guinée, R. Heijungs, et al. 2008. Critical review of the current research needs and limitations related to ISO-LCA practice. *ENEA, Roma.*

van Zelm, R., M. A.J Huijbregts, and D. van de Meent. 2009. USES-LCA 2.0 a global nested multi-media fate, exposure, and effects model. *The International Journal of Life Cycle Assessment* 14, no. 3: 282–284.

Social subcategories and indicators of SLCA inventories adapted to informal labour and self-employment: a case of Brazilian work market

Camila do Nascimento Cultri
Aldo Roberto Ometto
University of Sao Paulo
São Carlos School of Engineering
Adress: Trabalhador Saocarlense, 400, São Carlos, SP, Brazil.
Phone 55 16 3373 8287. Email: cultri@usp.br

TOPIC: Sustainable Life Cycle Assessment

Abstract
In all stages of production are generated social impacts that consequently affect the stakeholders. Products are result of a transformation process which involves the use of natural resources, energy and human labour. On the sustainability context is important to consider economic, environmental and social aspects of products. The Life Cycle Thinking is an idea to supply some tools that focus going beyond the production site and manufacturing processes so to include the social and socioeconomic impact of a product over its entire life cycle. Social Life Cycle Assessment is a systematic process used to assess the social impacts during the life cycle of a product. It allows identification of key issues, assessing, and telling the story of social conditions in the production, use, and disposal of products. The conditions of worker must be examined to identify the corporate influence on the individuals or communities. So, the main objective of this paper is to analyze the labour conditions on Brazil market based on the subcategories of social impact proposed by UNEP (2009). It was selected two work relationships (informal labour and self-employments) which about 50% of the economically active population is prone to work. While identifying the working conditions of Brazilians workers have to face in these industries, this paper will highlight why these conditions should be considered in the analysis of Life Cycle Impact Assessment. As result presents some relevant socioeconomic aspects based on cultural and traditional values as well as data on living conditions, poverty or wealth of the worker in Brazil. This case corroborates the analytical arguments that understand the informality on labour market as a basic problem in developing countries what need special focus on assessment.
Keywords: *Social Life Cycle Assessment, Social LCIA, Classification, Characterisation of social impacts*

Social Life Cycle Assessment: a technique to assess the social impacts of products
The main goals of life cycle thinking are to reduce a product's resource use and emissions to the environment as well as improve its socio-economic performance throughout its life cycle. This may facilitate links between the economic, social and environmental dimensions within an organization and throughout its entire value chain.
Based on the line the Life Cycle Thinking, the SLCA incentives to understand the events that are normally invisible to the "end consumer", but that directly or indirectly influence workers or some communities due to social impacts generated by the products along the production chain.
By definition *"a technique used to assess the social impacts, positive or negative, caused by the life cycle of a product, including extraction and processing of material, manufacturing,distribution, use, re-use, maintenance, recycling and final disposal, thus finishing the life cycle of this product " [1].*
Instruments of Social Responsibility like: OHSAS 18000 [2], SA 8000 [3], AA 1000, AFNOR 21000, Global Sustainability Reporting [4], Index of Corporate Sustainability and ISO 26000 [5] contributed to the principles of SLCA. Together with Brazil experiences on the ABNT NBR 16001:2004 [6] added specially attention to encourage companies to practice Corporate Social Responsibility (CSR) within a base of legal compliance order from the socially responsible behavior. These instruments incentives the social responsibility, as well as techniques to monitor and evaluate any systems management.
In 2009 was publicized the most important document of SLCA called "Guidelines for Social Life Cycle Assessment of Products" [1]. The consolidation of guidelines published by UNEP followed some parameters

guided by other techniques such as, for example, Social Impact Assessment (SIA), Health Impact Assessment (HIA), Strategic Environmental Assessment (SEA), Human Rights Impact Assessment (HRIA) and Sustainability Appraisal (SA). These subsidies have largely contributed to SLCA; however, the spread of this technique is to examine the social aspects in the life cycle of products and services the subject of studies considering the conditions of workers, consumers, local community, society and other actors in the value chain.

Different publics may be interested in the social assessment, in summary, studies with high impact factors in the area of life cycle were addressed on the following issues: investment decisions [7], design [8], industrial management [9], [10] and consumers [11] and public decisions [12].

The technical framework SLCA is composed by four phases (Definition of Goal and Scope, Life Cycle Inventory analysis, Life Cycle Impact Assessment and Life Cycle Interpretation). The aim of these methods for social assessments of product systems is to study the impacts on five fundamental stakeholder groups: employees, consumers, local communities, society and value chain actors.

Stakeholders are the key elements of SLCA, due to their relationship with the concerned product systems. The group of UNEP [1] appealed to the international treaties to bring together themes already established in the social and from them were established five categories of stakeholders and thirty-one sub-impact categories. For each category of stakeholders has developed a methodological sheets, which brings the definition of each subcategory relating them to relevant international documents. Each part is made by presenting the subcategory of its impact on socio-political context, with some metrics to collect general data (hot spots) and specific data. It also makes references to the availability of internationally information.

Nowadays, several issues about social subcategories are being discussed on SLCA and it adjusted to evaluate differences between countries or regions. Thus, the purpose of this study explored the social conditions of workers in Brazil. This case makes sense because half part of people doesn't have access to legal labour market. So, it is important to improve the methodological aspects of SLCA to evaluate each part of products which can are made by workers who lives in decayed conditions.

The Brazilian work market: typical forms of employment

Brazil stands out as a developing country with huge social specificities, due to its large territorial extension and it has around 192 million people (estimate from IBGE, 2010) [13] which represents one of the largest absolute populations of the world , especially as the fifth most populous nation on earth.

The Brazilian industry is characterized by heterogeneity between several industrial sectors, in fact, possible to understand by analyzing the contrast between regions that directly influence the quality of life and employment, and technological resources from the investment business [14] and [15]. The relationships of individual and collective work are regulated by the Consolidation of Labour Laws from 1943.

The labour market has approximately 79 million economically active people – PEA (46.7% of the population), of which only 35.4 million have registered (44% of EAP) in accordance with Ministry of Labour and Employment [16]. Despite having a complex labour laws, much of the population (approximately 50%) cannot work in formal regime, due to the high amount of taxes the government collects from businesses. Because this situation appears other types of employment, specially: informal work and self-employment. The work does not establish informal links and benefits between the employee and the company is literally a way that companies use for tax evasion to the government, which supplies official statistics could not calculate. And an independent worker is someone who lives on his own work, but who may not perform the tasks stipulated in contracts with wage settlements and legal rights. 2011).

Results and discussion

The aim of this paper is to analyze the feasibility of application of the subcategories of social impact proposed by UNEP [1] to Brazilian labour regimes. For this we selected two types of work (informal and self-employment) which approximately 50% of the population economically active is subject to work.

Analyzing the eight subcategories of the stakeholder impacts "worker" it appears that the indicators currently suggested by UNEP are insufficient to understand the performance of Brazilian products that have informal work and self-employment at some stage of the life cycle. From the standpoint of formal employment, in which employees are registered with signed, all sub-categories can be analyzed

However, informal work and self employment don't records on working hours, salary, health and safety. Thus, the issues of gender equality, child labour, freedom of association and collective couldn't be recorded and monitored

by the Brazilians authorities. For this reason, it is suggested that the analysis of work conditions include other subcategories that can effectively assess whether your profession or worker chose it for this lack of choice of employment, vocational training, etc.
On the Table 1 we present the subcategories and social indicators that should predict accuracy when analyzed informal labour or self-employment.

			Proposed	
Stakeholder	**Impact categories**	**UNEP Subcategories**	**Subcategories**	**Indicators**
Worker	➢ Human rights ➢ Working conditions ➢ Health and safety ➢ Cultural heritage	✂ Freedom of Association and Collective Bargaining ✂ Child Labour ✂ Equal opportunities/Discrimination ✓ Fair Salary ✓ Working Hours ✓ Forced Labour ✓ Health and Safety	❖ Government assistance ❖ Access to public resource (Public school, hospital, safety, etc.) ❖ Access to private resource	❖ Income ❖ Social Benefits/ Social Security ❖ work accident ❖ local salary ❖ motivation ❖ hereditary work ❖ security ❖ working hours ❖ opportunity to work in anyplace ❖ Own habitation

Table 1 – Social subcategories and indicators of SLCA inventories adapted to informal labour and self-employment

The Brazilian experience shows that different forms of work should be considered in the analysis of inventories of SLCA. This is because the worker, even in informal or self employment contributes economically to a choice of employment and income for the marginalized population who hasn't access the formal job.
Assuming measure how these forms of work represents the product; it is proposed that the rating is between formal employment, informal and self employment. This analysis can be characterized in two levels of impact: "internal" environment for the manufacturing of the product and "external" suppliers. As indicators suggested using the income, motivation, education, working conditions and living conditions, since the accessibility of population to these factors vary according to his opportunity in the labour market.

Conclusions
A major factor when starting a SLCA in developing countries is to specify the region where the product is produced through such an information specialist in socio-economic analysis can contribute to giving guidance on labour relationship in a given sector and region. In the Brazil, wages suffer varying effects depending on the type of industry, firm size, source of capital, the company's access to international markets, and other variables associated with the specialty of the manpower available in a given region.
The consumer must be guaranteed reliable, accessible and transparent information about product characteristics to enable him/her to choose the highest quality product with the longest service life, at the lowest cost, and whose price reflects its social impacts. In principle, all products and services should be included in this approach in order to achieve the overall minimization of the social impacts they cause. However, initial attention should focus on products that are effectively or potentially the most harmful to the living conditions of workers, as verified throughout of the informal labour and self employment.
This proposed of classification and characterization with relevant feature of Brazilian labour market needs to be appreciated by the community of SLCA, since this may represent the reality of other developing countries. However, it needs to be validated through case studies. Thus, the main suggestion is used the multi-criteria indicators to evaluated and judged on their feasibility and on their ability to produce reasonable results.

References

[1] BENOÎT C, MAZIJN B (eds) (2009) Guidelines for Social Life Cycle Assessment of Products
[2] DNV (1999) Occupational health and safety management systems — specification OHSAS 18001:1999. Det Norske Veritas (DNV)
[3] SAI (2001) Social Accountability 8000. Social Accountability International (SAI). New York 2005

[4] GRI (Global Reporting Initiative). Sustainability Reporting Guidelines. Version 2. Amsterdam, 2005.
[5] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (2010). ISO 26000 – Guidance Document on Social Responsibility, Geneva: ISO Central Secretariat.
[6] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR 16001: 2004 (Brazilian Standard: Social Responsibility Management System – Requirements)
[7] MÉTHOT, A FIDD. A green and socially responsible venture capital fund. Presentation on the Life Cycle Approaches for Green Investment – 26th LCA Swiss Discussion Forum, Lausanne, Switzerland, 2005.
[8] GAUTHIER, C. Measuring Corporate Social and Environmental Performance: The Extended Life-Cycle Assessment. J Bus Ethics 59 (1–2) 199–206, 2005.
[9] CAÑEQUE, FC. Evaluación de la situación laboral de empresas: El Análisis del Ciclo Vida como herramienta para el Desarollo Sostenible. Departamento de Economia i Organisación de Empresas, Universitat de Barcelona, Barcelona, Spain, 2002.
[10] DREYER, L. HAUSCHILD, M. & SCHIERBECK, J. A Framework for Social Life Cycle Impact Assessment. Int J LCA 11 (2) 88–97, 2006.
[11] SPILLEMAECKERS, S. et al. Integrated Product Assessment – The Development of the Label 'Sustainable Development' for Products Ecological, Social and Economical Aspects of Integrated Product Policy. Belgian Science Policy, Belgium, 2004.
[12] HUNKELER, D. Societal LCA Methodology and Case Study. International Journal of Life Cycle Assessment 11 (6) 371–382, 2006.
[13] IBGE (Instituto Brasileiro de Geografia e Estatística). Available www.**ibge**.gov.br/. Accessed 8 December 2010.
[14] SABOIA, João. Diferenciais regionais e setoriais na indústria brasileira. Econ. Apl. [online]. 2008, vol.12, n.1
[15] ARBACHE, Jorge Saba. Filiação industrial e diferencial de salários no Brasil. Rev. Bras. Econ. [online]. 2004, vol.58, n.2
[16] Brazilian Ministry of Labour and Employment. Available www.mte.gov.br. Accessed on 8 January 2011.

Life Cycle Greenhouse Gases in a Power Plant

S.P. Lopez-Gil *[1], F.T Wakida[1], M. Gonzalez[2] and N. Suppen[2]

[1]Facultad de Ciencias Químicas e Ingeniería, Universidad Autónoma de Baja California. Calzada Universidad, Mesa de Otay, Tijuana, Baja California, México, CP. 22390. patricia.lopez@uabc.com.mx, fwakida@uabc.edu.mx , Tel: ++ 52 664 9797500, EXT. 54300. Fax ++ 52 664 6822790.
[2] Centro de Análisis de Ciclo de Vida y Diseño Sustentable CADIS, o. nsuppen@centroacv.mx, mgonzalez@centroacv.mx,

ABSTRACT

The main objective of this study was the calculation of the carbon footprint of a thermal power station using life cycle assessment methodology. The functional unit is 1 KWh and the system boundaries are fuel extraction and transport, power generation, transmission and distribution of electricity. Data collection was conducted directly in the thermal power station and the calculations of the pollutant emissions were carried out using the emission factors developed for the organization that owned the plant. Carbon dioxide equivalents were determined using the IPCC factors. Three power generation processes installed in the thermal power station were analyzed: gas turbine, conventional steam generation and combined cycle units. The carbon footprint calculated for the thermal generation station was 500.33 gCO2e/KWh in the reference year 2008. The process with the lowest CO2 emission was combined cycle (321 gCO2e/KWh) and the highest was gas turbine (954 gCO2e/KWh). Life cycle assessment is a useful planning tool for the electricity generation companies to reduce their greenhouse gas emissions.

Introduction

A forward looking approach for 2024 of the electricity generation sector in Mexico established as one of the main actions "to reduce the environmental impact in the electricity generation establishing as fundamental activity the account of the greenhouse gases emissions".

Worldwide the electricity sector is considered the main generator of CO2 emission worldwide, contributing approximately 41% of the total CO2 emissions in 2005. At the same year, energy sector contributes 31% of the total CO2 emissions in Mexico (OECD, 2007).

Life cycle assessment can be useful for the electricity generation sector by identifying the power generation technologies that generate higher potential environmental impacts and as a planning tool in the construction and process control in new electricity generation stations. Life cycle assessment (LCA) has been used in different studies to evaluate the CO2 emissions of the electricity generation sector. Matsuno and Betz (2000) analyzed the processes of Japanese electrical generation stations. They found average values of direct emission of 380 gCO2/KWh and 450 gCO2/KWh delivered to the end users. Di et al. (2007) calculated the emission of the Chinese system of electrical generation. They determined a value of 877 g de CO2 for every KWh delivered to the end user. Kim and Dale (2005) stated that the electrical system in the US produces in the year 2000 an average of 694 gCO2/KWh during the power generation stage. The lowest emission of CO2 reported was in Brazil (138 gCO2/KWh) because of 82% of the electrical energy is produced by hydroelectric power plants (Coltro, 2003).

This study accounted the GHGs (CO2 equivalent) emitted in 2008 in the generation and distribution processes of a thermal power station. This thermal power station has the three of the generation processes most used in Mexico:

conventional steam generation, gas turbine and combined cycle.

The analyzed thermal power station produced in 2008 a total of 3,975,446.98 MWh, which the gas turbine unit A (GT A) generates 0.05%; gas turbine B unit (GT B), 0.03%; gas turbine C unit (GT C), 5.80%; conventional steam generation A unit (SG A), 10.31%; conventional steam generation B unit (SG B), 9.52%; Combined cycle unit A (CC A), 41.81% and Combined cycle unit B (CC B), 32.50%. The National Center of Energy Control (CENACE, for the Spanish acronyms) selected combined cycle units to provide energy to the electrical system because of their higher thermal efficiency than gas turbine unit. The gas turbine units are used only for backing the electrical system in emergency events.

Calculation of the life cycle carbon footprint of the thermal power station

A life cycle assessment of the thermal power station was carried out considering the life cycle stages of generation, transmission and distribution of electrical energy which main function is to provide electricity to the end user. The functional unit is “kWh of power supplied to end users”. In the studied organization, the electricity generation is a single exit thus there is a lineal relation between the inlets and exits. An exemption is the thermal power station that uses residual oil as fuel; this process was not considered in this analysis. The data collection was conducted in situ in 2009. The data collected were: a) Consumption and raw material: auxiliary services, chemical substances and fuels. b) Outputs: Product quantification, gas emissions and discharges to water bodies and soil. c) Other environmental aspects such as data of noise level, hazardous waste generation and urban solid waste. d) Energy balances. e) Thermal efficiencies of the power generation units.

Based on the above life cycle inventory the green house gas (GHG) amounts were calculated using the IPPC classification class “Level 3: fuel statistics and data related to combustion technology applied jointly with the emission factor of the technology; that include the use of models and emission data in facilities”(IPPC, 2006). These results were used in conjunction with emission factors stated in CFE-GUI-PA-008 guide elaborated by the Federal Electricity Commission (CFE in Spanish). This document provides specific emission factors for every power generation technology in function of the fuel quality, carbon content in fuels, burner type used in the combustion and technology advance. Every GHG emission was calculated by multiplying the fuel consumption volume by the corresponding factor emission. The equivalent grams of CO2 were obtained by multiplying every pollutant by its global warming potential factor, a timescale of 100 year was selected for this study (IPCC, 2007). Subsequently, the resulted equivalent grams of CO2 of the GHG were summed and divided by the power generation in KWh to obtained the total equivalent grams of CO2 per KWh. Statistic data published by Weisser (2006) were used to calculate the extraction, refining and transport of fuels. These data indicate the percentage of the accumulated emissions 12% for fuel oil, 20% for carbon and 17% for natural gas. A value published of 10.7% by CFE was taken for the calculations of losses for transmission and transport of electricity (SENER, 2010).

Results

GHG emissions were quantified for a thermal power generation considering three stages: a) extractiom, refining and fuel transportation; b) electricity generation and c) transmission and distribution of electricity. Electricity generation was the stage with highest contribution of total emission of GHG (74%). Three types of electricity generation technologies were analyzed in the studied thermal power station. The technology with the highest environmental impact in terms of GHG emissions was gas turbine and the lowest were the combined cycle. Energy production is not the same in all the generation units, it varies according to the thermal eficiency and availability. Table 2 shows that a lower thermal eficiency produces a higher thermal regime and carbon footprint. Conversely, a higher thermal eficiency generates a lower thermal regime and carbon footprint. The gas turbine A unit (GT A) emmited the highest amount of GHG with 1168 gCO2e/KWh and the lowest was CC A with 321 gCO2e/KWh in the year 2008. Table 2 shows the gas turbine units had the highest number of start-ups, which indicates that theses unit had to be started because of emergency events in short period of time o practice tests were carried out in these dates.

Table 1. Unit characteristics in the power plant.

Unit	Plan type	Year operation	Power Generation 2008 (MWh)	Net efficiency (%)	Thermal efficiency (Kcal/KWh)	Emissions gCO_2e/KWh	Plant operation mode
GT A	Gas Turbine	1982	1,907.507	13.46	6,388.99	1168	89 start up in a year. Emergency generation.
GT B	Gas Turbine	1982	1,053.998	13.63	6,310.42	1153	54 start up in a year. Emergency generation.
GT C	Gas Turbine	1999	230,023.55	29.12	2,953.66	540	129 start up in a year Emergency generation.
SG A	Steam Generation	1991	410,002.36	33.75	2,548.51	467	Cycling operation.
SG B	Steam Generation	1991	378,515.72	32.30	2,662.86	504	Cycling operation.
CC A	Combined Cycle Generation	20001	1,661,983.43	49.01	1,754.84	321	Base load
CC B	Combined Cycle Generation	20001	1,291,960.42	48.02	1,790.94	327	Base load

Figure 1 shows the historical total average carbon footprint of CO2 e/KWh emission from 1993 to 2009. The total average of CO2 e/KWh emission was 1200 gCO2 e/KWh in 1993 and 640 gCO2/KWh in 2008, reducing approximately 50% of GHG emission. Moreover another decrement in GHG emission was observed in 2009 because another combined cycle unit replace the existing steam generation units. The total average emission for 2009 was 573 gCO2e/KWh.

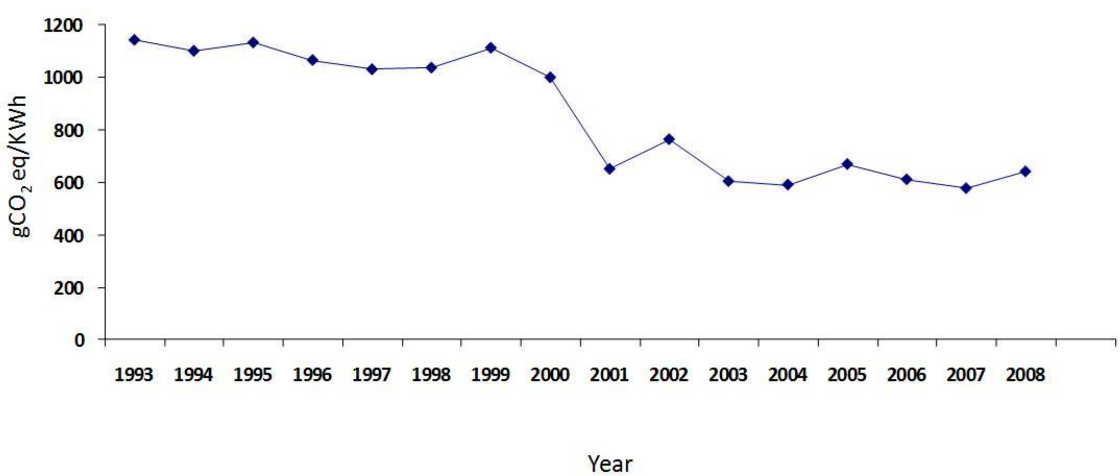


Figure 1. Carbon Footprint of 1 KWh

Conclusions

The LCA methodology is a useful tool to evaluate the environmental impacts of the electrical sector taking into account the technology used. The power generation technology with the lowest environmental impact in terms of GHG emission was combined cycle with 321 gCO2e/KWh and the highest resulted with 954 g CO2e/KWh. A considerable decrement (50%) in the average GHG emission was observed in the period of 1993 to 2009 because of the replacement of conventional steam generation by a newer technology (combined cycle).

The life cycle assessment is a tool that the power generation company can use to plan its operation taking into account the reduction of GHG emissions and to contribute the international commitments established in the Kyoto protocol.

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References

Coltro L, García E, Queiroz G (2003). Life Cycle Inventory for Electric Energy System in Brazil, International Journal of Life Cycle Assessment 8, (5) 290-296.

Comisión Federal de Electricidad (CFE) CFE-GUI-PA-008, 2008. Guía para elaborar inventarios de emisiones de gases efecto invernadero por la operación de centrales termoeléctricas (Guide to prepare inventories of greenhouse gas emission in the termal power station operation). Gerencia de Protección Ambiental, Comisión Federal de Electricidad. Distrito Federal, México.

Comisión Federal de Electricidad (CFE) 2010. Portal electrónico www.gob.mx marzo 07, 2010

Di X, Nie Z, Yuan B, Zuo T (2007). Life Cycle Inventory for Electricity Generation in China, International Journal of Life Cycle Assessment 12, (4) 217-224.

Draft International Standar ISO/DIS 14066 Greenhouse gases-Competence requirements for greenhouse gas validation teams and verifications teams.

Dubreuil, A. (2001). Inventory for Energy Production in Canada. International Journal of Life Cycle Assessment 6, (5) 281-284.

Hennicke, P. (2005). Long term scenarios and options for sustainable energy system and for climate protection: A short overview. International Journal of Environmental Science and Technology 2, (2) 181-191.

International Energy Agency, World Energy Outlook, Paris, 2004.

IPCC (2001). Informe de Síntesis. Evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC), XVIII Reunión Plenaria del IPCC, Wembley, Reino Unido, 24-25 de septiembre del 2001.

IPCC (2006). Guidelines for national greenhouse gases inventories. Volume 2 Energy, Grupo Intergovernmental panel on climate change, IGES Japón.

IPCC, (2007). Fourth Assessment Report: Climate Change.

ISO 14040:2006 Environmental Management-Life Cycle Assessment-Principles and Framework

Kim S, Dale B (2005). Life Cycle Inventory Information of the United States Electricity System, International Journal of Life Cycle Assessment 10, (4) 294-304.

Lee KM, Lee SY, Hur T (2004). Life cycle inventory analysis for electricity in Korea. Energy 29 87-101.

Matsuno Y, Betz M (2000): Development of Life Cycle Inventories for Electricity Grid Mixes in Japan, International Journal of Life Cycle Assessment 5, (5) 295-305.

OECDE Organization for Economic Co-operation and Development/International Energy Agency (2007). CO2 emissions from fuel combustion. 2007 Edition. Paris, France.

OECDE Organization for Economic Co-operation and Development/International Energy Agency. Electricity Information (2008). Edition. Paris, France.

Peiu N, (2007): Life Cycle Inventory Study of the Electrical Energy Production in Romania. International Journal of Life Cycle Assessment 12, (4) 225-229.

Phumpradab K (2009): Life Cycle Assessment of Natural Gas Power Plants in Thailand. International Journal of Life Cycle Assessment 14:354-363.

Poder Ejecutivo Nacional. Plan Nacional de Desarrollo (National Plan of development). 2007-2012. Poder Ejecutivo Nacional. México

Rapun Jimenez J. L. (1999) Tesis Doctoral: Modelo Matemático del Comportamiento de Ciclos Combinados de Turbinas de Gas y Vapor, Departamento de Ingeniería Energética y Fluidomecánica, Escuela Técnica Superior de Ingenieros Industriales, Madrid España.

Secretaría de Energía, 2010. Indicadores www.sener.gob.mx

Weisser, D. (2006). A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies, Energy 32 (2007) 1543-1559.

The Mexican Life Cycle Inventory Database - MEXICANIUH

González-Colín Mireya*[1], Suppen-Reynaga Nydia[2] , Felix-Acuña Reynaldo[3]

Centro de Análisis de Ciclo de Vida y Diseño Sustentable (CADIS)
mgonzalez@centroacv.mx[1] nsuppen@centroacv.mx[2] rfelix@centroacv.mx[3]
Calzada Jinetes 22-B, Tlalnepantla, Edo. Mex., México C.P. 54020

ABSTRACT

In Latin America, market requirements are increasingly incorporating environmental variables thus increasing the use of methodologies that provide sound indicators and information on environmental impacts, such as life cycle assessment (LCA). In order to perform LCAs data on the different stages of the life cycle of a product must be collected in the form of an inventory - a life cycle inventory is the collection of data inputs and outputs of the product, as defined in ISO 14040 - . There is a need to develop LCIs so that companies and academics can perform LCAs closer to the reality of the region, in this sense the Center for Life Cycle Assessment and Sustainable Design (CADIS) in Mexico has been collecting and organizing a database of products, processes and services for the past six years. The present paper presents an overview of this development.

Keywords: life cycle inventory, database, Mexico.

Introduction

LCI databases are widely used and they must have important characteristics of transparency, good documentation and flexibility. Likewise, the generation of data should be practical and efficient.

In the late 90's, some databases have been published and developed by various institutes and organizations (Frischknecht et al. 1996; Frischknecht et al. 1994, Gaillard et al. 1997; Habersatter et al. 1996; Habersatter et al. 1998; Künniger and Richter 1995). However, the material or process data often do not match the operating characteristics, raw materials, technologies and / or emissions of the countries or regions where the use of LCA is in progress.

The development of Mexicaniuh

In recent years many companies in Latin America have started work on the field of LCA. Many of these companies at the beginning of the value chain are important partners in the development of regional data, especially that of fuels and electricity. For example big petroleum enterprises in the region such as Petrobras (Brazil), ECOPETROL (Colombia), PEMEX (Mexico), PDVSA (Venezuela), as well as power generation facilities in Cuba, Costa Rica, Argentina and Mexico, are paying attention to the development of LCA in other to make proper decisions in the development of laws and to reduce their environmental impacts.

When developing an LCI database, data can be collected directly or indirectly from companies Depending on the company, data can be directly calculated and determined from environmental reports, annual reports or reports that meet current legislation. This information can be used in conjunction with other data. LCI databases must be completed along the value chain of processes and products documented in them, therefore the participation of the different companies providing data and consensus in generic models is very important. In the case of Mexico, the LCI database has been mostly developed in conjunction with companies and taking into account the reality of local environmental problems.

The aim of CADIS is to offer a series of high quality generic and unified LCI dataset, for energy, oil and petrochemicals, biofuels, minerals and metals, chemicals, water, transport, agriculture, wood, building, leather and textiles, among others. This to ensure the credibility and reliability of the results of any LCA conducted in Mexico.

Scope and principles in Mexicaniuh

The selection of products and substances to be included in Mexicaniuh started in 2005. The geographical coverage includes Mexico and some Latin American regions. The unit processes included in this LCI database represent in most cases, an average of the latest technologies. An 90% of the analyzed product systems include the emissions from construction stage, 100% of the manufacturing stage and 70% of the disposal stage.

As far as possible, the database contains data from suppliers with similar unit processes. Inputs and outputs of the different processes are added only if:
a) Individual data are not available.
b) Individual data are confidential.

If data availability is poor, mass balances are used to determine the consumption of raw materials; in other cases a sensitivity analysis was conducted. According to the influence of the latter on the LCA results the LCI was maintained or adjusted. Some unit processes were also modeled considering market studies.

Some examples of modeling in Mexicaniuh include: the electricity dataset based on the production mix of energy delivered to the user. CADIS modeled in 2008 the generation and delivery of electricity corresponding to medium voltage.

In most datasets, the distances are estimated considering transportation of imports and exports; this information comes from reliable sources such as suppliers of raw materials and / or distributors of the products analyzed. The inputs and outputs for production have been collected and registered separately from the infrastructure. The mass and energy flows are represented by unit processes, including the use of land, the transformation and data of infrastructure. The datasets documentation complies with international documentation requirements and a software application is currently being developed.

Conclusions

It is very important to generate national inventories, due to the materials and processes used varies depending on geographical conditions. An LCI database was not available in Mexico prior to this work; the relevance of this work lies in the collaboration with industry for its development and with international expert for its documentation and operation. There is a systematic methodology for conducting a life cycle inventory; however, the recognition of the specific characteristics of each process and the obstacles and constraints for data gathering in different regions should be considered when developing life cycle inventories.

This work represents an effort to provide tools to further the use of LCA by different stakeholders in the Latin American region.

References

1) Frischknecht R., Bollens U., Bosshart S., Ciot M., Ciseri L., Doka G., Dones R., Gantner U., Hischier R. and Martin A. (1996) Ökoinventare von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. 3. Gruppe Energie - Stoffe - Umwelt (ESU), Eidgenössische Technische Hochschule Zürich und Sektion Ganzheitliche Systemanalysen, Paul Scherrer Institut, Villigen, Bundesamt für Energie (Hrsg.), Bern, CH, from www.energieforschung.ch.
2) Frischknecht et al. 1994; Frischknecht R., Hofstetter P., Knoepfel I., Dones R. and Zollinger E. (1994) Ökoinventare für Energiesysteme. Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. 1. Gruppe Energie - Stoffe - Umwelt (ESU), Eidgenössische Technische Hochschule Zürich und Sektion

Ganzheitliche Systemanalysen, Paul Scherrer Institut Villigen, Bundesamt für Energie (Hrsg.), Bern.
3) Gaillard G., Crettaz P. and Hausheer J. (1997) Umweltinventar der landwirtschaftlichen Inputs im Pflanzenbau. 46. Eidg. Forschungsanstalt für Agrarwirtschaft und Landtechnik (FAT), Tänikon.
4) Habersatter et al. 1996; Habersatter K., Fecker I., Dall`Acqua S., Fawer M., Fallscheer F., Förster R., Maillefer C., Ménard M., Reusser L. and Som C. (1996) Ökoinventare für Verpackungen. 250. Bundesamt für Umwelt, Wald und Landschaft, Bern, Schweiz.
5) Habersatter K., Fecker I., Dall`Acqua S., Fawer M., Fallscheer F., Förster R., Maillefer C., Ménard M., Reusser L. and Som C. (1998) Ökoinventare für Verpackungen. 250, 2. korrigierte und aktualisierte Auflage. Bundesamt für Umwelt, Wald und Landschaft, Bern, Schweiz.
6) Künniger T. and Richter K. (1995) Ökologischer Vergleich von Freileitungsmasten aus imprägniertem Holz, armiertem Beton und korrosionsgeschütztem Stahl. EMPA, Dübendorf.
7) Frischknecht, R.; Jungbluth, N.; Althaus, H; Doka, G.; Dones, R; Heck, t.; Hellweg, S; Hischier, R.; Nemeck, T.; Rebitzer, G.; Wernet, M. S. G. W., 2007, "Ecoinvent: overview and methodology". Data v 2.0. Dübendorf: Swiss Centre for Life Cycle Inventories, 68 p.
8) International Organization for Standardization – ISO (2006). ISO 14044:2006. "Environmental management – Life cycle assessment – Requirements and guidelines".
9) International Reference Life Cycle Data System (ILCD) Handbook, Specific guidance document for generic or average Life Cycle Inventory (LCI) data sets, June 2009, 37-61, 66 Y 81P.

Sustainability

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Towards a Life Cycle Sustainability Assessment of Products – A tool to increase competitiveness in developing countries and emerging economies

Valdivia, Sonia[1], Ciroth Andreas[2], Sonnemann Guido[3], Ugaya, Cássia Maria Lie[4], Lu Bin[5], Alvarado Carmen[5]

[1]SCP Branch, UNEP DTIE Paris,
15 rue de Milan,
75441 Paris Cedex 09, France
e-mail: sonia.valdivia@unep.org

[2]SETAC North America,
GreenDelta TC, Raumerstrasse 7
10437 Berlin Germany

[3]SCP Branch, UNEP DTIE Paris,
15 rue de Milan,
75441 Paris Cedex 09, France

[4]Federal Center of Technologic Education,
Parana, Brazil

[5]Research Center for Eco-Environmental Sciences
, Chinese Academy of Sciences
P. O. Box 2871, 18 Shuangqing
Road, Haidian District, Beijing, 100085, China

[6]Pré Consultants bv
Printerweg 18
3821 AD Amersfoort
The Netherlands

Abstract

Taking the life cycle approach means going beyond the traditional focus on production site and manufacturing processes and including the environmental, social, and economic impact of a product over its entire life cycle. In order to put life cycle thinking into effective practice, the United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC) launched an International Partnership, the so-called 'Life Cycle Initiative'. The Life Cycle Initiative contributes to the 10-Year Framework of Programs in order to pursue Sustainable Consumption and Production (Marrakech Process). The Project Group of the Life Cycle Initiative on Social Life Cycle Assessment started its work in 2005. Following the completion of the UNEP Guidelines for Social LCA of products, this Project Group has the aim to interlink current LCA tools and provide a triple-bottom-line sustainable development toolbox.

The authors propose a toolbox for Life Cycle Sustainability Assessment (LCSA) based on life cycle based techniques which are ISO 14040 conform: environmental LCA (E-LCA), social LCA (S-LCA) and life cycle costing (LCC). The aim of this toolbox is to contribute to better informed decisions on sustainability aspects of products. The toolbox presents categories and sub-categories of impacts for the three dimensions of sustainability; the toolbox does not imply neither impact assessment methods nor interlinkages models but provides recommendations on how to proceed with results obtained.

The toolbox proposed for LCSA has a high potential to be used by decision makers in Governments, agencies for international cooperation, business and consumers' associations. Still more research and applications are needed, but its application is already feasible and encouraged to speed the learning curve of the society.

Keywords: sustainability life cycle assessment, toolbox, social LCA, life cycle costing

A way to implement a LCSA

A common functional unit is defined and is the basis of all approaches developed in order to support decision making processes. Similar to a S-LCA, in LCSA an additional attribute of the functional unit related to the social utility or social performance of the products is needed.

LCC, S-LCA and E-LCA pursue different overall aims. While the LCC has the aim to provide an indication on costs along the product chain, E-LCA and S-LCA provide findings on environmental and social hotspots, correspondingly. The authors recommend to state this clearly before starting with the implementation of the three approaches. However, when undertaking an integrated study a common goal and scope has to be defined and should refer to the goal and scope of study in relation to the intended application. Apart from describing the functional unit, the goal and scope should address the overall approach used to establish the system boundaries. The system boundary determines which unit processes are included in the LCA and must reflect the goal of the study. In an integrated application, attributional modeling is proposed to limit the scope of the system.

Considering the early stage of this LCSA framework, no proposals and recommendations are given on the way to handle an integrated impact assessment. If a process has more than one output, the question is to which of the outputs should the burden be allocated. As long as quantitative inventory indicators are available, results should proportionally presented per output produced. A guideline on how to handle multiple output processes can be found in the ISO 14040-44 standards. In case of qualitative inventory indicators a description of results obtained per each product is recommended. Considering the early stage of integrated approaches, authors recommend to start with steady-state rather than dynamic approaches. The time-horizon has different perspectives in E-LCA, LCC and S-LCA and it is proposed to present the results in light of different time horizons: short-term and mid-term time periods for LCC and S-LCA and mid-term to long-term ones for E-LCA. The lecture of results depends on the goal of the integrated study. Three possible cases can illustrate the ways to make use of them: to understand if there are trade offs between economic benefits and environmental or social burdens; to understand which life cycle stages are critical; to understand if the product is socially and environmentally friendly.

The integrated approach proposed is ISO 14040/44 conform. Then, a critical review (CR) is mandatory for LCAs intended for comparative assertions where results are aimed to be made available to the public. If such studies claim to be performed according to ISO 14040/44, a CR shall not to be considered as voluntary.

What is next

- The set up of databases to help implementing the three approaches in a linked and consistent way.
- More research on the assessment of product utility and the sustainability of products in order to avoid the unethical use of the tools.
- More fluent integration of all three dimensions in one integrated assessment and better understanding of linkages of their impacts and potential escalation effects; hence, more convergence of separate “schools” of people applying social, cost, environmental assessment.
- More applications of integrated tools meaning E-LCA, LCC and S-LCA and learning experiences in order to reduce “trade-off errors” in sustainability decision support.
- More guidance and examples of review processes considering the importance of having strong involvement of concerned parties, especially when doing a S-LCA.

Conclusions

It is proposed to start looking at the whole picture instead of focusing on individual elements. The framework for LCSA is a toolbox with high potential to be used by decision makers in Governments, agencies for international cooperation, business and consumers’ associations. Still more research and applications are needed, but its application is already feasible and encouraged to speed the learning curve of the society.

References

[1] UNEP (2009). Guidelines for Social Life Cycle Assessment of Products (at http://lcinitiative.unep.fr).
[2] ISO 14040 (2006). Environmental Management – Life Cycle Assessment –Principles and Framework. International Organization of Standardization
[3] ISO 14044 (2006). Environmental Management – Life Cycle Assessment – Requirements and Guidelines. International Organization of Standardization
[4] Lu B (2009). Integrated LCA of Obsolete PC Recycling System, Research Center For Eco-Environmental Sciences, Chinese Academy of Sciences, Proceedings of the 2nd LCM China Conference, Beijing
Acknowledgement - The authors thank to the International Life cycle Board and Partners of the UNEP/SETAC Life Cycle Initiative for providing the financial resources needed for this partnership.
[5] David Hunkeler, Kerstin Lichtenvort, Gerald Rebitzer. Environmental Life Cycle Costing. 2008

An approach to the sustainable in impact category assessment: global warming

Hernández, F. Javier[1]; Morillón, David[2] and Hernández, Hermilio.[3]

[1] Universidad Autónoma de Nayarit. Parque San Jorge No. 121, Villas del Parque; Tepic, Nayarit. C.P. 63173, franjha@gmail.com. Tel: 311 2196703 [2] Universidad Nacional Autónoma de México; [3] Universidad Autónoma de Nayarit.

Abstract
The concept of sustainability is currently being discussed, debated and interpreted in different ways, however, is still difficult for practical application. The present work, rather than a definition of sustainability, provides reasoning for approaching this. With regard to global warming, humanity faces the challenge of achieving the balance between CO_2 emissions and land sequestration capacity. Based on the concept of carrying capacity, this research suggests determining a limit to the amount of CO_2 emission by energy consumption. To determine this limit, the concept of sustainability can be translated in quantitative criteria for measurement, so can assess the level of sustainability of a country's economic activities, as well as targets for reducing emissions which may be truly sustainable. The limit was calculated for the Mexican case.

Topic: Life cycle analysis: inventory and assessment of impacts.
Keywords: sustainability, load capacity, global warming, CO_2.

Introduction
Most of current economies are moved by the use of fossil fuels, it which are extracted from nature to produce energy [1]. The burning of fossil fuels produces emissions of gases to the atmosphere as the carbon dioxide (CO_2), the greenhouse gas (GHG) main of source anthropogenic, which, since the Antropoceno, the man has thrown out to atmosphere with greater speed than the capacity of absorption of Earth's carbon sinks [2], so the excess accumulated in the atmosphere gradually is contributing to the warming of the Earth.

Of environmental responsibility that demands sustainable development in terms of its definition in the Janeiro Rio Earth Summit in 1992, humanity faces the challenge of moving towards sustainability. According to Jacob [3] to move towards sustainability requires the identification of limits, both in economic activity and the capacity of the Earth. In this regard, with respect to global warming, the previous challenge can translated to: a balance reasonable between CO_2 emissions from fossil origin and the carrying capacity of sinks of carbon planet. The question is therefore what is the limit of CO_2 emissions by consumption of fossil energy that our planet can absorb and assimilate? What level of CO_2 emissions by fossil energy consumption can be considered sustainable?

There are products in the market that they use in their advertising the adjective "sustainable" or "friendly to the environment" to indicate the effort put into reductions in energy consumption and CO_2 emissions. However, the question arises what "sustainable" or "friendly to the environment" are in reality? The main objective of this text is to develop a method to evaluate the level of sustainability of products and services in the impact evaluation of the category: global warming, feasible of use in life-cycle analysis (LCA) studies.

Method
Develops it parameter: maximum load capacity of CO_2 (CCM_{CO2}) to assess the impact category: global warming. The parameter is based on the concept of carrying capacity to identify, the level

of CO_2 emissions from fossil consumed energy that the Earth's carbon sinks can capture and assimilate. The amount of CO_2 emissions from fossil origin of energy consumption that demand the implementation of an economic activity analyses it through indicator: intensity of CO_2 from energy consumption ($I_{CO2}CE$), which should be expressed in kilograms of CO_2 per used megajoule ($kgCO_2/MJ$). The comparison of the result of indicator ICO_2CE with the parameter CCM_{CO2}, identifies the level of sustainability of the actions.

The CCM_{CO2} was calculated for the Mexican case and was: 0.02918 $kgCO_2/MJ$. This means that the relationship between CO_2 emissions from fossil origin and energy consumption to manufacture any product or develop any economic activity in Mexico, must be less than or equal to 0.02918 $kgCO_2/MJ$. Higher values exceed the carrying capacity of our planet and contribute to the accumulation of CO_2 in the atmosphere; values minors, they point towards sustainability.

Conclusions

In a perspective of sustainable development, the determination of the CCM_{CO2} parameter and its comparison with the reality (expressed in terms of $I_{CO2}CE$), can make possible first the identification and quantification of the success or failures in the energy consumption of the economic activities of any country in the world. With its application in LCA studies, you can view and establish reduction targets that may be considered truly sustainable in the life cycle of a product.

References

[1] Of the total energy consumed in the world in 2006, nearly 81% came from fossil fuels (International Energy Agency. 2007. Key world energy statistics 2008. www.iea.org. Accessed: 03/11/2008), while in Mexico in the same year, its use was greater than 88 % (Secretaría de Energía. 2008. Balance Nacional de Energía 2007. www.sener.gob.mx. Accessed: 26/09/2008).

[2] The Period 2000 to 2007 global carbon budget analysis, notes that worldwide carbon sinks reduced its capacity of absorption and elimination in 5% in relation to 1990s (Hernández Ayón, F. J. 2009. Energía incorporada y emisiones de CO_2 en la edificación. Tesis de Doctorado en Arquitectura. D.F. México. UNAM).

[3] "For each element of the environmental capacity for each resource for each download of residues in the environment can identify it a maximum level of stock or flow, beyond which this capacity begins to wane. For an economy that take aim at sustainability, these peaks are actually restrictions, if economic activity exceeds them, already cannot be sustainable". Jacob words, quoted by: Alguacil G. Julio. 1998. Calidad de vida y praxis urbana. Documentos CF+S. www.habitat.aq.upm.es. Accessed: 10/02/2010.

A Capability Approach to Life Cycle Sustainability Assessment and Improving Competitiveness in Local Economies

ABSTRACT

Sustained high performance requires a balanced focus on top- down initiatives for results- driven action and bottom- up organizational development and learning initiatives to create a culture of continual improvement. UNEP and SETAC are promoting a capability approach to facilitate implementation of life cycle management in small to medium sized enterprises (SMEs), particularly in developing economies. The framework provides a structured sequence of improvement actions based on the experiences of leading companies. A decision- centric model provides a practical basis to assess organizational readiness for various life cycle methodologies, and an emphasis on context- based decision- making facilitates effective application of local knowledge to address the specific need and challenges of the company and its host community. Improvement projects are designed to meet the near term performance targets to ensure competitiveness, while also gradually building the components of a comprehensive managements system for long term performance.

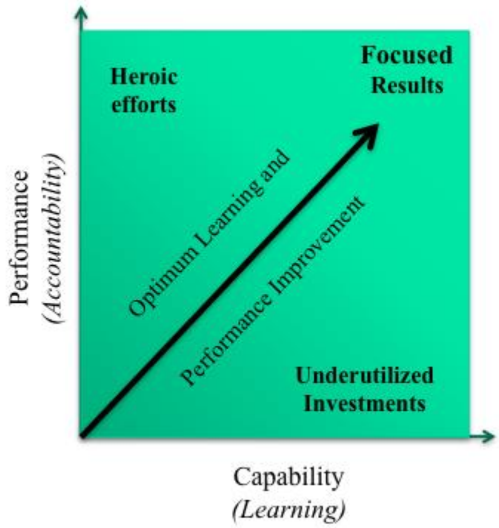
Introduction

A survey of CEOs that had committed to the UN Global Compact indicated that while sustainability had clearly become firmly embedded in top- level strategic thinking, it had yet to permeate core business routines —that is, into capabilities, processes and systems [1]. Companies that are recognized leaders in sustainability demonstrate a balanced approach that drives performance against near term improvement targets and invests in long-term organizational development.

- Johnson & Johnson reports progress against goals to reduce energy and water use, eliminate waste, optimize packaging and numerous other environmental objectives, and supports these objectives with environmental literacy goals to increase employee awareness and understanding of global environmental issues.
- Walmart formed sustainability value networks that bring together leaders from the company, supplier companies, academia, government, and non-governmental organizations (NGOs) to collaboratively develop solutions that benefit all stakeholders. The company is also committed to developing a sustainability index to make supply chin performance more transparent.
- Nike committed to an open innovation design process to deliver superior products that reduce or eliminate toxic materials and waste and increase use of environmentally- preferred materials. To guide their efforts, the company developed the Considered Index to predict the environmental footprint of a product prior to commercialization.

Research on organizational change has shown that sustained high performance requires both top- down initiatives for results- driven action and bottom- up organizational development efforts to instill a culture of learning and continuous improvement [2]. A single- minded focus on performance targets with insufficient investment in supporting systems demands heroic efforts by employees to "meet their numbers" and can lead to employee burnout. Similarly, over emphasis of systems, procedures and supporting infrastructure can result in under- utilized investments that yield poor returns. A balance is necessary for focused results that deliver maximum business value. This is illustrated in the following figure.

Figure 1



Balanced Assessment of Sustainability Performance

Discussion

The critical question becomes how to leverage the experiences of the leadership companies to more quickly diffuse sustainability into core business capabilities, processes and systems of companies across the value chain. Some lessons can be learned from similar challenges faced by quality improvement efforts in the 1980's and 1990's [4-6]. US lean manufacturing initiatives were built on the Toyota Production System, and researchers, academics, consultants, and business managers developed an expanded vision of the values, behaviors, and practices that constituted a "lean enterprise." This vision of what constituted lean provided little guidance on how. Practitioners were faced with a confusing array of principles, tools and practices lumped under the banner of 'lean production,' but given little help on the order or precedence for effective implementation. It is important to point out that leadership companies did not achieve their current position in a single huge leap. There is typically a multiyear history of incremental fits and starts. The leaders gradually developed the capacity for sustained high performance, moving from end- of- pipe compliance to pollution prevention and waste reduction at the source, to eco- efficient product design and development, and then to more robust sustainability programs.

Capability Development

UNEP and SETAC are partnering to promote a capability framework to speed the diffusion of life cycle management practices to small- to- medium sized enterprises (SME). The framework builds on the familiar Plan- Do- Check- Act quality improvement cycle to take advantage of previous investments in lean manufacturing [7]. Each improvement cycle starts with a management commitment to achieve goals matched to the organization's current state of understanding and practice of life cycle management. There is a commitment to quantify the organization's performance and set specific improvement targets. Improvement projects are then used to develop the procedures and systems necessary to achieve the performance targets. The fundamental difference, and benefit of the capability framework is that improvement projects are designed to serve a dual purpose of gradually building the components of a comprehensive management system while meeting near- term performance targets imposed by customers, investors, and other key stakeholders.

The framework is structured around key business processes. Leadership processes set the direction for the organization and determine if there is sufficient motivation and organizational support to achieve the defined goals for environmental performance and social equity. Life cycle management (LCM) processes provide the operational discipline to build, deliver, support, and retire product offerings in a safe, clean, equitable, and profitable manner. Enabling infrastructure ensures the necessary equipment, information, and people are in place over the long term. The framework evaluates the organization's decision- making processes to provide a practical basis for planning improvement efforts. Decisions design the organization. Resources are committed by decisions, and it is the use of resources that ultimately lead to the environmental and social impacts. Decisions are supported by information systems and the metrics used to monitor and control operations. Finally, sustainability requires a broadening of concern to include all interested stakeholders in the decision-making process. The capability framework presents a logical path (see Table 1) for the development of life cycle capabilities aligned with strategic objectives.

Table 1 – Roadmap for Building Capability

Maturity	Business Case	Management System	Indicators
Qualified	Risk avoidance License to operate	Work rules, procedures Inspections Emergency planning	Wastes, emissions Fines & penalties
Efficient	Process efficiency Improved operating margins	Risk assessment Management audits Training & development	Inputs & outputs Energy use Toxic chemical use
Effective	Top line growth Innovative products, new markets	Design for environment Annual program reviews Marketing & communication plan	GHG & water footprint Product impacts
Adaptive	Capital preservation Stronger balance sheet Sustainable prosperity	Stakeholder engagement Strategic government affairs Public- private partnership	Sustainability index Ecosystem services Externalities

The fundamental thinking behind this approach was that there is a logical sequence of skills that must be put in place to effectively manage sustainability issues. The foundational skills, such as hazard identification must be in place before attempting more complex methodologies, such as life cycle assessment. The framework is designed to gradually build the capability of the organization to manage more complex decisions with more inclusive processes. The span of concern is expanded from the facility to the enterprise to the value chain, and ultimately to civil society. Information and metrics become more diverse and complex to reflect the interests and values of the various stakeholders. At the beginning of the learning process, organizations rely on binary yes- no compliance measures. As organizations build capability, they move through cost- benefit calculations, eco- efficiency metrics, and finally to complex assessments of system resiliency and sustainability. Information systems will need to develop to handle non- financial measures of resource use and emissions, as well as both quantitative and qualitative measures of social impacts. Decision- processes are gradually developed to support long- term and precautionary perspectives. By focusing on capabilities, organizations can more effectively make use of established routines, tools and methods already embedded in their management systems and culture. By incrementally building capacity in a logical sequence based on the experiences of leadership companies, SMEs can move up the learning curve more quickly and target improvement projects more likely to succeed and better aligned with their strategic priorities.

Summary and Conclusions

Sustained high performance relies on a balanced approach that uses near- term performance targets for results- driven action combined with longer- term organizational development efforts to create a culture of continual improvement. The learning experiences of leadership companies can be used to develop a structured approach for the incremental development of organizational capabilities in SMEs with limited resources and experience with life cycle methods. A decision- centric model provides a practical basis for assessing organizational readiness for various methodologies. The emphasis on context- based decision- making also facilitates effective application of local knowledge to address the specific need and challenges of the company. This capability can be used for economic entrepreneurship to boost material production, or for social entrepreneurship to reform institutions and ensure decision- makers are held accountable to local priorities for sustainable development. Vital communities provide more competitive production facilities, thus maintaining alignment between local development goals and corporate business goals.

References:

1. Lacy, P., Cooper, T., Hayward, R., & Neuberger, L. 2010. A New Era of Sustainability: UN Global Compact-Accenture CEO Study 2010: Accenture.
2. Beer, M. 2001. How to develop an organization capable of sustained high performance: Embrace the drive for results- capability development paradox. Organizational Dynamics 29(4), 233-247.
3. Sharma, S., & Vredenburg, H. 1998. Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities. Strategic Management Journal 19, 729-753.
4. Scholtes, P. R. 1998. The Leader's handbook: A guide to inspiring your people and managing the daily workflow. New York (NY), USA: McGraw - Hill.
5. Sterman, J. D., Repenning, N., & Kofman, F. 1997. Unanticipated side effects of successful quality programs: Exploring a paradox of organizational improvement. Management Science 43(4), 501-521.
6. Nightingale, D. J., & Mize, J. H. 2002. Development of a lean enterprise transformation maturity model. Information • Knowledge • Systems Management 3, 15 - 30.
7. Swarr, T. E., Fava, J., Jensen, A. A., Valdivia, S., & Vigon, B. 2010. A capability framework to promote life cycle management practices in lower tier suppliers Paper presented at the SETAC North America 31st Annual Meeting. 2010, 7-11 November, Portland (OR), USA.

Life Cycle Assessment comparing Sugar Cane vs. Stevia Rebaudiana Sweetener, for Mexico City Market.

Salinas, Rodolfo[1] **and Güereca, Leonor**[2]
[1] ***Instituto Tecnológico de Estudios Superiores de Monterrey-CEM; and*** [2] ***Instituto de Ingeniería, UNAM***
Contact Info:✉ rodosalinas@gmail.com, ✆ +52-5539392444

ABSTRACT

Sugar cane consumption is fundamental in the diary diet not only for Mexican´s but for every person, because it provides the sensation of sweetness to the human palate. However, the abuse in consume of this product has caused several heath problems especially in Mexican population, as obesity, diabetes and hypertension among others. In the other hand, stevia sweetener is a natural non-caloric new product, ideal to substitute sugar consumption. However, in order to have strong sustainable criteria, is necessary to count on with a deepest scientific study that reveals the real benefits or damages caused by stevia sweetener consumption. In this way the study main objective was to compare both products using the life cycle assessment methodology, in order to quantify the impacts to human health and environment, as acidification, depletion of abiotic resources, depletion of stratospheric ozone, eutrophication and greenhouse effects.

Topic: LCA Management Trends: Sustainability LCA

Keywords: Stevia Rebaudiana Bertoni, Sweetener, Sugar Cane, LCA.

INTRODUCTION

Sugar cane is known for mankind for more than two thousand years, however paradoxical it may seems, it´s use was not popular until the seventeenth century, where this product wasn´t found in markets but only in selected pharmacies as a highly valued product. This because sweetness is definitely a feeling without which human taste can´t live, however, the abuse of its consumption has contributed to severe health problems as obesity and diabetes, and also the increasing use of biofuels have increased market price of sugar cane, and in many cases forced to use transgenic species that can raise the agricultural productivity to keep a relative market equilibrium.

In the other hand, stevia sweetener is presented as a natural non-caloric alternative product, that is obtained from a separation process by nano filtration and crystallization from road *Stevia Rebaudiana Bertoni*, a plant that is native to the Chaco region of South America, shared by Bolivia, Brazil and Paraguay. This plant has been widely used by the Guarani tribe, even before the arrival of Spanish to America.

The main purpose of this paper is to analyze the impact of sugar cane, and stevia sweetener, both products consumed in Mexico City, taking into account sugar produced in the industrial sugar block of Veracruz, about 400 km away, and the stevia sweetener, produced in the city of La Paz in Bolivia, which must be transported 5,334 km to reach the final destination.

PROCEDURE METHOD OF LIFE CYCLE ASSESSMENT

An analysis inventory was performed separately for sugar cane and stevia sweetener, taking into consideration all agricultural and industrial processes, also characterization and interpretation of the entire life cycle chain for each of them. In order to make a correct comparison it was defined and used a “functional unit”, based on per capita sugar consumption in Mexico (2009), estimated at 52 kg compared with 0.186 kg of stevia sweetener, this comparison is based on the sweetness of each product, considering that the analyzed sweetening power of stevia sweetener is 279 times greater than the Sugar Cane.

METHODOLOGY:

The Life Cycle Assessment (LCA) is the methodology used to assess the potential impacts of production chain in both scenarios, it´s accepted and recognized internationally for evaluating environmental burdens and impacts associated with the development of a product or process, it takes into consideration all stages of life cycle of the product studied, considering the environmental performance of the generation of products and services.

The ACV is standardized by the ISO 14040, which states the following 4 steps: Definition of the objective and scope of the study, Collection of Life Cycle Inventory, Evaluation of impacts, and Interpretation of results.

OBJECTIVE´S DEFINITION

The main objective was to determine the environmental impacts of the stevia sweetener production compared with sugar cane, in order to use this as marketing information for the company Sweetnatural, and a possible implementation of this product as a natural non-caloric ecologic sweetener in the Mexican market.

SCOPE OF THE STUDY

In order to complete the life cycle of both products, this study considered the following macro processes:

- ⇨ Cultivation.
- ⇨ Transport of raw material to factory.
- ⇨ Industrialization.
- ⇨ Final transport to consumer.

For sugar cane it was considered that the cultivation and industrialization takes place in Veracruz México and the final product id transported by truck to México D.F., in the other hand, for stevia sweetener if was considered that *stevia rebaudiana bertoni* is cultivated and industrialized in La Paz Bolivia, from which must be transported to the same final market by plane.

COLLECTION OF LIFE CYCLE INVENTORY

The information required for the development of the assessment was based on 2 important sources, and cropping data transport in the case of Sugar cane is based on the thesis "life cycle analysis and use of ethanol from sugar cane in Mexico "prepared by the MSC. Diana Jaramillo, ITESM 2010. Moreover, the data of industrialization of sugar reports were obtained from the Center for Transition Studies Democratic A.C. Mexico.

On the other hand, the cultivation of Stevia data was obtained from the Manual: "Technical Recommendations for a Sustainable production Ka'A'he'e (*Stevia rebaudiana Bertoni*)" adapted to production in the Caranavi population (La Paz, Bolivia).

Complementary production details of process were based on the thesis "Technical-Economic Feasibility Project for Stevia rebaudiana Bertoni production in La Paz Bolivia "by Eng Limache Imbert, 2006.

It should be mentioned that were not taken into account in the studied impacts of sugar cane the impact caused by burning cane harvesting and the burning of bagasse as a by-product of the industrialization process of sugar.

Complementary it must be mentioned that for the lack of some information, the following considerations and assumptions were made in order to make the analysis:

- An analogy was made about data of electricity production in Mexico taking information from the electricity production of Luxembourg, since the resemblance of the energy matrix in terms of distribution of power plants, hydroelectric and nuclear power.
- In the absence of production data of products 2-4D Gramoxone, Karmex, Foley, Klerat and Nuvacrón in the agricultural production of sugar cane and Damonet, Carbaryl, and Kasugamycin in Stevia agricultural production, all these compounds have been omitted analysis.

The Life Cycle Inventory analysis was developed through TEAM 5.0 software, the application and impact categories selected correspond to those performed by the Institute of Environmental Sciences CML_2000 Leiden University.

In this way the 6 categories of study selected from the methodology LCA were:

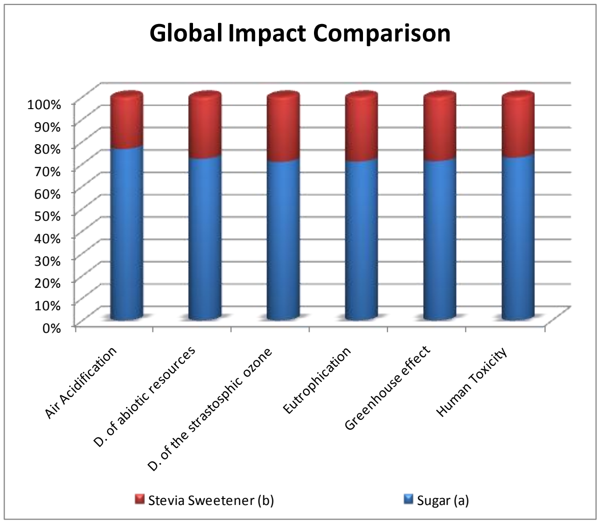
Table 1. Impact categories selected for the study

CML-2000 Category	Indicator
Air Acidification	g SO_2 eq
Depletion of abiotic resources	g Sb eq
Depletion of the strastosphic ozone	g CFC-11 eq
Eutrophication	g PO_4 eq
Greenhouse effect	g CO_2 eq
Human Toxicity	g 1-4, DB eq

RESULTS

The contributions by each stage of both systems at each of the selected impact categories are presented in figure 1:

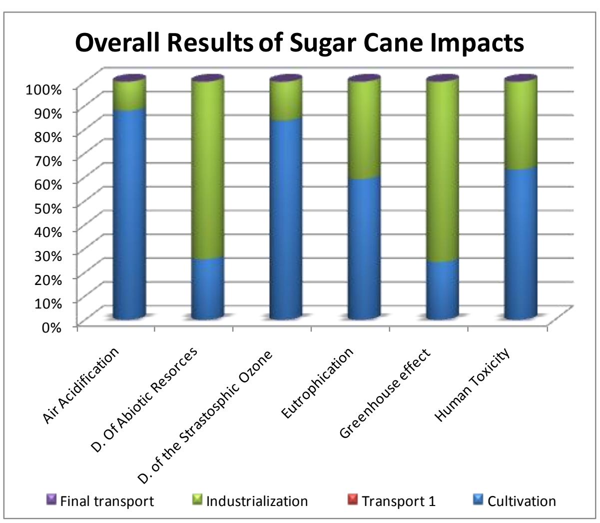
Figure 1. Global Impact Comparison



As can be seen in an overall comparison between functional units, it is shown that the cane sugar causes in average 72.55% more impact on the environment than the stevia sweetener, taking into consideration the selected impact categories.

Meanwhile, for a better understanding, in the following figure it´s showed the impact contribution of each thread of sugar cane life cycle.

Figure 2. Sugar Cane Impacts by Thread



The system of sugar cane production generates significant impacts derivate from growing, especially in acidification with 87.86% and decrease of stratospheric ozone with 83.73%, as well as Human Toxicity with 63.15% and eutrophication with 59, 17%.

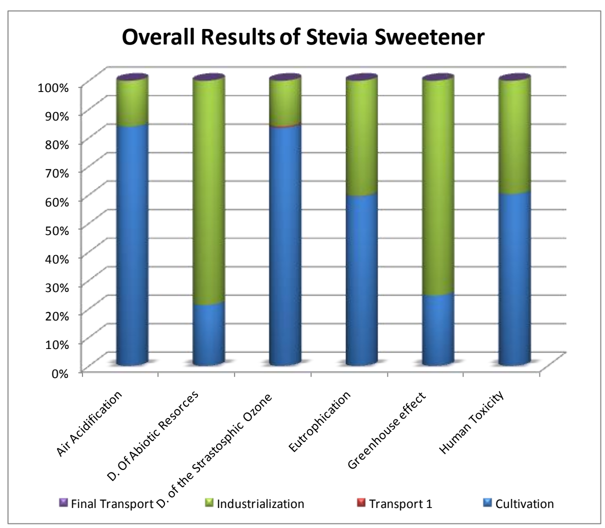
Moreover, the industrialization of sugar has a strong impact on abiotic resources depletion with 74.48% of the total, and also contribution to greenhouse gases with a 75.70%.

In general it can be seen that the transport activity 1, corresponding to the movement of cane cut from the harvest area to the genius 8 km away, has an impact of only 0.003%, and transport 2, corresponding to the movement sugar from the mill in Veracruz to the final place of consumption in Mexico City contributes only 0.01% of the global impacts.

From system analysis of cane sugar life cycle it can be said that the 2 processes that have more impact are the cultivation with 57.29% and industrialization with 42.70% of total impacts in the system.

In the other hand, the overall results of the impact caused by Stevia Sweetener life cycle are presented in Figure 3.

Figure 3. Stevia Sweetener Impacts by Thread



Taking a close approach to the results, equally the stevia cultivation process has a high contribution in acidification with 83.90% and in stratospheric ozone with 83.52%, last but not least, important impacts exists from cultivation process in human toxicity with 60.24% and eutrophication with 59.49%.

For its part, the industrialization contributes very significantly in the areas of abiotic resource depletion with 78.64%, and in the emission of greenhouse gases with 75.31%.

Overall, the thread with the biggest contribution to the environment is the cultivation with 55.52%, followed by industrialization with 44.34%, and land transport with 0.001%, and finally air transport with 0.0005% of total impact.

Table 2. Summary of categories impacts selected for the study

CML-2000 Category	Indicator	Sugar (a)	Stevia Sweetener (b)	Relation Impact (a/b)
Air Acidification	g SO_2 eq	3.74	1.13	3.30
D.of abiotic resources	g Sb eq	6.37E-03	2.44E-03	2.62
D. of the strastosphic ozone	g CFC-11 eq	2.02E-05	8.29E-06	2.44
Eutrophication	g PO_4 eq	1.79E-01	7.26E-02	2.46
Greenhouse effect	g CO_2 eq	833.39	336.08	2.48
Human Toxicity	g 1-4, DB eq	26.49	9.87	2.69
Comparative				**2.66**

According to the summary made, we can see that the system of cane sugar has an impact on the environment 2.66 times greater than stevia sweetener, ranging from 2.44 times greater in depletion of the ozone layer to 3.30 times greater on air acidification.

CONCLUSIONS

According to the life cycle assessment conducted in both systems, for sugar cane production and stevia sweetener, both targeted for consumption in Mexico, the following conclusions were reached:

• Sugar cane consumption causes a 2.66 times greater impact on the environment than stevia sweetener consumption, comparatively being this second an environmentally friendlier product because it has less impact on the environment.

• In addition, stevia production equivalent to reach sugar cane sweetness requires only 8.49% of land amount used for growing cane, so it can be obtained the same amount of sweetness per unit with fewer resources and with a much smaller impact on the environment.

• From the resultant characteristics of stevia cultivation and industrialization, it can be said that is an organic product, but also ecological, for its low environmental impact compared to sugar cane.

• It is highly likely that if cane harvesting burning and bagasse burning are taken into account, the impacts caused by sugar cane system would increase significantly more.

• Sweetnatural stevia sweetener penetration into the Mexican market is ecologically feasible, beyond the direct benefits that bring the product itself, such as: is a non-caloric sweetener, contains no synthetic molecules, is a 100% organic and 100% natural.

REFERENCES

ACDI VOCA, Plantación de Stevia en el municipio de la Asunta, Nor yungas, La Paz – Bolivia febrero de 2010.

Cassacia Javier, Álvarez Edgar, Recomendaciones técnicas para un producción sostenible del Ka´a´he´e (Stevia Rebaudiana Bertoni) en el Paraguay, Ministerio de Agricultura y Ganadería, Sub secretaría de estado de agricultura, dirección de investigación agrícola, Paraguay 2006.

Hale Andy, Stevia Rebaudiana: Propiedades, mercados, y factibilidad de producción de un cultivo de venta al contado en Bolivia, USAID Bolivia, Diciembre de 2001.

Jaramillo Diana, Análisis del Ciclo de Vida de la producción y uso de etanol de caña de azúcar en México, ITESM Estado de México, Mayo de 2010.

Limache Imbert, Proyecto de factibilidad técnico económico para la producción de Stevia cristalizada en la ciudad de La Paz, Escuela Militar de Ingeniería "Mcal. Antonio José de Sucre", Diciembre de 2006.

Montoya Isabel, Quintero Julián, Sanchez Óscar, Cardona Carlos, Evaluación del impacto ambiental del proceso de obtención de alcohol carburante utilizando el algoritmo de reducción de residuos, revista de la facultad de ingeniería Universidad de Antioquía, Medellín – Colombia 2006.

Ometto A.R., Roma W., Ortega E., Emergy life cycle assessment on fuel ethanol Brazil, UNICAMP facultade de engenharia de alimentos, Sao Carlos Brasil 2004.

Saavedra Juan, Vargas olga, Estimación del impacto del cultivo de caña de azúcar utilizando la metodología de análisis de ciclo de vida ACV, Universidad de Los Andes, Colombia.

Sustainable Resource Management (SRM) in Latin America and the Caribbean (LAC) region

Valdivia, Sonia[1], Tonda, Elisa[2]

[1]SCP Branch, UNEP DTIE Paris,
15 rue de Milan,
75441 Paris Cedex 09, France
e-mail: guido.sonnemann@unep.org

[2]PNUMA ROLAC,
Clayton, Ciudad del Saber - Avenida Morse, Edificio 103
Corregimiento de Ancón - Ciudad de Panamá, PANAMÁ

Abstract

The Latin America and the Caribbean (LAC) is a major source of renewable and non-renewable resources for the world market. This region is rich in minerals reserves. Water quality problems are common to the whole region. The LAC region includes 23 % of the world's potential arable land. As such, improving resource management in the region promises to have important benefits for the inhabitants of LAC. The present paper introduces the 2-year project "Strengthening National Capacities for Sustainable Resource Management (SRM)" (GESRE, for its Spanish abbreviation) which has the aim to strengthen capabilities on SRM and promote SRM practices in the LAC region.

Background

The project started in 2010 and is being implemented by UNEP. The focus of the SRM project includes actions and organizations within a system that help facilitate the use and continuous provision of natural resources in order to cover the needs of the present without compromising the capacity of the future generations of covering its own needs. It is about an integrated approach for resource management. Therefore, SRM avoids the transfer of impacts of a productive chain to another, of a category of impact to another, and from one region to another.
Outcomes expected at the end of the project are

- Established networks on SRM of public officials and relevant stakeholders.
- National action plans launched and opportunities identified for SRM in the LAC region.
- A knowledge management system including training materials on the critical natural resources identified by the region.

First results

As a result of the implementation of this project during the 1st year, The GESRE project has created a platform based on a public expression of interest which includes about 170 stakeholders from 30 countries including participants from governments, private organizations, NGOs and academia. In addition, the launch event, two stakeholder consultations and two training events took place in 2010 which also provided substantial input to finalize the report on "Critical Resources Evaluation Report in LAC region". The report identifies six critical resources which relate to the following sectors: Agricultural land (agro-industry), wood (forestry), landscape (tourism), metals (mining), fisheries (fishing), water (all sectors).

Next steps

Next steps are the implementation of two national SRM pilot projects including training activities for the countries selected and for the region are envisaged as part of this project. As a result of the 2-year project, recommendations for national strategies and plans in LAC countries will be drawn. Learnings and highlights will be disseminated in the region.

Criteria for the selection of productive chains

Pilot projects in two different critical natural resources in LAC in two different countries will be implemented. Following criteria will guide de selection of pilot projects:

- consideration of a critical natural resource in the country with reserves are under risk the next decades
- resource use reduction
- water use reduction along the life cycle
- GHG reduction along the life cycle
- social co-benefits for the local communities around the areas of resource extraction
- employment creation possibilities
- increased or new income for the workers, shareholders, suppliers or the local community around the resource extraction activities
- supply chain involvement

Conclusions

The waste societies are increasingly producing shorter product life cycles with an intense consumption of natural resources. Considering natural capital as foundation of our economy and society, a pre-condition for growth and development, sustainable resource management practices in our production models are needed. This project offers the possibility to test sustainable practices in the extraction and use of critical natural resources in Latin American and the Caribbean region, and hence, to use the natural capital of countries as the basis for sustainable development.

Ecodesign tools: review and applicability characterization

Sandra M. Luz [1], Armando Caldeira-Pires [2], Paulo M. C. Ferrão [3]

[1] Faculty at Gama– University of Brasília, Brazil, email: sandraluz@unb.br
[2] Department of Mechanical Engineering, University of Brasília – Brazil
[3] Center for Innovation, Technology and Policy Research - Instituto Superior Técnico, Lisbon, Portugal

ABSTRACT

This work signalizes the important innovation in the industry, the Ecodesign process approaching. Ecodesign not only is the environmental component inserted with design of a product or service, but also there is a mind change process, involving ecological, economical and social aspects. This work shows an ecodesign tool review and the relation between many actors and ecodesign concepts. For that, the tools characterization was made in point of view of users, considering all basic concepts necessary to apply ecodesign to product development.

Key-words: Ecodesign tools, concepts, characterization.

INTRODUCTION

The environment is a complex system, which includes the physical environment (water, air and ground), living beings and natural resources. All of these are strongly interrelated. Unfortunately, due to the intense human activities, a wide adverse impact on the environment has been observed. When the environment and potentials hazards are discussed, global warming might be the most pressing issue currently, but there are many more aspects, e.g., the depletion of raw materials and amount of water consumption. The environmental problem tends to be increased, because the planet would be unable to support the weight of 6-8 billion people approaching western standards of consumption. Today, 20% of the population is consuming 80% of available resources [1].

Thus, special requirements within sustainable development have been approaching to consider these environmental problems, mainly about products, process and services. The Ecodesign comes to help us together with life cycle thinking. Nowadays, many companies have an interest to include environmental requirements in early stages of a project. Thus, during the last decade, the efforts linked to integrating environmental constraints in the design of products [2]. For more than 10 years, tools suitable for supporting the practice of ecodesign have been developed as much by academic researchers as by industry. Therefore, this work intend to study some ecodesign tools and evaluated if these tools promote a change in our minds (all actors), which includes environment aspects in the products and service developments just in the beginning of the projects.

ECODESIGN CONCEPTS

The basic idea of ecodesign is the reduction of environmental impacts throughout entire product life cycles by improved product design. Once it is understood, why the environment is a significant and relevant topic, companies are then better able to deal pro-actively with the requirements coming not only from the legislators, but also business and private customers, the market, and other stakeholders. In addition, those companies that have a strategic and pro-active approach to ecodesign are likely to open the door to creative innovation [3]. There are many motivations to implement Ecodesign strategies in the industries. Internal drivers, including manager´s sense of responsibility, the need for increased product quality, the need to improve the image of the product and the company, reduce costs and increase employee motivation [4].

Within Ecodesign concepts, there are many of tools that can be used for designers to implement in their product. Before that, we can to define the Ecodesign as a process or requirement that you put in your design with an environmental component. Figure 1 shows the main concepts necessary to implement the Ecodesign. The knowledge of environmental problem and the conscious about the dangerous consequences on the human life is an important concept that the all actors must know, for example, the consumers, designers, managers, etc. Another important concept brings the product life cycle and system/product related to function and economic requirements [4].

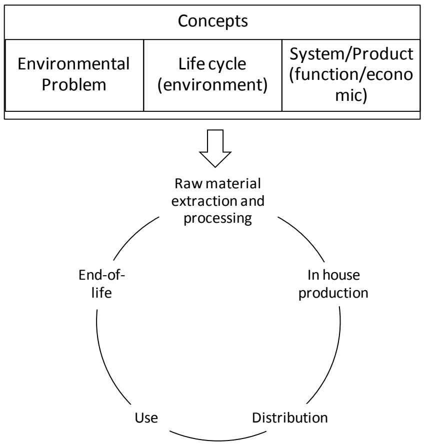


Figure 1. Ecodesign concepts and relation with life cycle phases.

ECODESIGN TOOLS: A REVIEW

One of the surest means of achieving sustainable development in our consumer society is to design ''ecological'' products and services. Ecodesigning products indeed encourages a global approach designed to prevent or minimize impacts emerging throughout the whole life cycle of products and concerning all types of environmental impacts [2]. Some environmental issues change traditional design where: new types of information: These include information on the environmental impact of materials, components and process; new information providers: information about reuse, disposal - have been motivating; and new types of decisions: Ecodesign strategy.

Wheel strategies

Within wheel strategies Ecodesign strategy, the Ecodesign tool is related to new concept development where the dematerialization, shared use of the product, integration of functions and functional optimization of product (components) are the major challenge. Most environmental impacts are "locked-in" at design stage, which is when key decisions are made on materials, manufacturing methods and how the product will be used and operated. A dressing environmental impact at the design stage will produce solutions that likely to be environmentally positive and cost effective [5]. Table 1 shows a typical wheel strategy.

Table 1. Points within wheel Ecodesign strategies related to product life cycle [4].

Points	Strategy
Materials	Cleaner materials, renewable materials, lower energy content materials, recycled materials and recyclable materials; Reduction in weight, reduction in (transport) volume.
In house production	Alternative production techniques, fewer production steps, lower/cleaner energy consumption, less production waste, fewer/cleaner production consumables.
Distribution	Less/cleaner/reusable packaging, energy-efficient transport mode, energy-efficient logistics.
Use	Lower energy consumption, cleaner energy source, fewer consumables needed, cleaner consumables, and no waste of energy/consumables.
End-of-life	Reliability and durability, easier maintenance and repair, modular product structure, classic design, strong product-user relation; reuse of product, remanufacturing/refurbishing, recycling of materials, and safer incineration.

About the point ´concept´, dematerializing, with resource efficiency and zero waste is one of key Ecodesign strategies to be improve the environmental quality of as product or service, where to design products and manufacturing process for maximum resource use efficiency. This means using the minimum quantity of materials and other resource inputs such as water or energy thought the product life cycle. Increasingly, products should be designed so they can be managed in closed cycles to eliminate waste, either in natural cycles (e.g. composting) or industrial cycle (e.g. recycling).

Checklists

Checklists permit the product to be analyzed according to functional characteristics. The ecodesign checklist encompasses all needs analysis related to fulfill social needs of a product, making the questions in respect to the real necessity of this product and the potential environmental improve that this product can suffer (main and auxiliary functions, effectively and efficiently, improvement of functions and possibility of radical product innovation. The second requirement is in respect to production and supply of materials components [6]. This question is more related to kind of material, treatments, transport and energy.

In respect to in-house production, questions about the process are made, including treatments, connections printing labeling, auxiliary materials, energy consumption, waste and quality. About distribution, the questions are made within the problems in the transport, type of packaging, means of transport and efficiency. About the utilization, the questions are related to problems in the using, operating, servicing and repairing the product, energy requirement, direct or indirect, consumables, technical lifetime, repairs, auxiliary materials, possibility of easy maintenance, disassemble replacement and aesthetic life time. About recovery and disposal, there is possibility of reuse, disassembled without damage, recyclable, identifiable, and detached quickly and incineration problems of non-reusable product parts [7].

MET matrix (Material cycle, Energy use and Toxic Emissions)

Matrix methods may be quantitative or semi-qualitative. The purpose of these simplified assessment methods is to limit the data collection by the manufacturer. Data are generally limited to physical dimensions such as the mass of the materials constituting the product or energy consumption. In material cycle and energy use, there is input/output information. Although for toxic emissions, there is only output information, if it is possible a recovery, energy and materials can be generated and avoided, respectively [4].

Life Cycle Assessment

Life cycle assessment (LCA) is the reference environmental assessment tool. It is indisputable from a theoretical point of view. It is the most effective tool for environmental assessment and makes the most advanced analyses possible [2]. On the other hand it appears difficult to use in a business, as it requires so much time and expertise. It is an expert’s tool above all else and its use has to be confined to research issues (academic research, R&D). Simplified LCAs are user-friendlier. They are based on the use of generic databases, which considerably reduce the time necessary for acquiring the data for the assessment. Nevertheless, the use of generic databases is challenging from the point of view of the scientific strictness required for the environmental assessment of products. The simplified LCA is often a good compromise between the relevance of the results provided and its potential for use in the enterprise [2]. The life cycle approach is of crucial importance for Ecodesign since it allows the concept of prevention to be deployed in such a way that the best solution is chosen for the whole life cycle [4].

Information/inspiration

Lofthouse [7] indentified a range of problems with existing ecodesign tools and a number of criteria on which to base the design of more appropriate tools for industrial designers. In this study, the author takes as reference the main actors to development of ecodesigin: designers in large multinationals, novice designers, design consultants with little experience in ecodesign, ecodesign experts and environmental affairs personnel. As a result of this study, a holistic web based tool to help many actors with information and inspiration (Information/inspiration) was developed.

ECODESIGN IMPLEMENTATION

One part of the implementation is to educate engineers of the experienced and technical performance values. All ideas are collected; evaluation of all ideas according to the same criteria, such as market attractiveness and technical feasibility; including environmental aspects assures that environmental aspects are considered at strategic level [8]. Controlling and implementing these environmental objectives requires suitable structures, procedures, and tools. In many cases, the concept of Ecodesign has not yet become quite clear, and potential benefits go unnoticed [9]. The Table 3 shows some ecodesign tools related to actors and concepts. A recent work also threats the Ecodesign implementation in agreement with actors, where designers, marketing, environmental expert and others are involved in this process.

Table 3. Relation between tools, concepts and actors.

Tool	Tool Description	Concepts	Actors
Checklist	Questions about material, energy and final disposal of products	Environmental problems Life cycle	Consumers, environmentalist, manager, marketing, Designers/Engineering designers, product designers.
Wheel strategies	Suggestions about materials consumption	Environmental problems Life cycle System/Product	Designers/Engineering designers, product designers.
Information Inspiration	Designer formation (education)	Environmental problems Life cycle	Designers/Engineering designers, product designers.
LCA	Life cycle assessments	Environmental problems Life cycle System/Product	Designers/Engineering designers, product designers.

The Table 4 shows the relation between ecodesign strategies and life cycle phases. It was clear that the critical aspects of ecodesign implementation are decrease of materials and energy of products and services consumption, increase of recyclability, renewable resources maximization, increase of product lifetime, and increase of products and services substitution. This has confirmed the importance of the development and implementation of an integrated approach, which deals with the entire life cycle of products, at member state and Community level [10].

Table 4. Relation between main strategies and life cycle phases (↓=decrease, ↑= increase).

Strategies	Life cycle phases					
	Concept	Material	In house production	Distribution	Use	End-of-life
Materials	↓	↓	↓	↓	↓	--
Energy economy	--	↑	↑	↑	↑	↑
Final Disposal	--	↓	↓	↓	↓	↓

Conclusions

In this work we concluded with the Ecodesign review that the tools involve aspects related to best choice of material, lesser energy consumption and more effective final disposal offering recycling, energy generation and reuse. In addition, the main concepts necessary to implement these tools are environmental problems and to solve them with ecodesign strategies based on product life cycle. All actors should know information about product life cycle and environmental problems related to them.

References

[1] Manzini, E. Design, ethics and sustainability guidelines for a transition phase, DIS-Indaco: Politecnico di Milano, 2006.

[2] Le Pochat, S., Bertoluci, G., Froelich, D. Integrating ecodesign by conducting changes in SMEs. J. of Cleaner Production, 15, p. 671-680, 2007.

[3] Vezzoli, C., Manzini, E. Design for environmental sustainability. Springer- Verlag: London, 2008.

[4]Brezet, H., van Hemel, C. Ecodesign, A promising approach to sustainable production and consumption, edited by UNEP, Paris, 1997.

[5] J. Niemann, S. Tichkiewitch, E. Westkämper Design of sustainable product life cycles, Springer, Springer-Verlag: Berlin Heidelberg, 2009.

[6] W. Wimmer, R. Züst, K.-M. Lee Ecodesign implementation: A systematic guidance on integrating environmental considerations into product development;, springer: netherlands, 2004, 140 p.

[7] Lofthouse, V. Ecodesign tools for designers: defining the requirements. J. of Cleaner Production, 14, p. 1386-1395, 2006.

[8] Ölundh, G., Ritzén S. Making an Ecodesign choice in project portfolio selection, IEEE International Engineering Management Conference, 2004, p. 913-917.

[9]development, W. Wimmer, R. Züst, Kluwer Academic publishers, v.3, New York, 2003.

[10] IPP (Integrated Product Policy) The Journal of Sustainable Product Design, 9, 1999

Comparative Life Cycle Assessment for two wastewater treatment plants in México

Adba Musharrafie[1], Patricia Güereca[2], Nadia Blanco[1], Edgar Martínez[1], Alejandro Padilla[2], Liliana Romero[2], Margarita Cisneros[2], Juan Manuel Morgan[2], Adalberto Noyola[2].
[1] Instituto Tecnológico de Estudios Superiores de Monterrey, Carretera Lago de Guadalupe km 3.5, Atizapán de Zaragoza, Estado de México, CP 52926, México.
[2] Instituto de Ingeniería, Universidad Nacional Autónoma de México, Circuito Escolar-Ciudad Universitaria, Distrito Federal, C.P. 04510, México.
E.mail: LGuerecaH@iingen.unam.mx

Abstract

This paper presents a Life Cycle Assessment (LCA) of two municipal Wastewater Treatment Plants (WWTP) of low capacity, comparing two different technologies: Stabilization Ponds and Activated Sludge. For proposes of this assessment was considered as functional unit the total amount of treated water during a period of time of 20 years, which was considered as lifespan of WWTP. The Impacts are analyzed under the CML2000 methodology, getting results of each technology evaluated and their subprocesses: construction, equipment fabrication and transport, operation and landfill. The results show that the Stabilization Ponds technology has a better performance in four of seven categories assessed, while the Activated Sludge showed good performance just in three of them.

Keywords: Life Cycle Assessment, Wastewater treatment plants, Stabilization Ponds, Activated sludge.

Introduction

The Wastewater Treatment has become an important dimension due to the pollution associated if the wastewater is not treated.

Nowadays in Latin America there is an investment of millions of dollars with the aim of installing new WWTP to ensure the mitigation of pollution effects and avoiding health damage caused by untreated wastewater.

Therefore, it is assumed that any kind of technology use for treating wastewater will avoid the environmental pollution; however, it is necessary to submit an objective assessment and a systematic evaluation of Wastewater Treatment technologies, so as to identify improvement areas and also support the process of making environmentally responsible decisions.

LCA is a methodological tool that evaluates the environmental effects associated with any given activity from the initial gathering of raw materials from the earth at the point which all materials are return to the earth (Curran, 1996).

Based on the above, this study makes a comparison between two wastewater treatment technologies, Stabilization Ponds (LE) and Activated Sludge (LA).

Methodology

For this assessment the environmental impacts were evaluated as the following categories: Air Acidification (AA), Aquatic toxicity (AT), Depletion of Stratospheric ozone (DSO), Eutrophication (EU), Greenhouse effect (direct, 100 years) (GEI), Human Toxicity (HT) and Photo-oxidants formation (POF), according to the CML2000 models.

The functional unit chosen was the total amount of treated water during a period of time of 20 years, which was considered as the lifespan of WWTP, being 11,352,960 m^3 in 20 years to LE and 7,568,640 m^3 in 20 years to LA. This study considered the next subsystems: manufacturing and transport, construction, landfill and operation. The raw materials extraction, cement fabrication and the electricity generation are adopted from the DEAM database (associated to the TEAM 4.0 software) considering the USA Electricity mix. All the data related with the operation stage were proportionate directly by the WWTP operators, while construction, the equipment fabrication and transport were estimated according to scientific reports.

The Stabilization Ponds technology (PTARLE), has a treatment capacity of 18 l/s and a total area of 50,000 m^2, and considers the primary and secondary treatments; this study include the process of dry sludge.

The Activated Sludge technology (PTARLA) has a treatment capacity of 12 l/s, and an area of 2,800 $m^{2,}$ considering three treatment process: primary, secondary and tertiary process. The digested sludge is discharged to drain. Both wastewater treatment assessed include the process described at Table 1.

Table 1 Unitary processes for the two technologies analyzed

PTARLA		PTARLE	
01_PRE	Pre-treatment	1_PRE	Pre-treatment
02_CB	Pump operation (cb)	2_CB	Pump operation (cb)
03_TQP	Primary Treatment Tank	3_BDG	Bio digester
03a_SP	Blowers	4_LGA	Anaerobic Ponds
04_RB	Bioreactor	5_LGF	Facultative Ponds
05_TQS	Secondary Treatment Tank	6_LGM	Maturation Ponds
06_DL	Sludge Digester	7_LCH	Dewater sludge
07_TQC	Chlorination Tank	VRTD	Discharge
08_CBAT	Cb Treated Water		
09_CBPG	Cb Purges		
VRTD	Discharge		

Results and discussion

Air Acidification

Figure 1 shows that the PTARLA has a greater impact on air acidification, which is mainly due to SOx and NOx, assuming they are produced by electricity generation, which is consumed in the operation of the equipment. This is consistent with that reported by Tillman et al. (1998), Lundin et al. (2000), Hospido and Moreira (2008), who indicated that the greatest impact of acidification emissions are caused by the production of electricity.

Aquatic toxicity

Figure 2 shows that PTARLA has a greater impact in the aquatic toxicity because the influent water contains metals such as cadmium and copper mainly. Therefore, the treated water contains these components that to the end of the treatment process the treated water produce aquatic toxicity.

Stratosphic ozone depletion

Figure 3 shows that the PTARLA generates the greatest impact mainly of CFC's which is produced by the process of solid waste landfill.

Eutrophication

Eutrophication is one of the priority criteria for the definition of sustainable wastewater treatments, Hellström et al. (2000). Figure 4 shows that PTARLE has greater impact on eutrophication; this is due to the amount of phosphorus contained in the effluent water.

PTARLA's contribution is due to the discharge of digested sludge to sewage and treated water, with a high content of phosphorus and phosphates.

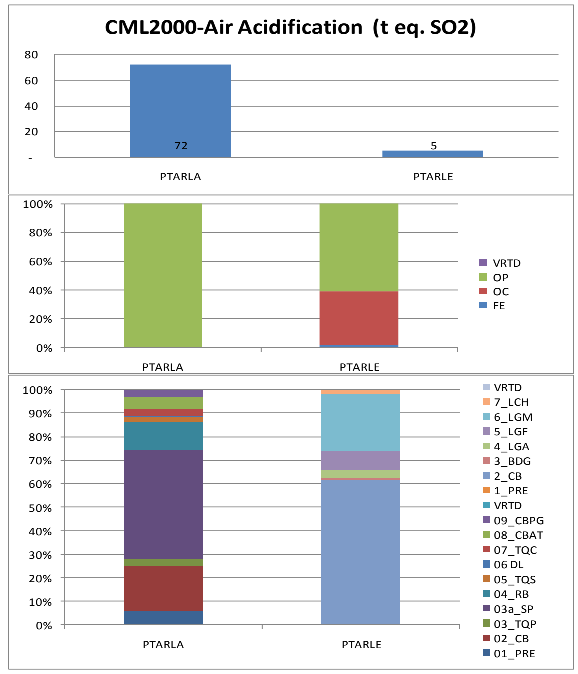


Figure 1 Environmental impacts associated to the two technologies analyzed.

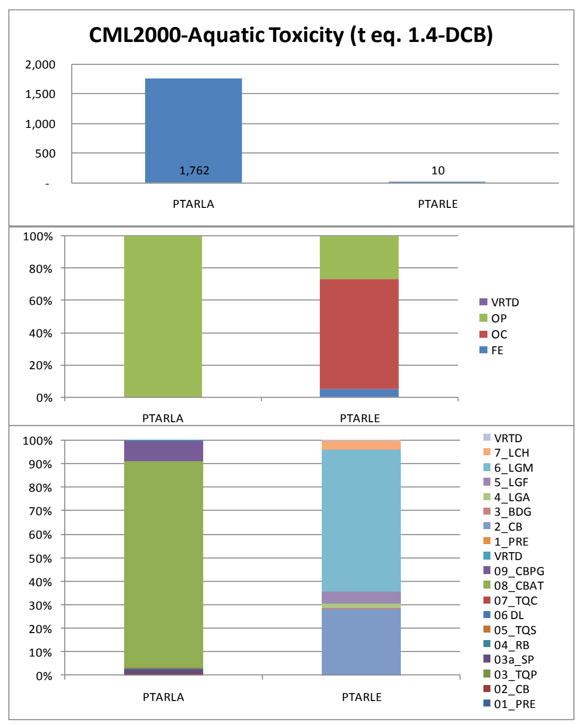


Figure 2 Environmental impacts associated to the two technologies analyzed.

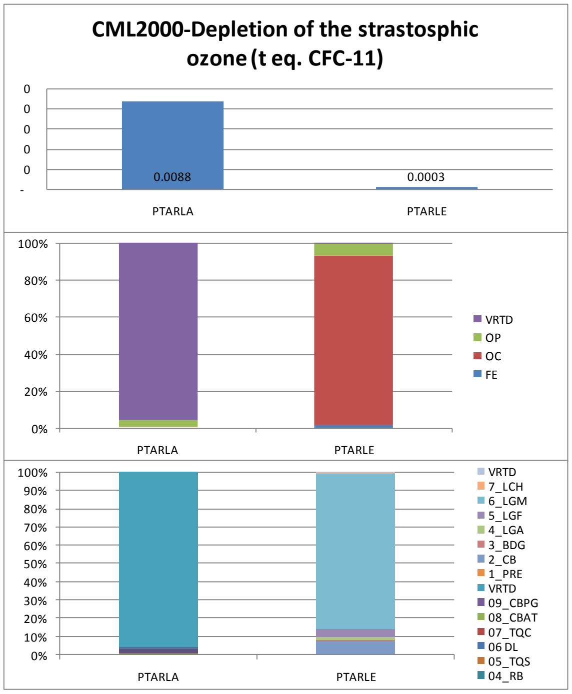


Figure 3 Environmental impacts associated to the two technologies analyzed.

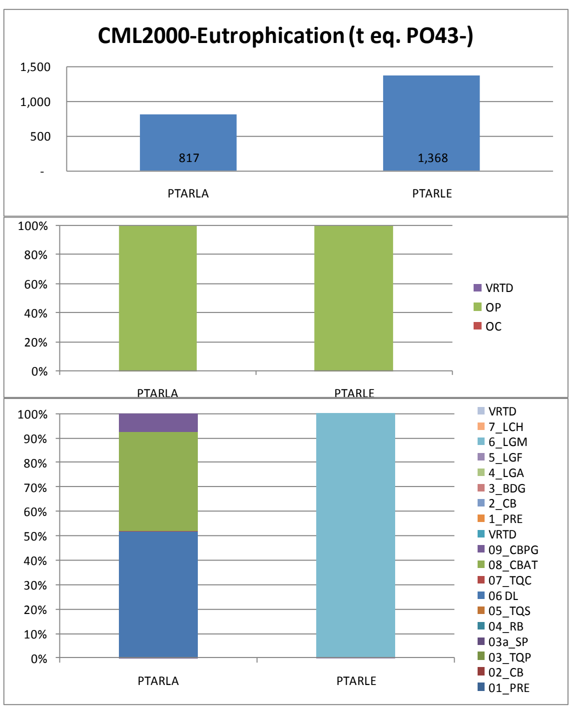


Figure 4 Environmental impacts associated to the two technologies analyzed.

Greenhouse Gasses

Figure 5 shows that the PTARLE has the greatest potential impact for emissions of greenhouse gases are largely to the impoundment process (mainly anaerobic ponds).

The process of stabilization ponds, produce higher emissions to the environmental as a result from the process itself (Gallego, 2008), because it generates greenhouse gases (GHGs), such as CH_4, N_2O de CO2, this is consistent with all the reported by Zambrano et al. (2007). In general when the process is evaluating the emissions generated by the process itself, the system of stabilization ponds has a high global warming potential greater than the activated sludge system.

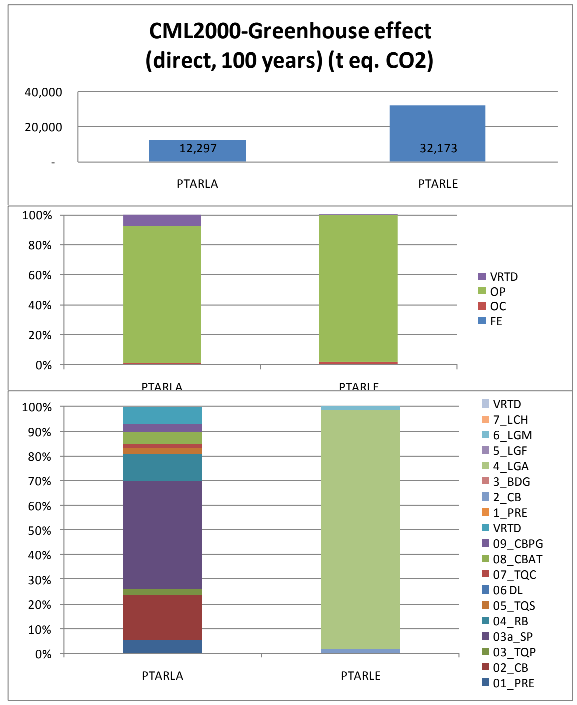


Figure 5 Environmental impacts associated to the two technologies analyzed.

Human Toxicity:

Figure 6, the PTARLA has a greater impact due to emissions of certain toxic substances such as arsenic (As) or hydrogen fluoride (HF), Nickel (Ni) and Benzene (C6H6), output of electricity generation, which is engaged in the operation of the plant.

Photo-oxidants formation

Figure 7 shows that PTARLE contributes mainly to the formation of photo-oxidants, due to methane gas (CH_4) produced in anaerobic ponds. In the case of PTARLA the impact is associated to equipment operation and energy consumption.

Conclusions

Mexico is working to achieve the goals set by the Government in 2030 on the treatment of wastewater; the application of life cycle assessment is valuable to choose appropriate technologies for wastewater treatment.

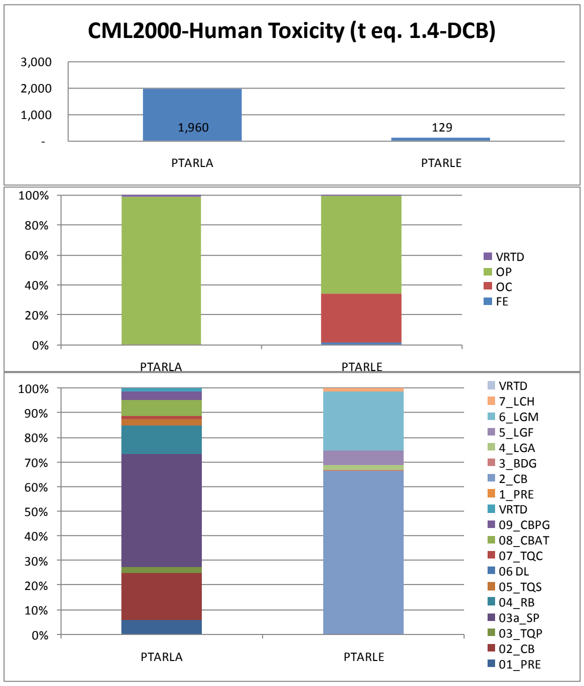


Figure 6 Environmental impacts associated to the two technologies analyzed.

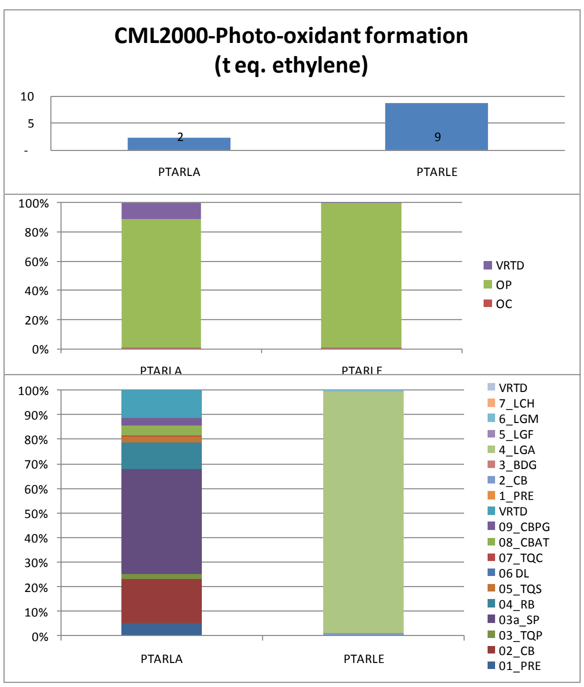


Figure 7 Environmental impacts associated to the two technologies analyzed.

In this case study, Activated sludge technology shows better performance in the categories of Greenhouse Effect, eutrophication and photo-oxidants formations, while the stabilization ponds have better performance in Air Acidification, Aquatic Toxicity, Stratospheric ozone depletion and human toxicity.

It is necessary to continue developing life cycle assessment inventories and their applications within the energy sector, as one of the uncertainties associated with these results is the use of life cycle inventory of U.S. electricity production.

The results of this study indicate that wastewater treatment plants produce an environmental benefit but also generate environmental impacts associated to its life cycle.

The alternative to generate electricity from renewable energies in this kind of process would greatly reduce the environmental impacts associated with this activity

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Reference

Curran MA. 1996. Environmental life cycle assessment. USA: Mc-GRAW-HILL. 1.2 pp

Gallego et al. 2008. Environmental performance of wastewater treatment plants for small populations. Spain. Resources, Conservation and Recycling 52, 931–940.

Hospido A, Moreira MT, Feijoo G. 2007. Environmental performance of a municipal wastewater treatment plant. Spain. Int J LCA 9 (4) 261-271.

Hospido A, Moreira MT, Feijoo G. 2007. A comparison of municipal wastewater treatment plants for big centres of population in Galicia. Spain. Int J LCA 13(1) 57-64.

Hellström D, Jeppson U, Kärrman E (2000): A framework for system analysis of sustainable urban water management. Environmental Impact Assessment Review 20, 311-321.

Tillman A-M, Svingby M, Lundström H (1998): Life Cycle Assessment of municipal waste water systems. Int. J. LCA 3 (3) 145–157.

Lundin M, Bengtsson M, Molander S (2000): Life Cycle Assessment of wastewater systems: Influence of system boundaries and scale on calculated environmental loads. Environmental Science Technology 34 (1) 180–186.

Zambrano et al. 2007. Análisis ciclo de vida en sistemas de tratamiento de aguas residuales, Colombia. Seminario Prevención y Control de la Contaminación del Recurso Hídrico.

USING THE METHODOLOGY OF LCA IN SEARCH OF IMPROVEMENT IN SLICED BREAD MANUFACTURING: A CASE STUDY IN RIO DE JANEIRO, RJ.

RIBEIRO, MARCOS AURELIO JUSTINO (CEFET-RJ) *

FILHO, JACI GUILHERME DIAS (CEFET-RJ)

ASSUNÇÃO, JOSE ANTONIO (CEFET-RJ)

XAVIER, LEYDERVAN DE SOUZA (CEFET-RJ)

* **Address:** CEFET / RJ. DIRECTORATE OF RESEARCH AND GRADUATE. Av Maracanã 229, Block E, 5th floor, Maracana, Rio de Janeiro, CEP: 20271-110, RJ, Brazil. +55 21 2566-3179 / maurelio.justino @ gmail.com.

ABSTRACT

This work describes an application of Life cycle Assessment Methodology (LCA) in the sliced breads manufacturing of a company located in Rio de Janeiro, aiming at the improvement of the environmental performance. The scope is limited to the investigation of processes operated inside the manufacturing plant assuming, as functional unit, a set of data provided by 102 days of production. The balances of mass and energy are computed applying the software UMBERTO from raw material preparation to final product packaging, focusing opportunities to minimizing bread components usage, water and energy consumption, and equivalent CO_2 emissions. So doing, LCA is adopted, with the help of other tools as, for example, recycling and waste treatment to support the manufacturing processes management, providing indicators for environmental performances evaluations, rational use of resources and environmental impacts reduction. In a broader perspective, developed in another research, the effort of representation and assessment of the stage of the sliced bread life cycle presented here aims to contribute to integration of environmental performance indicators mapped in operations outside the manufacturing plant to accomplish a sustainable development strategy.

theme: life cycle assessment: inventory and impact assessment.

Keywords: bread, Life Cycle Assessment, Sustainability, performance evaluation.

INTRODUCTION

Since the last quarter of the twentieth century the concept of sustainability is shown as a major principle guiding the society to plan its development, ensuring the maintenance of life in the earth and the availability of natural resources for future generations. This is concerned with the substitution of the type of industrialization adopted since the beginning of the Industrial Revolution that still exhausts non-renewable resources and produces high rates of waste and pollution, through the generation of residuals, solid and liquid, , and gas emission, causing undesirable impacts, especially on biodiversity, natural habitats and bioregions, sometimes turning them into hostile areas to human habitation (Egri et Pinfield, 2007).

In this work, partial results of a master degree research, the object of interest is to improve the manufacturing process of bread, a chief product for mankind feeding with about 6 million years of history, seeking an improved production of sliced breads in a company located in Rio de Janeiro. To carry out the research we adopt the methodology of Life Cycle Assessment (LCA) as a support ~~tool~~ for representation of the process, and performance evaluations through the indicators produced by the methodology, identifying areas for improvement concerning with the production-related environmental impacts. The proposed approach uses the software UMBERTO - developed by the Institute for Energy and Environmental Research, University of Heidelberg (IFEU) and the Institute for Environmental Informatics Hamburg University (IFU) - based on the communication language of Petri nets for representation and analysis flows of materials and energy in the production process.

EVALUATION OF THE LIFE CYCLE OF THE PRODUCT AND CLEANER PRODUCTION

According to ABNT NBR ISO 14044 Norm, "Environmental Management – Life Cycle Assessment – Requirements and Guidelines", the LCA is a technique used in the study of the the environmental impacts associated with a product (understanding also service as product), consisting of four basic stages: (i) "the phase of definition of objective and scope"; (ii) "the phase of analysis of the inventory", composed by compilation of inputs and outputs linked to the system being studied according to the definition of objective and scope (LCI); (iii) "the phase of evaluation of the impacts" to provide additional informations for the ICV (LCIA); and (iv) phase of interpretation, summarizing the LCI and LCIA results for decision making and management according to the definitions of the objectives and scope.

The use of LCA, and the comparison of products, is nowadays regarded as one of the most appropriate tools for achieving goals for sustainability (Curran, 1999), as it allows the measurement of all stages of production, primary phase to obtain a cleaner production, which is still the application of an integrated preventive environmental strategy applied to products and services, in manufacturing phase as well as consumption, since the row material acquisition to final disposal, to reach a better understanding dealing with potential impacts and increase overall efficiency and to reduce risks to human health and the environment. Beyond the scope of the optimization process, some organizations, under the marketing point of view, adopt LCA as a way of adding value to the image itself. The adoption of environmental labeling programs (ABNT NBR ISO 14020) and the statements of commitment to the environment are also recognized in this way and can lead organizations to best placements in the market they serve. This conduct reflected favorably on those who maintain relations with their products and services such as environmental agencies and authorities, suppliers and consumers. In this context, both these players can determine their expectations for how products or services must be performed, but also return information for non-compliance with the requirements desired.

CASE STUDY

In search of broader goals, giving rise to this paper, we propose to adopt LCA as a way to represent and evaluate - applying UMBERTO – the mass and energy flows of the slice bread manufacturing processes, always committed with a sustainable strategy to seek environmental performance improvement, as part of a wider production strategy integrating the view of supply chain management in the Company with the LCA thought to approach the slice bread production and intensify interaction among suppliers and customers. In All efforts are directed to increase efficiency and efficacy in the use of materials, energy and knowledge aiming at the rational use of resources and reduction of negative environmental impacts, as well as social and economics. Figure 1 illustrate the scope of the wider production strategy been considered in a broader perspective, developed in a Master Degree research. The highlighted box indicates the limits corresponding to this paper excluding the possible environmental impacts arising from transport and transformation processes and other upstream and downstream. The final boundary of this study is the bread packed, inside the delivery area of the industry.

To apply the LCA methodology in the analysis of inventory and evaluation of impacts in the of through the manufacturing processes of sliced breads, in the plant located in Rio de Janeiro, a plan was prepared to collect data along the production line, to conduct interviews with the production manager, production supervisors, maintenance people and the general manager. Reports were also used to control production and shipping, to obtain technical data pertaining to the many variables of the production process.

The manufacturing process, monitored and analyzed during the period from March to June 2010, comprises the following steps: inventory of raw materials and preparation room of prescriptions, divider operation, fermentation chamber, boiler, kiln, cooler and packaging area.

The functional unit corresponds to the total production of sliced bread for 102 days, with an average weight of 500 grams. During this period 16,812 prescriptions recipes were processed and the production was held 10,480,860. The production line efficiency reached 97.5%.

10,092,936 loaves were packaged and efficiency of the packing area was 96.30%. The loss of production represented 3.70% of the amount of packaged bread. By UMBERTO software, were launched and mapped all relevant information of the production process of breads, such as, electrical energy consumption ,thermal energy generated from natural gas consumptions, water consumption, and those related to raw material consumptions and residuals produced by wheat flour, yeast and some micro-ingredients needed to the sliced bread manufacturing. The integration of economic, environmental and social dimensions, according to will be evaluated in later stages of the main research, concerned with the fourth phase of LCA expectative as a separated research object.

RESULTS

To present a complete model of LCA of sliced breads, according to ABNT NBR ISO 14044 would require a broader analysis, considering not only the production process gate-to-gate, but also the earlier stages, such as the wheat crop and the generation of energy, as well as the subsequent processes such as distribution, warehousing in supermarkets, consumer use and disposal of packaging as well as the returns of products out of date premised for consumption. The extended representation intended for other researches should also address the economic, social and environmental importance for the sustainable development of the bakery industry.

The LCA model and the search for cleaner production led the organization to understand its production system so different from that used hitherto. In the new representation, we identified other relevant process variables that demanded their own forms of measurement. The organization has identified the need to measure the energy consumed by industry and not only the total energy, but also the water consumption of the boilers and to that edited by fermentation chamber. The emission levels of carbon dioxide generated by burning natural gas in furnaces, boilers and generated by the fermentation process, the basic principle of making breads also have become important aspects of measurement. So, was identified by estimation, an emission of 183 tons of carbon dioxide only in the transition T7, highlighted in Figure 2, referring to the process of generating steam by the boiler. Because it is a food company, there is no requirement fro the State to measuring these emissions to the atmosphere, requiring only the measurement and presentation of monthly effluent, the result of sewage treatment plant of the factory. Another reflection of the research process was the modification of the confidence interval of the weight mass applied to the cutting operation, creating a more appropriate process specifications, thus enabling a lower consumption of raw materials and maintaining the characteristics and quality of the final product. This measure also provided lower costs of production and consumption of natural resources.

CONCLUSION

It was concluded that the application of LCA methodology in the company offered a powerful mechanism for manufacturing processes evaluation and improvement through the adoption of a specialized knowledge concerned with sustainable development. This happens in search of better environmental performance integrated with economic and social outcomes in a advanced management perspective. In this sense, the LCA methodology, given its high degree of coverage by clearly established criteria and facilities implemented through the use of specialized tools like UMBERTO, also enables the utilization of other advanced management tools for development of strategies integrating the view of supply chain management of the Company with other types of interaction among suppliers and customers. use can and should bring good results in identifying factors related to sustainability performance as a whole and, therefore, significant reductions in indicators of impacts production system.

REFERENCES

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. **ISO 14044:** Environmental Management – Life Cycle Assessment – Requirements and Guidelines. Rio de janeiro: ABNT, 2009.

Coltro, L. Life Cycle Assessment (LCA) in: Life Cycle Assessment as a management tool \ Coltro Leda (ed.). Campinas: CETEA \ ITAL. 2007.

Nahuz, Marcio Roberto Augusto. The system and ISO 14000 environmental certification, Journal of Business, São Paulo, v.35, n.6, p.55-66, Nov. / Dec. 1995.

UMBERTO - A Software Tool for Life Cycle Assessment and Material Flow Analysis - User Manual. Institut für Umweltinformatik: Hamburg Institut für Energie und Umweltforschung, Heidelberg, 1998

WEULE, H. Life-Cycle Analysis - A strategic-element for future products and manufacturing technologies, Annals of the CIRP, Germany Berne, p.181-184, v.42/1/1993.

CURRAN, M. - The Status of LCA in the USA. Int J. LCA, vol.4 (3) 123-124. Landsberg. Germany: Ecomed, 1999.

Egri, CP, Pinfield, LT Organizations and the biosphere: Ecology and environment in Handbook of organizational studies \ organizers of the original edition: Clegg, Stewart R., Hardy, Cynthia; Nord, Walter R.. Organizers of the Brazilian edition: Caldas, Miguel; Fachin, Roberto and Ficher, Tania. São Paulo: Atlas, 2007.

Environmental consequences of wastewater treatment by activated sludge technology. A life cycle assessment approach

Edgar Martínez[1], Patricia Güereca[2], Adba Musharrafie[1], Alejandro Martínez[2], Liliana Romero[2], Margarita Cisneros[2], Flor Hernández[2], Juan Manuel Morgan[2], Adalberto Noyola[2],

[1] Tecnológico de Monterrey, Carretera Lago de Guadalupe km 3.5 Atizapán de Zaragoza, Estado de México, CP 52926, México.

[2] Instituto de Ingeniería, Universidad Nacional Autónoma de México, Circuito Escolar-Ciudad Universitaria, Distrito Federal CP 04510, México.

Corresponding Author: Patricia Güereca (LGuerecaH@iingen.unam.mx)

ABSTRACT

Wastewater treatment is an important task that aims to reduce water pollutants, however it is important to evaluate these processes to identify the hot spots of the system and propose strategies to reduce or minimize the environmental impacts. In this article a comparative life cycle assessment is developed in order to evaluate the use of sludge activated technology in a waste water treatment plant in Mexico City, compared with a scenario in which no treatment is performed to contaminated flow. The CML 2000 models and the TEAM™ 4.0 software are considered. The assessment shows that in the stages where electricity is used the impacts are greater. For air acidification, stratosphic ozone depletion, greenhouse effect, human toxicity and photo-oxidant formation, the real scenario of wastewater treatment has a greater impact on the environment, while for the categories of aquatic toxicity and eutrophication the no treatment scenario has the greatest impact.

Keywords: Life Cycle Assessment, wastewater, activated sludge treatment.

INTRODUCTION

The construction and operation of Wastewater Treatment Plants (WWTP), turns out to be one of the theoretically benefit the environment, as principal aim the removal of contaminants in wastewater. But now society began to demand that the majority of processes, products or services, are examined in order to minimize the environmental impacts generated by these activities, so the removal of contaminants from water is not sufficient, but it is also important to minimize environmental impacts associated with complete wastewater treatment.

The Life Cycle Assessment (LCA) is a methodological tool has been used to assess the environmental impacts associated with wastewater treatment, considering their whole life cycle and taking into account all the environmental impacts asocial.

In this paper presents a LCA which assesses the environmental performance of WWTP activated sludge flow of 1.4m^3/s, which is compared with a scenario in which no performing the treatment of wastewater

METHODOLOGY

Analyze the following categories of impact: air acidification, aquatic toxicity, human toxicity, eutrophication, greenhouse effect, and photo-oxidant formation, according to the models CML2000 (Guinèe, 2001). It is considered that the treated water is used in public services such as landscape irrigation, water supply for industrial and aquifer recharge Xochimilco, Tlahuac and Mixquic. The Functional Unit of this setudy is the amount of treated water during the lifetime of the plant (20 years), assuming a total of 906,344,640 m^3. The treatment system was compared with the hypothetical case of using untreated water for the same purpose as currently used. The subsystems considered are fabrication and transport equipment, construction, and landfill operation. The raw materials extraction, cement fabrication and the electricity generation of the DEAM are adopted database (Associated to the TEAM 4.0 software) considering the USA electricity mix. All the data related with the operation stage proportionate were directly in the WWTP while the construction and equipment fabrication and transport were estimated according to scientific reports.

RESULTS AND DISCUTION

Air Acidification

Figure 1a shows the total contribution scenario where generally is the stage of wastewater treatment by activated sludge process generates a 3.18 times greater impact than the proposed scenario without treatment. This is due mainly to the scene of “activated sludge” is necessary to use electricity for the operation stage (Figure 1b), where the process but it helps in activated sludge aeration and water pumping plant in put (Figure 1c), due mainly to emissions of sulfur dioxide generated in the process of generating electricity.

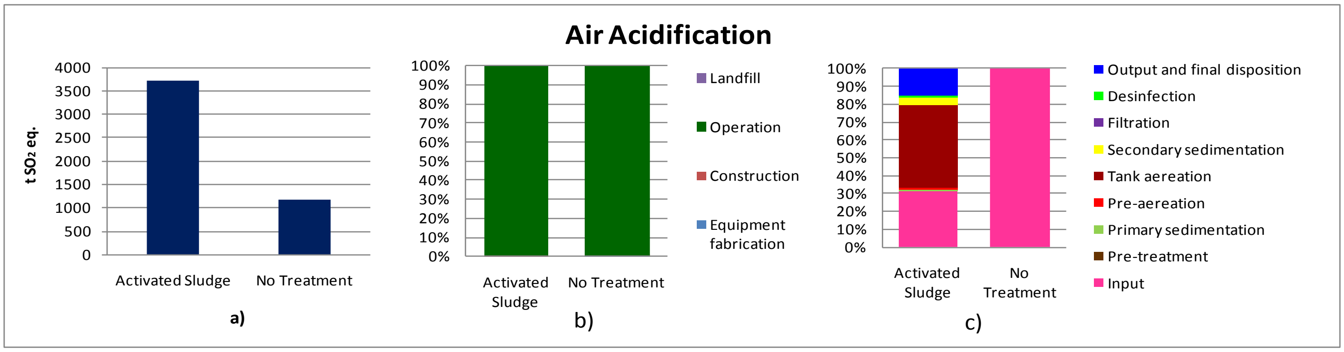

Figure 1: Impacts associated with water treatment by activated sludge and the scenario of no treatment. a) Total impacts, b) impacts by subsystem, c) impacts of sub-processes within the operation.

Aquatic Toxicity

Figure 2a shows that the impact of aquatic toxicity is 1.2 times higher for the scenario of no treatment. Figure 2b shows that the greatest contribution to the impact occurs in the operation, which includes the output process and final disposition, which is due to the quality with which the effluents are discharged (Figure 2c). For the scenario of no treatment, it is logical that the greatest impacts are greater for the quality with which water is discharged. For the scenario "activated sludge" is presented this impact because it does not make the removal of compounds that affect aquatic toxicity. The criteria pollutants in this category are copper, chromium and cadmium, found in the water to be discharged.

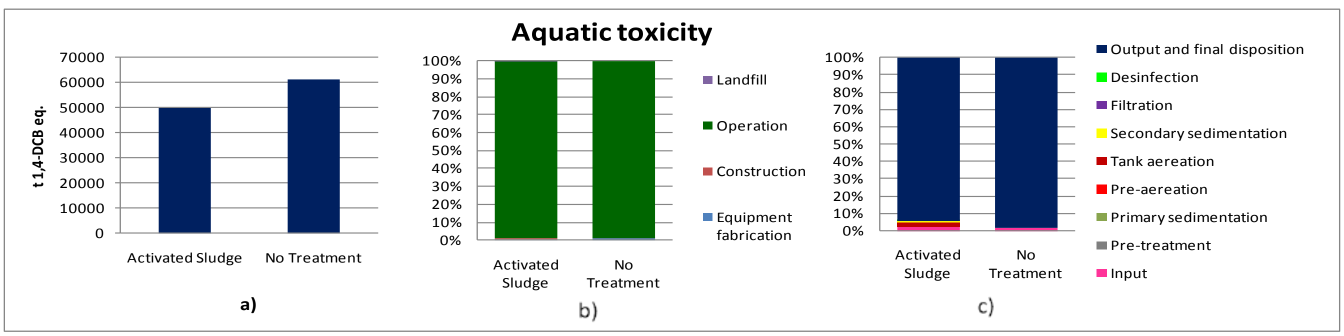

Figure 2: Impacts associated with water treatment by activated sludge and the scenario of no treatment. a) Total impacts, b) Impacts by subsystem, c) impacts of sub-processes within the operation.

Stratospheric Ozone Depletion

Figure 3a shows that treatment with activated sludge has an impact 3.18 times higher than if no treatment was done, which is mainly due to surgery (Figure 3b), and within this period the unit processes that most impact are which require higher energy consumption (aeration, pumping water to the input and output and final disposition). This is due to the use of fossil fuels for electricity generation.

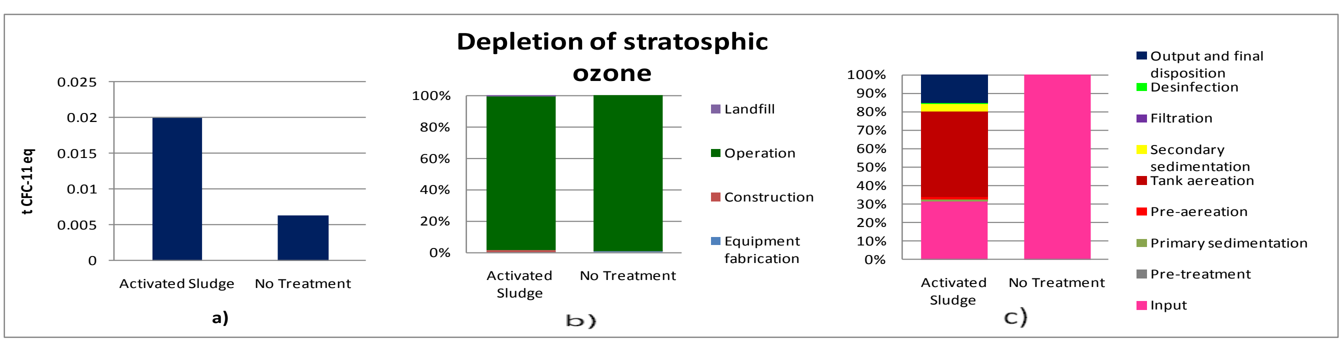

Figure 3: Impacts associated with water treatment by activated sludge and the scenario of no treatment. a) Total impacts, b) Impacts by subsystem, c) Impacts of sub-processes within the operation.

Eutrophication

Figure 4 shows that the second stage of untreated water has an impact 1.8 times greater than treatment with is mainly due to the operation stage (figure 4b), and within it to 100% of the impacts is attributed to the process output and final disposition (Figure 4c) due to the quality of water with which it is discharged, and that is not the removal of phosphorus and ammonia re the main contributors to this impact.

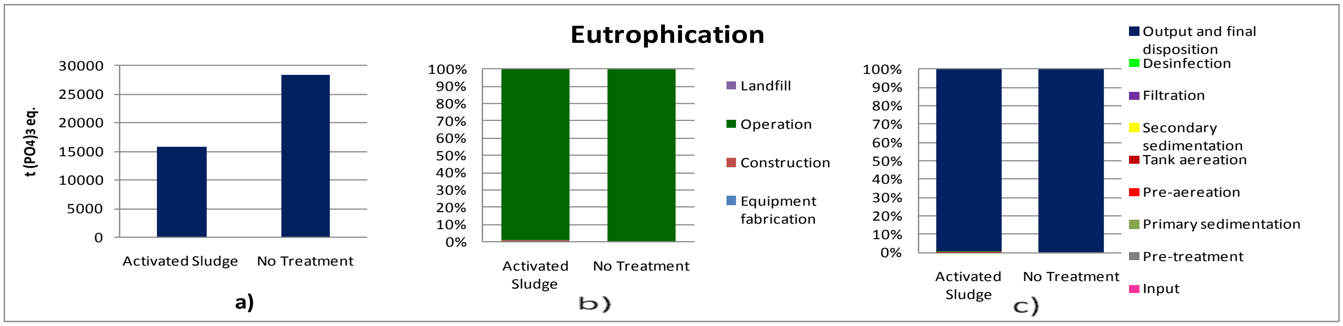

Figure 4: Impacts associated with water treatment by activated sludge and the scenario of no treatment. a) Total impacts, b) Impacts by subsystem, c) Impacts of sub-processes within the operation.

Greenhouse effect

Figure 5a shows that treatment with activated sludge generated 3.17 times more impact that the scenario of no treatment, which is attributed to the operation stage in figure 5b. According to the figure 5c unit processes that contribute most are those that require the use of electricity: aeration, pumping plant input and output to the plant –for instance treatment with activated sludge-, and the input pumping the scenario of no treatment. This is due to the consumption of fossil fuels for power generation. In this category carbon dioxide is the principal agent that influences the impact.

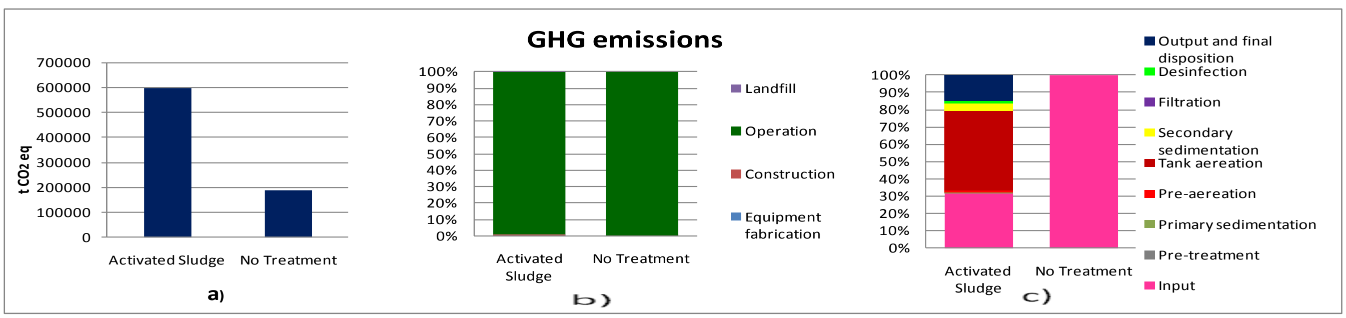

Figure 5: Impacts associated with water treatment by activated sludge and the scenario of no treatment. a) Total impacts, b) Impacts by subsystem, c) Impacts of sub-processes within the operation.

Human Toxicity

For this category of impact the Figure 6a shows that treatment with activated sludge generated a global impact 1.86 times greater than no treatment, which can be attributed to the operation (Figure 6b), where the unit processes that require the use of electricity (output and final disposition, aeration input), are major contributors (Figure 6c). Criteria pollutants in this category include arsenic, benzene and nickel generated in the process of generating electricity.

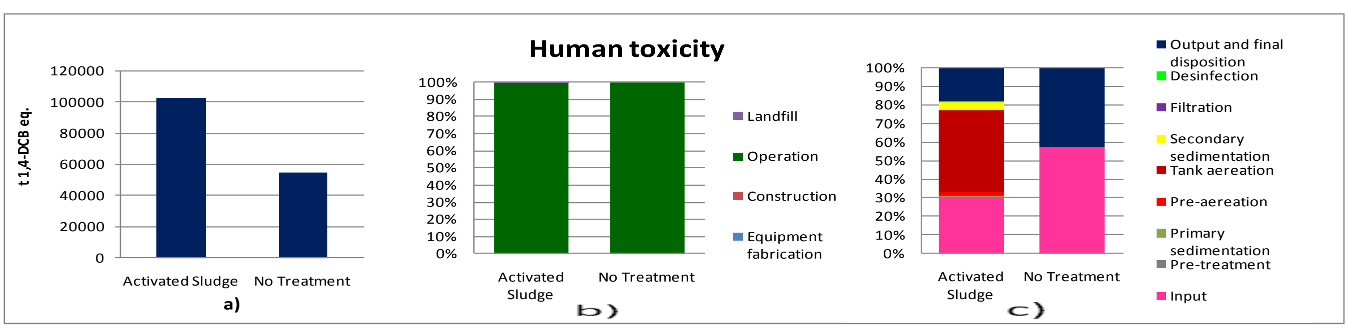

Figure 6: Impacts associated with water treatment by activated sludge and the scenario of no treatment. a) Total impacts, b) Impacts by subsystem, c) Impacts of sub-processes within the operation.

Photo-Oxidants Formation

Because one of the precursors for this impact is burning, it is expected that the scenario that generates a greater contribution to the formation of photo-oxidants is the one with a higher consumption of electricity. Thus in Figure 7a shows that the stage of wastewater treatment by activated sludge has a 3.15 times greater contribution to the stage where there is wastewater, which is due to operations carried out during operation (Figure 7b), where the processes that require more electricity is generated the greatest impact (output and final disposition, aeration and input) (Figure 7c). For his category carbon monoxide is the pollutant approach.

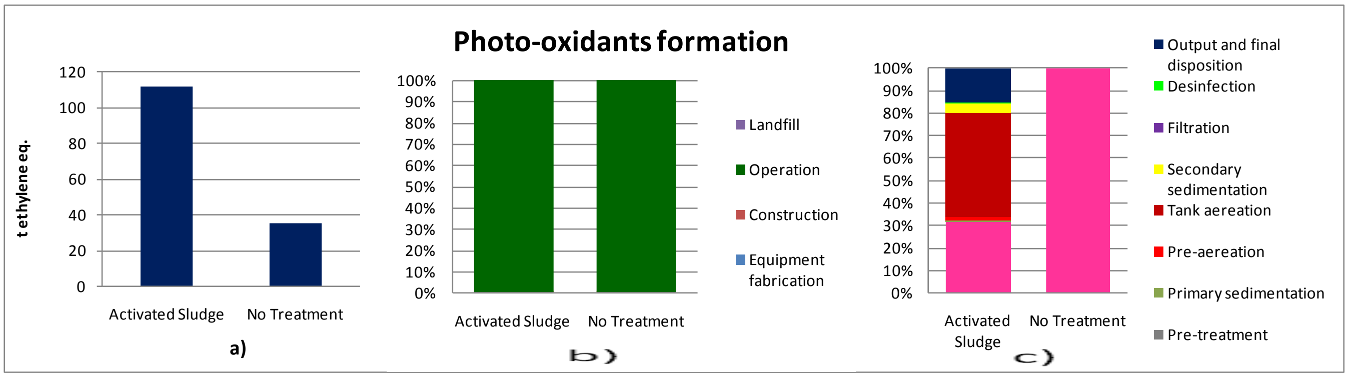

Figure 7: Impacts associated with water treatment by activated sludge and the scenario of no treatment. a) Total impacts, b) Impacts by subsystem, c) Impacts of sub-processes within the operation.

CONCLUSIONS

According to the results can conclude that the use of technology in the process of removing contaminants in water has a negative impact on the environmental impacts, mainly due to fossil fuel use and the use of energy power for the different processes that constitute the treatment train in the activated sludge WWTP.

The operation stage is where the impacts are generated, while construction, manufacturing and transportation of equipment and landfill have no significant impacts for any category.

No treatment has a greater impact in the categories of eutrophication and aquatic toxicity because the water keeps the amount of nutrients intact. For these two categories, the treatment with activated sludge continues to have impact because the process does not remove 100% of the nutrient associated with these categories.

According to the results, it is recommended that an energy plan, which seeks an alternative to using fossil fuels in generating electricity to supply energy to meet the need of the WWTP, just as the issue of sludge causes a problem because they not given proper treatment, hence wasting a potential energy source that would help reduce consumption of mains by utilizing gases generated during treatment of sludge.

REFERENCIAS

Gallego, A., Hospido, A., Moreira, M. T., & Feijoo, G. (2008). Environmental performance of wastewater treatment plants for small populations. *Resources Conservation & Recycling* . Obtenido de ScienceDirect.

Guinèe, J. (2001). Life Cycle Assessment: An operational guide to the ISO standards. Leiden.

Hospido, A., Moreira, M. T., & Feijoo, G. (2008). A Comparison of Municipal Wastewater Treatment Plants for Big Centres of Population in Galicia (Spain). *Int J LCA , 13* (1), 57 - 64.

Hospido, A., Moreira, M. T., Fernández-Couto, M., & Feijoo, G. (2004). Environmental Perfromance of a Municipal Wastewater Treatment Plants. *Int J LCA , 9* (4), 261 - 271.

ISO. (2000). ISO 14000. Environmental Management. Genève.

Machado, P. (2006). LIFE CYCLE ASSESSMENT OF WASTEWATER TREATMENT OPTIONS FOR SMALL AND DESCENTRALIZED COMMUNITIES: ENERGY-SAVING SYSTEMS VERSUS ACTIVATED SLUDGE. *10th International Conference on Wetland Systems for Water Pollution Control* , 1203 - 1213. Lisbon, Portugal.

Suh, Y. (2001). *Considerations in Life Cycle Inventory analiysis of municipal astewater treatment systems.* Obtenido de Oral presentation at COST 624 WG Meeting, Bologna, Italy: http://www.ensic.inpl-nancy.fr/COSTWWTP/

LCA of Laundry Detergent using Malaysia Background data

Background, aim and scope

Life Cycle Assessment was conducted on Laundry Detergent using the Malaysia background data. Before this most of the LCI in Malaysia was conducted using European background data. Data for electricity, water, transport, petroleum and natural gas for this study were obtained from Malaysia scenario. This plays an important role in terms of accuracy and reliability of the data in conducting Life Cycle Assessment in Malaysia.

Materials and Methods

Detailed production data of a laundry detergent in Malaysia were obtained from Southern Lion manufacturing site as the basis of this study. Combination of surfactant such as LASH and MES were used in the production of laundry detergent. Site specific data for LASH and MES were obtained from this study. Life Cycle Inventory of MES covered palm oil seedling, fresh fruit bunches, crude palm oil, methyl ester and production of MES. Impact to the land use was excluded in this study due to the limitation of data. Background data for Malaysia was also developed in this study. Literature data and JEMAI LCA PRO database were used to cover remaining data gaps. Life Cycle Inventory of the whole production of laundry detergent was created. This research used JEMAI LCA PRO software to conduct life cycle inventory and impact assessment.

Results and Discussion

Laundry detergent was found to have significant environmental impacts on the use stage. About 60% of the CO2 emission was from the use stage followed by 29% from the production stage. Remaining were from the disposal stage and transportation. The results show that LASH has significantly higher environmental impacts compared to MES for two impact categories mainly fossil energy resource consumption and global warming.

Conclusion

Environmental impacts of laundry detergent were estimated in a cradle to grave. The major contributors to the environmental impacts of laundry detergent in aggregating methods were fossil energy resource consumption and green house gas emission. Change in pattern of use stage will change in the CO2 emission significantly. Higher percentage of MES will also reduce the environmental impact in the overall life cycle assessment of laundry detergent.

Recommendations and perspectives

Since it was proven that MES surfactant has significantly lower environmental impact compared to LASH surfactant, it is recommended to use MES surfactant in higher percentage in the production of laundry detergent compared to the LASH surfactant. Recently only about 2% was used in the production of laundry detergent. If more than 10% of MES was used in the production of laundry detergent there will be significantly lower environmental impact to the environment mainly in the fossil energy consumption and green house gas emission.

Waste Management

CILCA 2011
MÉXICO

The Fenix Project: Giving Packaging a New Life
Spain

Application Life Cycle Impact Assessment oleaginous waters treatment systems
Cuba

Life Cycle Assessment of three scenarios of charcoal production in the eastern amazon
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The assessment of ecological effect using LCA and its application for evaluation the investment projects supported from ecological funds
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Municipal Solid Waste Management using Life Cycle Assessment: Anaerobic Digestion on Biogas Plant Case Study
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Plastic bags in Mexico: a review of results of a Comparative Life Cycle Assessment Study
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Life Cycle Analysis of Solid Waste Generation in Santa Maria Beach
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Opportunities for the use of LCA in waste management in Portugal
Portugal

The Fenix Project: Giving Packaging a New Life

Rubén Aldaco[1], María Margallo[1], Alba Bala[2], Pere Fullana[2], Angel Irabien[1]
[1]Departamento de Ingeniería Química y Química Inorgánica, Universidad de Cantabria (UC)
Avda. de Los Castros, s.n. 39005 Santander, Spain
e-mail: aldacor@unican.es Tel. +34 942 20 15 86
[2]Escola Superior de Comerç Internacional (ESCI-UPF)
Pg. Pujades, 1. 08003 Barcelona, Spain

ABSTRACT

The FENIX project aims at developing a software tool to assist Spanish and Portuguese municipalities in the decision-making for packaging waste management from a life cycle perspective, integrating environmental, economic and social aspects. The tool will allow the different users to introduce and modify parameters (km travelled, selection between different collection and treatment options, plant efficiency, etc.) to adapt the models created in the tool to the real situation. With the aim of promoting more sustainable packaging waste management and minimizing environmental impact, the tool will aid in creating more sustainable collection systems adapted to the different situations of today's European societies, fostering sustainable development and the protection of our environment.

Topic: Industrial Applications: Waste Management and Recycling

Keywords: Sustainable, Packaging, Waste, Management

1. Introduction

Municipal waste generation has been increasing in Europe during the last years, moving from 458 kg per person in 1995 to 518 kg per person in 2005, and being that the general trend in all European countries. Approximately 35% in weight of municipal waste is packaging waste, and it is also increasing every year.

Currently, all the population in Portugal and 97% of the population in Spain, have access to the selective collection of light packaging and paper and cardboard. However, in terms of territorial coverage, only 73% of municipalities in Spain have implemented this system. Spanish municipalities are very dispersed located from one another, and one single municipality can contain different towns without any physical connection between them. In fact, there are 8,111 municipalities formed by more than 56,400 towns, the majority of which have less than 50 inhabitants. As a result, there is a growing concern and open debate about the convenience, from the economical, social and environmental point of view, of extending the selective collection to those areas.

From an environmental perspective, raw material used, energy consumption and emissions during packaging production are quantitatively comparable to the levels consumed and emitted during the recycling process of waste packaging materials. To obtain raw materials from waste recycling, it is necessary to collect, transport, classify and finally process them, which also imply the consumption of water, energy and additional materials. Thus, it is necessary to make a balance and check whether environmental benefits of selective collection and recycling are higher than resource consumption and pollution during those processes.

Life Cycle Assessment (LCA) is a well known and objective tool for environmental analysis of products and services. LCA could be used to compare different waste treatment options or to compare different stages of the process (containers production, transport, recycling, landfilling…). This methodology allows to determine which stages are the most environmentally harmful and to do a balance among the benefits of the recycling activity in comparison with collection and transportation phases, for instance.

In order to achieve all the potential benefits of LCA for packaging waste management, it is essential to have an interactive and easy-to-use LCA software tool, including different waste treatment options and models that could be adapted to different realities.

The FENIX project aims at developing a software tool to assist Spanish and Portuguese municipalities in the decision-making for packaging waste management from a life cycle perspective, integrating environmental, economic and social aspects. The tool will allow the different users to introduce and modify parameters (km travelled, selection between different collection and treatment options, plant efficiency, etc.) to adapt the models created in the tool to the real situation. With the aim of promoting more sustainable packaging waste management and minimizing environmental impact, the tool will aid in creating more sustainable collection systems adapted to the different situations of today's European societies, fostering sustainable development and the protection of our environment.

2. Objectives

Figure 1 shows the Fenix conceptual diagram.

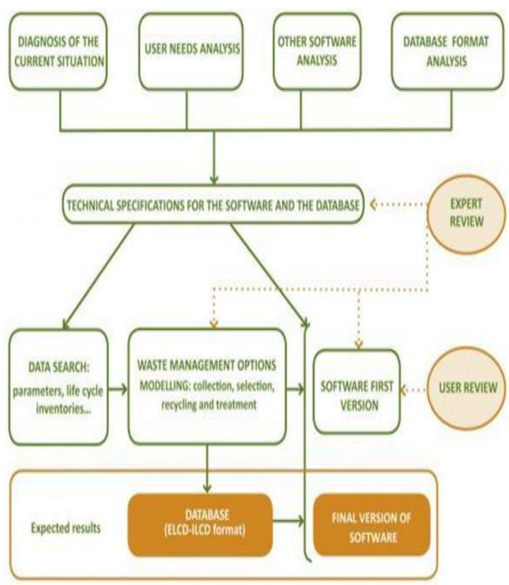

Figure 1. Fenix conceptual diagram.

The FENIX project aims at developing a software tool to assist Spanish and Portuguese municipalities in the decision-making for packaging waste management from a life cycle perspective, integrating environmental, economic and social aspects. The tool will allow the different users to introduce and modify parameters (km travelled, selection between different collection and treatment options, plant efficiency, etc.) to adapt the models created in the tool to the real situation.

With the aim of promoting more sustainable packaging waste management and minimizing environmental impact, the tool will aid in creating more sustainable collection systems adapted to the different situations of today's European societies, fostering sustainable development and the protection of our environment.

Specific objectives:

The specific objectives of the project are:

- Show the usefulness of LCA to make decisions related to waste management issues.
- Create and adapt the new software to the user's real needs.
- Compile data and create a specific database on waste management processes for Spain and Portugal.
- Share the knowledge outcomes among other Spanish and Portuguese institutions (universities, technical institutes, etc.) in order to facilitate the establishment of an Iberian network of experts on LCA and waste management.
- Transfer the results to other European regions.
- Training project collaborators on waste management, LCA, and the use of the GaBi software.

3. Actions

Action 1: Overall project operation
This action includes, among others: coordination of the communication among the Consortium, planning the activities to be performed by each institution, establishing the common format to present the outcomes of the project, prepare the documents to be delivered to the European Commission, and preparation of the annual and periodic meetings.

Action 2: Monitoring
For a well performance of the project, it is necessary to measure and document the effectiveness of the project actions as compared to the initial situation, objectives and expected results. As it will be a 3-year project, it

is proposed to carry out activity reports, which will be coordinated by ESCI with contributions of the rest of the partners.

Action 3: Audit
An external verification, by an independent auditor nominated, of the financial statements provided to the Commission in the final project report will be carried out.

Action 4: Regulatory Framework and Legal Issues
The main objective of this action is to analyse the regulatory framework of waste management in the area under the study but also in the whole Europe, since the final aim of the project is the transfer of knowledge of the FENIX outcomes into other European regions or countries.

Action 5: Methodological Development
This action includes some activities:

- Analyse the needs of the final users of the tool.
- Analyse the different packaging waste collection systems within the area of the study.
- Search experiences in other countries.
- Choose the best database format for environmental inventory data collection.
- Select waste management models and waste treatment technologies to be modelled into the software.
- Establish the technical requirements for the software and the database.
- Select some Spanish and Portuguese pilot municipalities that will be involved in the project.
- Assign responsibility among project collaborators.

Action 6: Data Search and Modelling
this action is divided into three main activities: modelling of technologies and processes, data search and writing of inventory life cycle reports.

Action 7: Software Development and Maintenance
Models of processes and packaging waste management technologies will be done using the Gabi 4.0 software, one of the most widely LCA software used worldwide. Since one of the objectives of this project is to make a friendly useful tool to obtain LCA results easily in order to assist municipal and regional waste treatment decision-makers, it will be necessary to create an easy interface to deal with database contents and the models created within Gabi. This interface should gather the needs and requirements of future users as far as possible and allow the user to make some changes in variable parameters like the type of container, the km between the city and the treatment facilities or chose one or another treatment processes.

Action 8: Ongoing Revision
Taking into account the ISO 14044:2006 standards, it is necessary to carry out a revision of the software and the database by external experts in order to guarantee the quality of the final versions. This task will be done under this action.

Action 9: Transferability basis
This project aims at spreading life-cycle thinking and the use of LCA for packaging waste management to the rest of municipalities in Spain and Portugal, and to other European countries. Especially to those who have not so much experience on packaging waste management and treatment technologies and LCA. Furthermore, it is intended to determine the usefulness of the new software for governance.

Action 10: Training, communication and dissemination
It is one of the main objectives of this project to spread the knowledge to stakeholders related to packaging waste management as far as possible. Some training courses for selected municipalities will be performed in order to encourage them to participate (giving data, testing the demo version of the software and using the final version) at the beginning of the project. These courses will be also used to spread the life-cycle approach and the benefits of using LCA for waste treatment management among other municipalities once the final version is ready.

4. Partners and Collaborators

The FENIX project foresees the cooperation of universities and other centres in Spain and Portugal for data collection and modelling of collection processes, transport and waste treatment. The main goal of this collaboration is to share experiences, raise awareness on packaging waste management from the LCA perspective, and create a network of experts that can help to extend the use of LCA for waste management issues in these countries.

Table1. Partners and Collaborators of the Fenix Project.

Partners
▪ ESCi – GiGa
▪ Ecoembes
▪ Sociedade Ponto Verde
▪ PE-International
Collaborators
▪ Universidad San Jorge
▪ Universidad de Cantabria (SOSPROCAN)
▪ Centro Tecnológico de Miranda de Ebro
▪ Escola d'Engineyeria d'Igualada (UPC)
▪ Instituto Tecnológico Metalmecánico (AIMME)
▪ Instituto Tecnológico del Mueble, Madera, Embalaje y Afines (AIDIMA
▪ Instituto Tecnológico del Plástico (AIMPLAS)
▪ Universidad de Santiago (USC)
▪ Instituto Andaluz de Tecnología (IAT)
▪ Cátedra Ecoembes de Medio Ambiente de la Universidad Politécnica de Madrid (UPM)
▪ Universidad de Tras- os-Montes e Alto Douro (UTAD)
▪ LNEG - Laboratório Nacional de Energia e Geologia
▪ CCIAM - Climate Change Research

5. Expected Results

The expected results of the project are:

- A user-friendly and flexible tool for easy obtaining environmental Life Cycle Assessment (LCA) results of packaging waste management. This tool could be used by different European regions and municipalities in order to assist them in the decision-making process. It will be prepared for future updating to include new technologies of processes and it will allow users to change some parameters like: type of truck used, number of containers, total amount of waste collected, distance between the municipality and waste treatment facilities, etc.

- A life cycle inventory database of packaging waste management technologies and treatments compatible with ELCD/ILCD and available for free to the LCA community.

- Contribution to congresses, meetings, etc. to disseminate the project by means of presentations or posters in different international events about the state of the project. Major items will be packaging waste management, LCA and governance.

- Publications about packaging waste management and the use of LCA for decision-making in this area.

- Increasing knowledge about waste management and LCA within the area of the study and also at European level by means of dissemination and transferability.

- Favouring the start-up of an Iberian LCA network of experts on LCA and waste management.

Acknowledgements

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Application Impact Assessment Life Cycle oleaginous waters treatment systems.

Martines Pastora [1], Rosa Elena [1], Pérez Maira [1], Leiva Jorge [2], Rodríguez Iván [2], Esperanza Guillermo [1].
[1]Applied Chemistry Study Center, Central University of Las Villas. Road to Camajuaní Km. 5.5. Santa Clara, c/p 54830, Villa Clara, Cuba.
[2]Chemical Engineering Department. Central University of Las Villas. Road to Camajuaní Km. 5.5. Santa Clara, c/p 54830, Villa Clara, Cuba.
***corresponding author: pastoramn@uclv.edu.cu**
Telf: (53) (422)-11863, 81510 Fax: (53) (422)-81608

ABSTRACT
In recent years, recognition of environmental and social issues has increased dramatically. An improper disposal of sewage can cause contamination of surface water, groundwater and soil, causing health problems that affect almost all life.
Usually in the selection of technology used in controlling pollution from wastewater, only have in mind is often technical and social aspects, qualitatively addressing the environmental component, which is why this work is to: assess the environmental impact of processing carried out at laboratory scale through the use of Life Cycle Assessment as a criterion in selecting the less powerful system.
By using the methodology developed by the use of professional software SimaPro Pre v 7.2 of Consultant and the use of the methodology Recipe (H), from the information provided by the physical-chemistry performed, the preparation of the inventory entries and outputs of the three scenarios relevant objects of study and considering the scope of work only emissions to water in each stage to the Functional Unit of 1 m^3 of wastewater to treat, it was determined that the main environmental impacts associated with categories human toxicity and ecotoxicity in different medium, was more human toxicity category.
The application of the methodology for environmental comparison of the efficiency of treatment demonstrated that both alternatives reduce environmental impact, but the scenarios 2 and 3, result in a reduction of 99% of the pollution load of the effluent expressed in points.
Topic: LAC Management Trends. LAC Methodology: LIC and LICA.
Key Words: Life cycle Assessment, oleaginous waters, environmental impact, disposal oleaginous waters.

INTRODUCTION

In recent years interest has grown in the oleaginous waters treatment, due to the difficulty presented by these waters to be subject to treatment as a result of their physical-chemical and causing adverse effects to the environment available in the natural water bodies. They come from different sources and vary widely in composition and physical properties. In the particular case of distributed power generation, the possibility of environmental damage, caused mainly by their liquid waste, is extremely large due to the infiltration of subsurface soil or contamination of surface water and underground in case of accidental spills or dumping of such waste without the required quality [1].

The goals of treatment of wastewater are basically two: to protect the water bodies by preventing the discharge of polluted wastewater and get adequate quality water for reuse or discharge taking into account the current legislation [2].

Taking into account the physical and chemical characteristics of the oleaginous waters, several authors [3] as primary treatment a physical separation, which allows separate water, fat, oils and hydrocarbons, by the difference existing density? The three phases are subjected to heating (depending on fuel characteristics) to facilitate the separation of water is occluded and the fuel can be recovered and reused in other processes. The water phase consisting of droplets less dense phase (emulsion microscopic), allows secondary treatments such as dissolved air flotation or centrifugation, which removes the organic material could have been drawn and the biological relevance as tertiary treatment, which allows predominantly microorganisms such as bacteria (*Pseudomonas, corynebacteria and mycobacteria*), yeasts and even some green algae have a greater surface contact with the emulsion particles are microscopic, providing access to it and allowing its degradation. In this sense, constructed wetlands are considered biological treatment plants, low-cost technology, easy to operate and maintain because they require a low number of workers and few electromechanical equipment, as well as its simple construction, low energy and harmony with the environment.

In the selection of technology used in controlling pollution from wastewater, only have in mind many times, technical and social aspects, addressing only qualitatively the environmental component, which is why the applicability of Cycle Analysis (LCA) in environmental impact assessment systems for wastewater treatment, appears to be an effective tool to establish criteria in the selection of them [4].

The Life Cycle Analysis (Life Cycle Assessment), is one of the P+L tool, which evaluates the environmental impact of a process or product at every stage involved from production to disposal, from the extraction of resources to the distribution of the product already developed or treatment of waste products. This involves identifying and quantifying the energy, materials used and wastes released into the environment at each stage of the life cycle of a product. This will assess the environmental impact and are better options [5].

Taking into account the degree of significance that has acquired the oleaginous waters treatment and the need to treat them to properly dispose of or reuse them, have led to the planning of next objective: to assess the environmental impact of processing carried out on a laboratory scale, by use of Life Cycle Assessment as a criterion in selecting the less powerful system.

LCA METHODOLOGY

The P+L tools used in the certification of organic products, eco-indicators, initial environmental review, eco-map, Ecobalance, MED Matrix, Life Cycle Assessment (LCA), environmental accounting, flow analysis, analysis risk and eco-design, these are used at the enterprise level to achieve sustainable products and processes are fundamental to achieving the overall objective of sustainable development, which is itself the ultimate goal of environmental management [6].

The method of life cycle analysis (LCA) was selected in our work to quantify the environmental impacts of three alternative scenarios on a laboratory scale, for the treatment of oleaginous waters generated in the centrifuge process fuel used in distributed power generation.

For quantification of impacts, a methodology was developed taking into account the provisions of [7] NC-ISO 14040 and [8] ISO 1441 and that it meets the needs of effective treatment available to help mitigate the impacts caused environmental, whether they were discharged to the environment without treatment. This study to our knowledge has not been done in our country so far.

The following are the phases of LCA under ISO 14040.

Functional unit.

Functional unit was taken as 1 m^3 of oleaginous waters to be treated.

System limits.

Figure 1 shows the system boundaries for LCA, which begins with the input of untreated oleaginous waters and ends with the treated water for discharge into the receiving body or reuse in the process of spin considering three alternative scenarios.

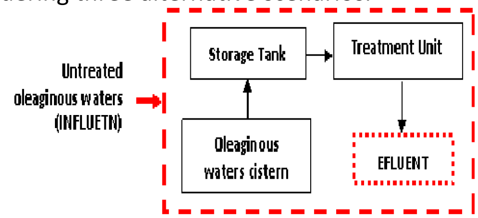


Figure 1: Diagram of the system limits

Description of alternative schemes.

Scheme 1*. *Physical separation and discharge into the environment. The oleaginous waters (influent), skip and a 7.8 m^3 rectangular tank capacity, whose function is to provide the necessary space debris to decant or settle by gravity and flotation separation in three phases: product (fuel), impurities and water. Within the cistern walls exist, similar to the fat traps that allow the separation of the water and the fuel by density difference. The water (effluent 1) is pumped to a tank (9 m^3) for discharge to the environment.

Scheme 2*. *Physical separation, natural treatment and discharge into the environment. From the storage tank the water flows by gravity to the system of subsurface flow constructed wetlands horizontal (HFS), consisting of two polyethylene trays containing a bed of 15 cm thick, an area of $1m^2$, a flow of 0,014 m^3/day, consisting of a granular media (gravel) and a level of water to be sufficient to simulate a natural wetland system. In the HFS were planted *alternifolius Cyperus* species. The objective of this subsystem is to remove the main contaminants in the water from the primary treatment (physical separation) and the treated water (effluent 2) is discharge to the environment.

Scheme 3. Physical separation, natural treatment and reuse water in the fuel centrifugation. In this scenario takes place the same treatment system as in scheme 2, but the treated water (effluent 2) is recycled in the process of centrifuging the fuel.

In assessing the environmental impact of alternative treatment scenarios not included consumption of electricity, because it works with existing gravity simulating the unevenness in the location of the study. In figures 3 and 4 show the different.

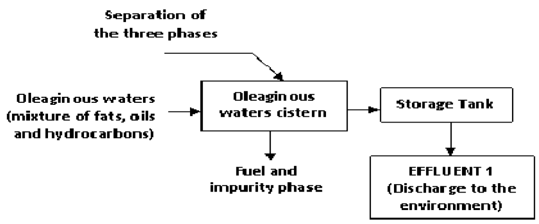


Figure 2. Scheme 1

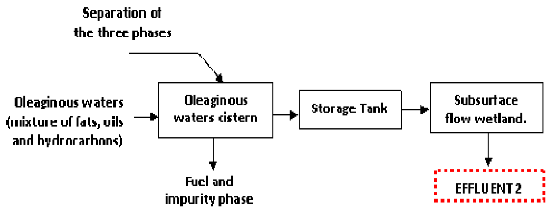


Figure 3. Schemes.2 and 3

2.5. Impact assessment and methodology.

Reducing the environmental impact of the process was evaluated considering the% removal of each pollutant, using the methodology Recipe (H) with the program SimaPro Pre v 7.2 of Consultant, the selection of the method due to the possibility of evaluating the impact categories related with toxicity, human toxicity, ecotoxicity, terrestrial ecotoxicity, fresh water marine ecotoxicity.

2.5.1. Requirements of data quality.

The data were obtained from the physical characterization, physical-chemical and mass balance performed in one of the centrifuges of GE which conducted the study, the functional unit set. This study allowed to estimate the volume of oleaginous waters generated in operation 12 months (1 year), taking into account the fuel consumption for power generation in the same period. However data are taken from the database *Ecoinvent V 1.01*, analyzing in detail the cases most similar to our conditions.

Inventory analysis.

One tool that has been extremely useful to carry out a comprehensive waste management is the Life Cycle Inventory (LCI). The ICV begins at the moment in which a material becomes waste (ie, it loses its commercial value), and ends when it ceases to become waste and becomes a useful product, into usable energy or inert material in landfill. "Inputs" in a system are the solid and liquid waste, energy and other resources. The "outputs" or products of the system may be useful materials "revalued" (reused, recycled, composted or incinerated derivatives with energy recovery), air emissions or water and inert materials that are disposed in landfills.

The inventory was make for 12 months of operation (1 year), data from the foreground of this phase were calculated from mass balance, based on a m^3 of oleaginous waters treatment and and the results of the characterization physical chemistry.

The level of detail is achieved in the inventory depends on the availability of data and level of complexity to be obtained and can be applied an approximation or simplification of these procedures where necessary.

Input data.

- Water consumption in the process.
- Characteristics of oleaginous waters without treatment study. (Influent).
- Characteristics of materials after a natural separation as primary treatment. (Effluent 1).

The physical-chemical characterization was performed taking into account the provisions of the APHA 2005 [9].

Output data.

- Characteristics of oleaginous waters after a natural treatment (subsurface flow constructed wetland) as a secondary treatment (effluent 2).

RESULTS AND DISCUSSION

Physical-chemical characteristics of oleaginous waters. Inventory.

In Table 1 is a summary of the inventory of major pollutants identified in the physical-chemistry performed.

Table 1. Primary data inventory for the pollutants in the alternatives schemes.

Pollutants	Unit	Influent	Scheme 1	% Rem.	Schemes 2 and 3	% Rem.
pH	U	6.76	7.43	-	7.80	-
DQO	**(Kg/m^3)**	3.47	0.84	75.79	0.0420	95.00
G y A	**(Kg/m^3)**	12.22	0.38	96.89	0.0380	90.00
HC	**(Kg/m^3)**	8.06	0.27	96.65	0.0270	90.00
ST	**(Kg/m^3)**	0.9	0.71	21.11	0.1420	80.00
Pb	**(Kg/m^3)**	2.24E-04	2.20E-04	-	1.10E-05	95.00
Cu	**(Kg/m^3)**	1.80E-03	1.50E-03	-	7.50E-05	95.00
Zn	**(Kg/m^3)**	5.30E-04	5.17E-04	-	2.59E-05	95.00
Fe	**(Kg/m^3)**	1.77E-03	1.75E-03	-	8.75E-05	95.00

3. Environmental Impact assessment.

Figure 4 shows the results obtained by applying the methodology Recipe (H) to the untreated oleaginous waters (influent), where the category most impacted human toxicity is worth 1.84 points, less significant results obtained in the categories associated with the ecotoxicity in different media.

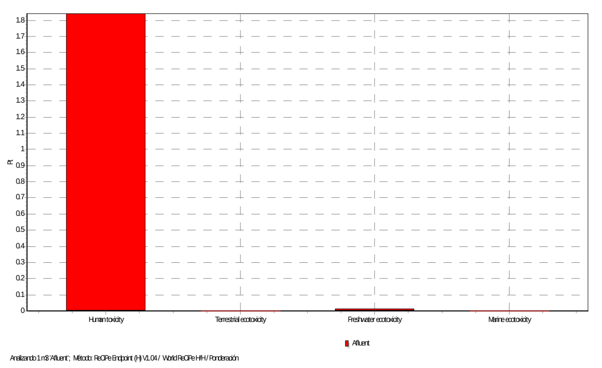


Figure 4. Impact assessment of the influent.

Figure 5 shows the comparative analysis of the results of chemical values - physical effluent of different schemes, which are achieved with the implementation of the proposed alternatives, we can see that both significantly reduce the impact, but scenarios 2 and 3 considered for treatment of oleaginous waters achieved the reduction of the total impact by 99%.

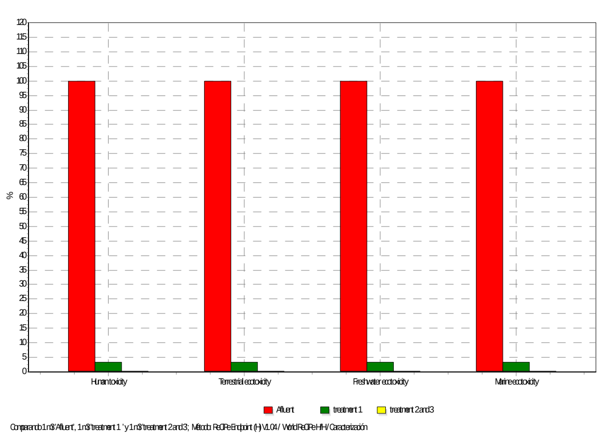


Figure 5. Ccomparative analysis of the different schemes.

CONCLUSIONS.

This article provides detailed results that allow an assessment of the environmental performance of different alternative scenarios for the treatment of oleaginous waters. By using the methodology developed in this work by the use of LCA software SimaPro Professional v 7.2 and the use of the methodology Recipe (H) untreated oleaginous waters (influent), identified the main environmental impacts associated with human toxicity categories , and ecotoxicity in different mediums, was more human toxicity category (1.34 points). The comparative analysis of the results of chemical values - physical effluent in different schemes, with the implementation of the proposed alternatives, shows that the impact is greatly reduced, but the schemes 2 and 3 achieved a reduction of the total impact on a 99%, proving to be the cleanest.

This environmental assessment of alternative schemes can take advantage of an analysis of the effects that may occur in other fields such as technical impact analysis, economic and social development.

REFERENCES.

[1]. Lafuente, S. 2000. Métodos de separación física para el tratamiento de desechos de refinería. Yacimientos Petrolíferos Fiscales Bolivianos. Cochabamba. Bolivia.

[2]. Escalas, A. 2006. Tecnologías y usos de las aguas residuales en México. Consultar el sitio http://www.conagua.gob.mx/eCNA/Espaniol/Publicaciones/Subsector1999/Cap6_9.

[3]. Metcalf & Eddy 2005. Tratamiento y depuración de aguas residuales. Editorial Labor SA. España.

[4]. Monistrol, A., Vidal, N., Poch; M. 1999. Análisis del ciclo de vida aplicado al tratamiento de aguas residuales, en Tecnología del agua (41-47), junio 1999.

[5]. Hospido, M.T. Moreira, F. Omil, M. Fernández-Couto y G. Feijoo. 2004. Análisis del Ciclo de Vida y aplicación a EDAR. Gestión de lodos de depuradora. Ponencia extraída del II Congreso Gallego de la Calidad. España.

[6]. La revista de la empresa y el medio ambiente en la comunidad valenciana febrero 2007. No. 40. El análisis de ciclo de vida (ACV); una herramienta para la mejora ambiental de productos. Pag 4.

[7]. National Office Normalization ISO 14040. 2009. Environmental management LAC. Cuba.

[8]. National Office Normalization ISO 14041. 2009. Environmental management LAC. Cuba.

[9]. APHA, AWWA, WEF. 2005. Standard Methods for the Examination of Water and Wastewater. 21th Edn. Washington, DC, USA.

LIFE CYCLE ASSESSMENT OF THREE SCENARIOS OF CHARCOAL PRODUCTION IN THE EASTERN AMAZON

Rodrigues, Thiago[1]; Caldeira-Pires, Armando[2]; Rousset, Patrick[3]

[1] UnB, Forest Engineer Department – PhD candidate in Forest Sciences, Brasília, DF, Brazil – EFL/UnB
[2] UnB, Energy & Environment Laboratory, Brasília, DF, Brazil – LEA/ENM/UnB
[3] CIRAD, Biomass and energy Department, Brasília, DF, Brazil – CIRAD/SFB
thiagoefl@gmail.com

ABSTRACT

The Amazon forest is well known for its wealth of resources. There is a great abundance of iron ore and wood. This situation has promoted the development of pig iron industries based on charcoal for their thermal processes. The current scenario is a pig iron industry that uses charcoal produced in small brick kilns with biomass from sawmill residues. But there are other two potential scenarios that may develop, depending on economical, environmental, technical and political issues. The second is more technologic: charcoal production in big metallic kilns using wood from planted forests. The third is more social: charcoal production in bigger brick kilns using the mixture of wood from forest management residues and sawmill residues. So a Life Cycle Assessment is proposed to verify which scenario is better from an environmental viewpoint. The impact analysis showed that the most important impact categories are Global Warming Potential, Human Toxicity Potential and Terrestrial Ecotoxicity Potential. The second scenario causes less impact, due to sequestration of CO_2 during the development of trees and to lower emissions on carbonization.

Topic: LCA Industrial Applications – Waste management and recycling
Keywords: LCA, Charcoal, Forest Management, Amazon.

Introduction

In the southern Amazon, there are the greatest mineral resources of the world. The “Serra dos Carajás” (Mountains of Carajás), in the municipality of Parauapebas, state of Pará, is a large deposit of iron ore and other minerals. Due to this abundance, in the early 1970 a big project was implemented in the region: Projeto Grande Carajás (Great Carajás Project). This project has promoted a great transformation in the economy and logistics of the region [1]. In the city of Marabá, eastern of Pará, there was created an industrial district to smelt these iron ores into pig iron. Nowadays, there are about 17 industries that produces around 1.8 millions tons of pig iron per year or 25% of the whole brazilian production [2].

These numbers reflects the demand for energy inputs required for the thermal reduction of iron ore. The industries have defined the charcoal as the most important energy input, even if there is one that uses coke. The production of one ton of pig iron requires 0.8 tons of charcoal [3]. So for 1.8 millions of tons it is necessary, at least, 1.4 tons of charcoal per year.

In order to achieve this amount, industries are planting huge surfaces of *Eucalyptus sp.* for charcoal production. More than 60 thousand hectares are already deployed and industries intend to have 200 thousand hectares of energetic forests until 2015 [2].

Another way to have charcoal is the utilization of residues from the timber industry. The forest management in the state of Pará is a very important activity, it represents almost 40% of the 15.3 millions m^3 of logs extracted from natural forests in Brazil in 2009 [4]. This activity generates a great amount of residues, since the felling of trees in the deep forest to the cutting of logs into lumber in the sawmills, the average yield is 41% of processed wood, so 59% of residues [5].

The production of charcoal is realized mainly with brick kilns known as “rabo quente” or “half-orange” kilns. They are easy and relatively cheap to build, but the gravimetric yield does not reach more than 25%, the loading and unloading phase is performed manually, it has a small volume of charcoal per cycle and the whole cycle is long, at least seven days [6]. So to meet the demand it is necessary to build many kilns. On the other side, a more industrialized kiln is proposed. The DPC technology (Dry, Pyrolysis, and Cooling) utilizes a metallic kiln in a "closed" process. It means that all pyrolysis gases are burned to dry the biomass on another chamber, so there is no emission to the air [7].

Goal and scope

In this context of resources and carbonization technologies, there are several parallel activities to produce, prepare, recover and transport the biomass to the carbonization sites and then to transport the charcoal to the pig iron industries. So, there are important flows of energy and mass that must be assessed to verify which scenario is better, from an environmental perspective. Three scenarios were considered (Figure 1).

The project aimed to assess and compare the impacts associated with the production of charcoal in three different scenarios according to the biomass origins and the technologies adopted.

The principal scenario (base) is the production of charcoal in small brick kilns using sawmill residues. The second scenario is the production of charcoal in metallic kilns using wood from planted forests. And the third scenario is the production of charcoal in brick kilns with a mix of residues from forest exploitation and sawmills (Figure 2).

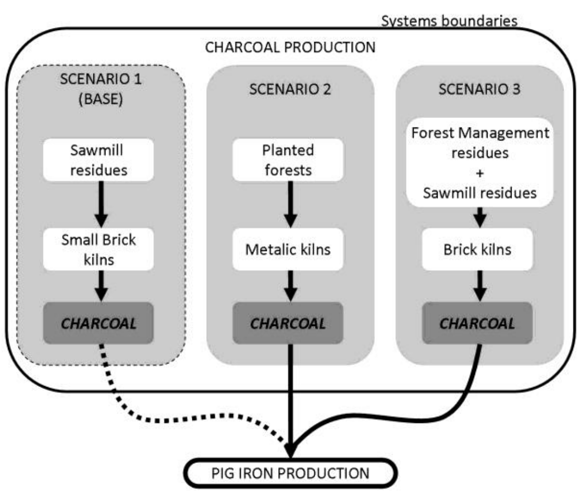


Figure 1 – Three scenarios for charcoal production in Pará, Brazil.

This research is limited to the state of Pará, Brazil. The time covered was the years before 2008, due to the economical crisis that happened that period and has strongly affected those industries. The functional unity is the production of 1000 m^3 of charcoal.

Life Cycle's Inventory

The elaboration of the inventory was initially based on the results of panoramic questionnaires applied on the production of biomass and the production of charcoal. Those questionnaires were answered with secondary informations obtained on scientific literature, industrial association's reports and governmental databases. The missing information was collected directly in the study area.

The sawmill residues are recovered right after the processing of logs and transported to the carbonization courtyard by truck. The wood from planted forests is produced in a seven year cycle and plantations are realized with seedlings of *Eucalyptus sp.* The harvest, bucking, storage and transport of logs to the carbonization courtyard are mechanized. The forest management residues are collected at least one year after logs extraction. The collection, bucking, storage and transport to the carbonization courtyard are mechanized. The site of carbonization is about 50 Km far from the biomass sources. The transportation and production of auxiliary materials processes were based on the information from the software database, GaBi 4.3.

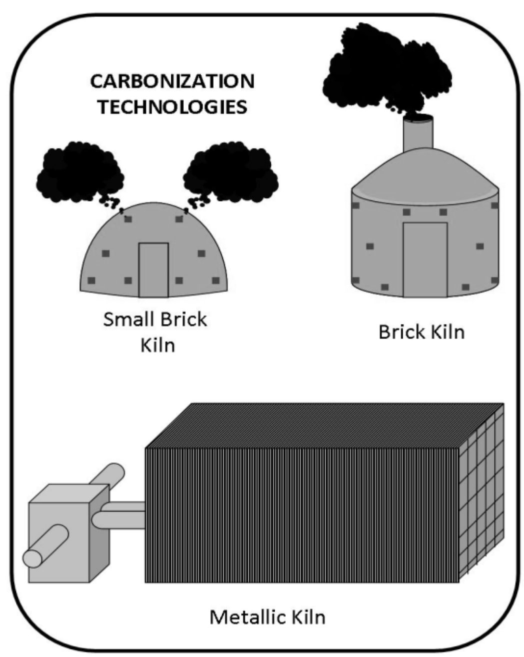


Figure 2 – Carbonization technologies.

For the SCENARIO 1, the usable (for carbonization) sawmill's residues are about $0,3m^3$ for each cubic meter of log processed for lumber. The small brick kilns have a gravimetric yield of 25%.

In SCENARIO 2, one hectare produces about 300 m^3 of round wood per year. The metallic kilns used in this situation have a gravimetric yield of 35%.

In SCENARIO 3 the mixture proposed is 87% of sawmill residues and 13% of forest management (FM) residues. The FM residues are about 2 m^3 for each cubic meter of log extracted from forest. The brick kilns have a gravimetric yield of 25%.

The SCENARIO 1 is the most representative in the region, almost 85% of the biomass comes from sawmills and more than 90% of the charcoal is produced in small brick kilns. But several changes are taking place due to environmental, technical and economical issues and the plantation of energetic forests are increasing every year. The metallic kiln is a more industrial way to produce charcoal with greater yields, less pollution and less manpower. The FM residues are a promising alternative because the sustainable management is increasing in the northern region, so the availability of biomass for charcoal too. The transportation of biomass is realized by dump trucks that use diesel with 2000 ppm of sulphur.

Impact Analysis

After the measurement of all mass and energetic flows in three scenarios, an impact analysis was realized. For this task it was used the CML 96 methodology. This analysis showed up that there are three principal impact categories associated with the scenarios proposed: Global Warming Potential (GWP), Human Toxicity Potential (HTP) and Terrestrial Ecotoxicity Potential (TETP). Table 1 presents the values for the impact categories in each scenario.

The impact analysis showed that the technological increase in the charcoal production system has positive effects for the environment. Especially because of planted forests that remove the CO_2 from the atmosphere during seven years for tree development. Also the carbonization process in metallic kilns has low emissions due to its closed configuration, so less impacts on the workers health and on the soil. The three sequential graphics illustrates the impacts for each scenario.

The difference between SCENARIO TWO and the other scenarios is from the important consumption of fossil fuels during the activities of recovery and transport of biomass to the carbonization sites.

Table 1 – Main impact categories for the three scenarios (CML 96).

SCENARIOS	GWP *Kg CO_2-eq*	HTP *Kg DCB-eq*	TETP *Kg DCB-eq*
1	$3,10x10^6$	$1,40x10^5$	$5,87x10^8$
2	***$9,47x10^{-5}$***	$8,64x10^2$	$3,55x10^4$
3	$3,14x10^6$	$1,21x10^5$	$5,87x10^8$

Life Cycle Interpretation

The current carbonization system (sawmill residues + small brick kilns) has negative impacts on environment. But from another perspective it improves the supply chain of lumber because the residues become co-products.

The transition to the SCENARIO TWO is difficult, especially for economic aspects. Metallic kilns are expensive and they implicate in unemployment, in a region that there is a great lack of job. The carbonization is an activity for many people in the region, the huge demand on charcoal causes an improvement on the micro-economy.

There is a simple technical way to decrease the impacts of the current scenario: putting a chimney in small brick kilns and burning the gases that leave the carbonization. Among many gases, there is CH_4, known for being at least 20 times stronger as greenhouse gas than CO_2. Another improvable possibility is to use these burned gases for drying the wood or to begin pyrolysis in another kiln.

Another aspect that must be evaluated is the potential methane avoided emissions due to recovery of residues in the forest under sustainable management. Those residues are "artificially" added to the ground of forest at the moment of its exploitation. If they are left there to decompose, an extra volume of methane could be released to the atmosphere.

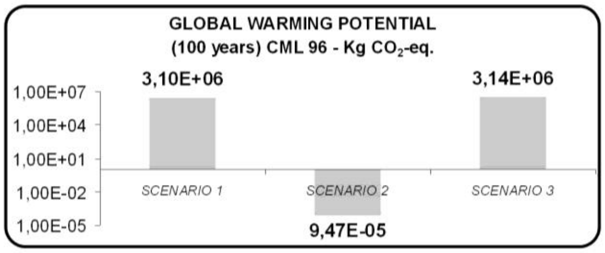


Figure 3 – Global Warming Potential for the three scenarios.

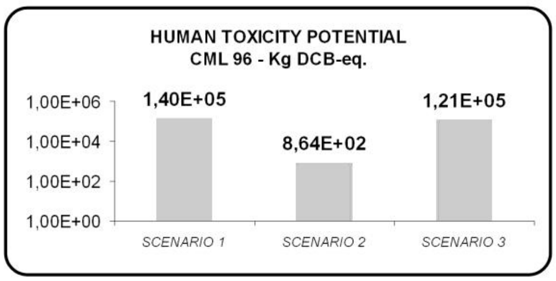


Figure 4 – Human Toxicity Potential for the three scenarios.

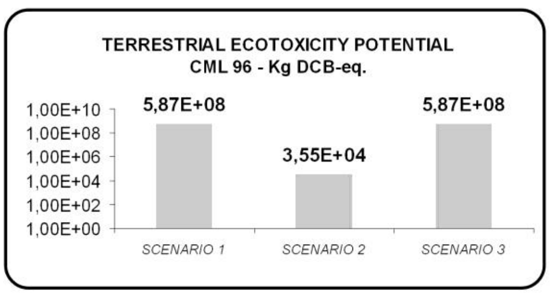


Figure 5 – Terrestrial Ecotoxicity Potential for the three scenarios.

Conclusions

The best environmental way to produce charcoal is using the wood from planted forests in metallic kilns. But this scenario is very difficult to implement in a small or medium term. It depends on several factors, mainly economic factors.

And this scenario does not have to be the only solution. As planted forests are increasing, improvements in recovering and transportation of biomass and carbonization processes can be done together. The utilization of forest management and sawmill residues must be encouraged, that could be a powerful tool to improve the efficiency of wood production chain.

More research must be done on those scenarios, especially on the recovery and the transport of residues from the forest management, in order to achieve most efficient ways. The aim of this industrial sector must be to find the best use of resources to ensure the sustainability of the activity.

Acknowledgments

This research was realized in a project financed by the French Development Agency (Agence Française de Développement - AFD) and it was coordinated by the International Center of Agricultural Research for Development (Centre International de Recherche Agronomique pour le Développement – CIRAD). The authors would like to thank the brazilian company CIKEL for hosting this research.

References

[1] Maurílio de Abreu Monteiro. 2005. Mineração industrial na Amazônia e suas implicações para o desenvolvimento regional. Novos Cadernos, Núcleo de Estudos Amazônicos – NAEA. v. 8, n. 1: 141-187.

[2] [SINDIFERPA] Sindicato das Indústrias de Ferro-Gusa do Estado do Pará. 2007. Eucalipto: Ouro verde para a sustentabillidade. Pólo Sustentável. n.1: 5 p.

[3] Maurílio de Abreu Monteiro. 2006. Em busca de carvão vegetal barato: o deslocamento de siderúrgicas para a Amazônia. Novos Cadernos, Núcleo de Estudos Amazônicos – NAEA. v. 9, n. 2: 55-97.

[4] [IBGE] Instituto Brasileiro de Geografia e Estatística. 2010. Produção da Extração Vegetal e da Silvicultura: 2009. Rio de Janeiro (RJ), Brazil: IBGE. v. 24: 45 p.

[5] Denys Pereira, Daniel Santos, Mariana Vedoveto, Jayne Guimarães, Adalberto Veríssimo. 2010. O setor madeireiro da Amazônia. In: Fatos Florestais da Amazônia. Belém (PA), Brazil: IMAZON. p. 31-37.

[6] Paulo César da Costa Pinheiro, Ronaldo Santos Sampaio, José Gonçalves Bastos Filho. 2005. Organização da Produção de Carvão Vegetal em Fornos de Alvenaria. Biomassa & Energia. v. 2, n. 3: 253-258.

[7] DPC Thermal Processing. 2010. O Processo DPC. http://www.dpcbiomassa.com.br/oprocesso.php. Accessed 17 december 2010.

SOCIAL BANKS: AN CONCRETE INSTRUMENT FOR EXTEND LIFE CYCLE OF PRODUCTS AND PROMOTE SOCIAL RESPONSIBILITY

Severo, Elisabeth
Schmidt, Thilo
Carvalho Filho, Arnaldo
esevero@hotlink.com.br

A strategy to increase the efficiency of natural resources is the extension of the life cycle of products, with the consequent reduction in the volume of waste in a given space of time as the basic principle of waste management: Avoid, Reduce, Reuse, Recycle and finally treat the waste properly. In this hierarchy, the social banks are a practical tool for the reuse of products, and a preferred strategy when compared to recycling.

Banks Social Project brings together the reuse of waste with the more efficiently manage resources and goods together with the responsible consumption and solidarity.

The ultimate goal is to create an ongoing commitment of industry in promoting social responsibility.

The operation is done through coordination of the database of Social Banks that receive, record, store and then distribute donated goods in perfect condition by the industries to the beneficiaries (Day care Centers, Assistance entities, hospitals, etc.).

In 2009, 14 Social Banks raised and donated goods and services as follows:

- 1,500 tons of food to 331 institutions (22,000 households);
- 680,000 meals;
- 721 mobile and 4 refurbished schools in Porto Alegre;
- 3500 tons of clothing;
- 500,000 books to public schools;
- Completion of 6 courses and professional training of 86 students in the textile field.

Banks Social besides being a fundamental instrument in the hierarchy of waste management by reuse, increasing the life cycle of products, is essentially a sustainable industry solidarity, contributing to reducing the negative environmental impact and social distortions.

Keywords: Social Banks, social responsibility, life-cycle management of waste.

Joanna Kulczycka
Łukasz Lelek
Mineral and Energy Economy Research Institute of the Polish Academy of Sciences
31-261 Cracow
ul. Wybickiego 7
T: +48 12 632 22 45
E: kulczycka@meeri.pl

The assessment of ecological effect using LCA and its application for evaluation the investment projects supported from ecological funds

There are many programs using LCA technique to support modeling of waste management systems by assessing its impact on the environment. In this study two kinds of the software IWM – 2 and SimaPro were used to propose a method for calculating the environmental impact of the investment, in order to facilitate decision-making in projects co-financed by the Structural Funds. IWM-2 is tool showing environmental burdens and benefits coming from waste stream, collection and treatment, it's sensitive to the composition of the waste, and change in the quantity of the fraction, whereas Sima Pro allow grouping the results in terms damage and impact categories, which is a base for calculating the environmental effect. The algorithm how to calculate the environmental effects for planned investment was presented on the example of municipal waste landfill in Promnik managed by Waste Management Company in Kielce. For analysis were taken into account the following scenarios:
S0 – situation where all collected waste going to landfill site,
S1 – the current situation without any investment - recovery of recyclables from separate collection, landfill gas recovery and energy production,
S2 – mechanical biological treatment (BMT) plant with aerobic fermentation,
S3 – BMT plant with anaerobic digestion.

The results show that landfill gas recovery and energy production causing more than 2 fold reduction in negative environmental effect compared to scenario with landfilling only, and the use of mechanical-biological treatment and using produced RDF fuel leads to significant environmental benefits. It can be compared to economic efficiency of such proposal and can be a base for ranking projects for supporting from ecological funds.

Keywords: LCA, waste management, investment projects, eco-efficiency

Analysis of the Impact of Energy Recycling Used Oils & Solvents Pemex Petrochemical In Focus On Life Cycle.

Guzmán -Lezama Felipe[1*] and Morales-Mora M.[1]

[1*] PEMEX-Petroquímica, Jacarandas 100, Colonia Rancho Alegre I, Coatzacoalcos, Veracruz 96558, Mexico.
Phone: +52-921-211-1337. E-mail: felipe.guzman@pemex.com

Topic: Waste Management and Recycling
Keywords: Recycling Used Oils

Abstract

Pemex Petrochemicals is a division of PEMEX that develops markets and distributes petrochemical products to meet the demand of domestic market and a cornerstone in the development of the petrochemical industry in Mexico.

Comprises 7 petrochemical complexes where products are manufactured in three value chains: aromatic, ethylene derivatives, derived from methane. For the development of these activities has a consumption of energy from the combustion of natural gas 25,145,000 Gcal/year.

Just as are generated annually 13,700 ton waste oils and solvents, with high calorific value 42,190 kJoule/kg, being incorporated as an alternative fuel in the steam generation process.

This activity has been economic benefits by not using natural gas; however it is necessary to assess environmental impacts, taking into account the characteristics of the new fuel and avoided products to save natural gas.

For Environmental Impact Assessment, was used as a tool of Life Cycle Assessment (LCA), as established by the ISO 14040.

The results of the environmental impacts are lower in all categories when recycling spent oils and solvents, presenting avoided products in the category radiation and minerals, however only replaced 5% by weight of natural gas.

Avoided products to stop using natural gas, buffer the environmental impact caused by energy recycling used oil and solvents resulting in minor impacts all categories. Mentioned above coupled with the economic benefits that are about $ 6.5 million U.S.D, we can conclude that this is a sustainable project with a great an opportunity of development.

INTRODUCTION

Pemex Petrochemicals is a division of Petroleos Mexicanos that develops markets and distributes petrochemical products selected to meet the demand of domestic market and a cornerstone in the development of industry in Mexico. Its main activity is based three main value chains: Aromatic, derived from ethylene, derived from methane.

It is located in Coatzacoalcos, Veracruz, with corporate offices in Mexico City, and seven petrochemical Complexes: Cangrejera, Cosoleacaque, Morelos, Pajaritos and Escolin located in the state of Veracruz, Independence, in the state of Puebla and Tula in Hidalgo State.

DEVELOPMENT

Derived from the operation of the facilities of Pemex Petrochemical, generates a significant volume of Oil and Solvents Spent, which are considered hazardous waste in Mexico [1], so its use is regulated and subject to government approvals, but allows its use and recovery reclassified as by-products. In the United States of America, spent oils are not considered home hazardous waste, but are subject to a regulation that establishes management standards [2]. Table 1 describes specific waste types that make up the oil and spent solvent.

Table 1. Hazardous Waste, Oil and Solvents Spent

Hazardous Waste	Types
Spent Lubricating Oil	Mineral Synthetic Mixed
Used dielectric oil free of PCB's	Mineral Synthetic Mixed
Heating Oil Spent	Synthetic hydrocarbon mixture
Spent Cutting Oil	Mineral, vegetable and mixed. Oily emulsions And semisynthetic
Spent Solvent	Mineral, synthetic and mixed.

As part of the improvement and evolution in the management and handling of waste mentioned above, was brought before the Ministry of Environment and Natural Resources, SEMARNAT, the approval of the Waste Management Plan Hazardous, in order to carry out recycling and energy recovery of 100% of the oils and spent solvents generated in all industrial installations of Pemex-Petrochemical, a situation that was originally carried out partially.

The industrial areas of Pemex Petrochemical have equipment such as furnaces and steam boilers which is used for heating services, process and power generation required for the operation of the facility.

Such equipment used, in most cases and a greater proportion of natural gas as fuel which is supplied by generating subsidiary of Petroleos Mexicanos, Pemex Gas and Basic Petrochemicals. As the annual energy consumption in Pemex Petrochemical in the order of 105 million Gjoul.

Significantly, it has the infrastructure for burning liquid fuels in the petrochemical complexes Morelos, Cangrejera, Pajaritos and Independence. The strategy outlined in the Management Plan is to use these facilities for the recovery of oil and spent solvents generated throughout the company and that are about 13,700 tons /year. The Figure 1 describes an overview of the management and recovery stages.

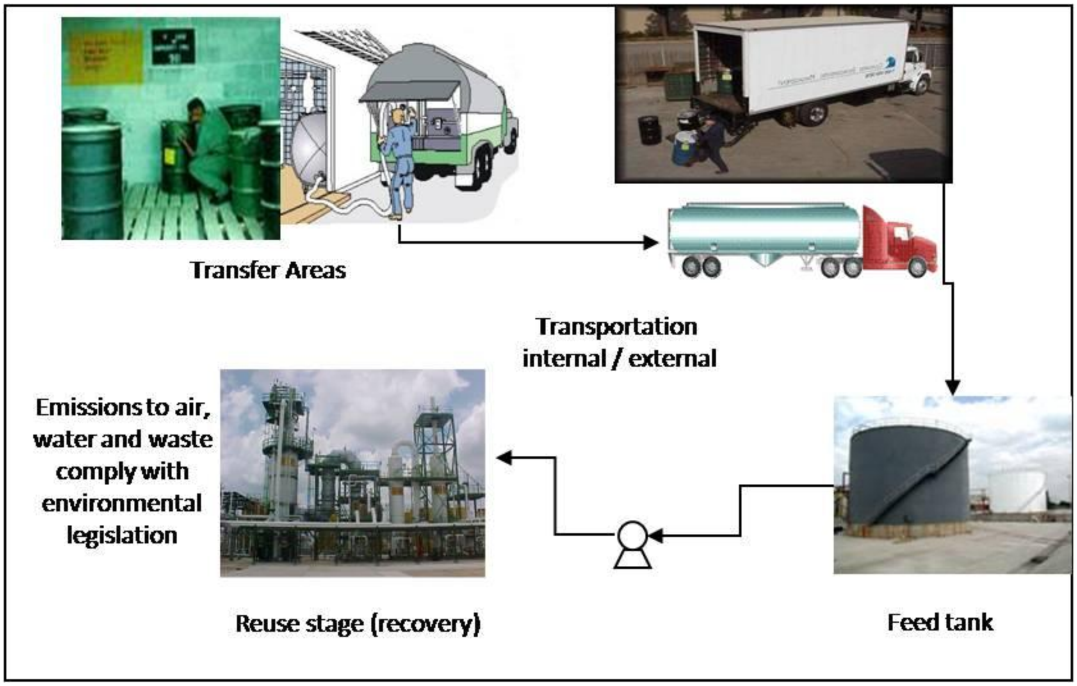


Figure 1. - Stages of handling spent oils and solvents

METHODS

For Environmental Impact Assessment, was used as a tool of Life Cycle Assessment (LCA), as established by the ISO 14040 and ISO 14044, the following aspects:

Functional Unit: Production of 1 ton of water vapor 45 and 60 kg / cm ².

Objective and Scope: To assess the impacts and compare the generation of 1 ton Water Vapor using natural gas as fuel (100%) vs. the generation of 1 ton Water Vapor using natural gas (95%) and oils and solvents used (5 %) as fuel.

Impacts were analyzed quantitatively considering three categories of global impacts

•Impacts on health.
•Impacts on the quality of Ecosystems.
• Impacts on Resources.

This paper was established as System Boundaries:

1.-Sweetened Processing of Natural Gas in Pemex Gas and Basic Petrochemicals, in order to assess the avoided products by not consuming part of natural gas.

2.- Steam Generation 45 kg /cm² and 60 kg/ cm², in Pemex Petrochemical.

Among the most important activities carried out, there are loads assigned as those relating exclusively to the steam generation process and in particular were considered avoidable charges recycling oil derivatives and solvents used to evaluate natural gas inventories stopped using.

RESULTS AND DISCUSSION

Derived from the energy reuse in steam boilers, oils and spent solvents generated at the facilities of Pemex-Petrochemicals, were obtained during period April 2008 (date of approval of the management plan by SEMARNAT) and October 2010, the following results:

•Hazardous Waste recovered: 32 933 ton.
•Energy exploited: 1,339,443 Gjoul
•Natural Gas stopped using: 26.720 tons.
•Economic Profit: 80 million pesos.
•Reduced environmental impact by recycling hazardous waste in the generation of steam.

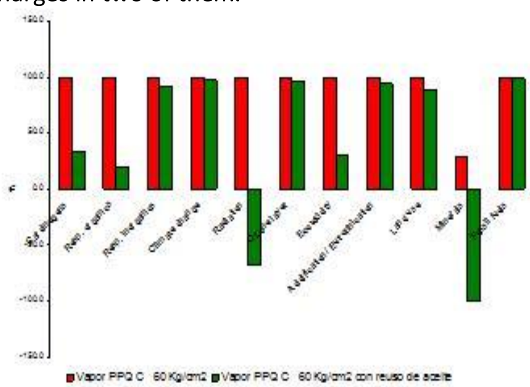
The inventories used for comparison come directly from the steam generation process in

Pemex Petrochemical and Social Responsibility Report of Petroleos Mexicanos [3] .

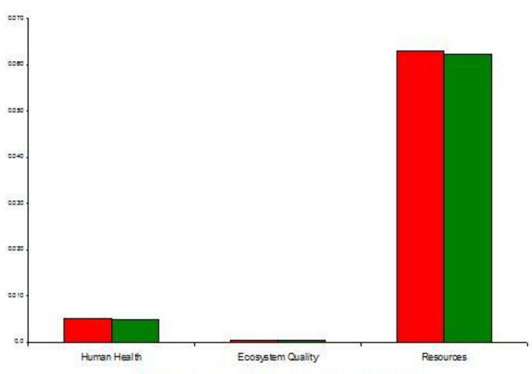
Since Pemex petrochemical not have information on the processes of production of some raw materials and inputs, it was necessary to use information from similar processes which data are available in Europe.

As a software tool for LCA SimaPro software was used in version 7.1 and as a method of evaluation used the Eco-indicator 99 (H).

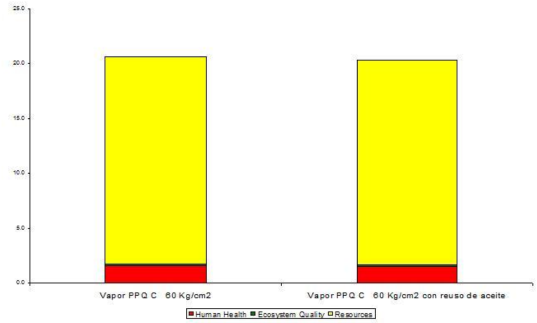
The results for intermediate points can be seen that the steam generation is lower impact energy recycling in all categories, reflecting avoided charges in two of them.



The results for endpoints, we can see that the steam generation has lower energy recycling impacts on Health, Ecosystem Quality and Resource consumption.



The results of the global impact based on single score (Pt) of the steam generation process to recycle waste energy compared with that used only natural gas, are consistent with previous results.



CONCLUSIONS

1. - Although fuel uses only 5% of oils and spent solvents, reducing the environmental impact is noticeable.
2.- The energy recycling spent solvents and oils for steam generation is a sustainable project, because it has environmental, social and economic.
3. - There is a high potential to increase in energy recycling spent solvents and oils.

REFERENCE

1.-MÉXICO, SEMARNAT, General Law on the Prevention and Integrated Waste Management.
2.- USA, CFR, Code of Federal Regulations, Part 279.
3.- Social Responsibility Report of Petroleos Mexicanos, www.pemex.com.

Municipal Solid Waste Management using Life Cycle Assessment: Anaerobic Digestion on Biogas Plant Case Study

Authors': Cárdenas Ferrer Teresa[1]; Santos Herrero Ronaldo[1], Rodríguez Fadre Niurka[2], Contreras Moya Ana Margarita[1], Rosa Domínguez Elena[1], , Ortiz Santos Edildo[1] Triana Diaz Niury[1].

Affiliations: 1: Universidad Central "Marta Abreu" de Las Villas, Facultad de Química Farmacia, Carretera a Camajuani km 5½, C.P 54830 Santa Clara, Villa Clara, Cuba teresacf@uclv.edu.cu
2: Laboratorio de Residuos Sólidos Urbanos (LARE), La Habana, Cuba.

Topic: Waste management and recycling.

Keyword: Biogas, Life Cycle Assessment (LCA), Municipal Solid Waste (MSW)

ABSTRACT

Cuban population growth and housing development, as well as other processes have produced a considerable increase in the amount and variety of solid waste generated. Problems generated due to an inadequate handling of these wastes are affecting cities and its outlying areas as well as small rural populations.

The inadequate management of solid wastes involves a series of processes [1] that can have a negative impact on the environment. Final disposal of all solid wastes in landfills is a problem affecting environment, human health and landscape since it has not been sufficiently discussed for a final decision in terms of ecology [2].

Wastes from agro markets in Cuba have a higher organic fraction and can treat in a biogas plant.

This paper presents the results of environmental assessments in biogas plant that utilized biodegradable solid waste from municipal agro market in Marianao, Cuba. A life cycle assessment (LCA) was used for environmental analysis. [3]

Potential impacts such as global warming, acidification, stratospheric ozone depletion, and human toxicity were analyzed.

The results of this research have shown the negative impact of the current urban solid waste management system regarding environment, ecosystem and human health in the city of Marianao.

In addition, the analyzed scenarios had a better performance than the current management system because they included the inorganic waste recycling process as well as the biological treatment of the organic fraction; and at the same time they achieved a reduction of the controlled dumping of waste.

The most feasible alternative from the environmental and economic point of view was A2 alternative; as it used the Urban Solid Waste organic fraction through biological treatment, as it recycled inorganic waste and reduced direct disposal of waste to landfill

INTRODUCTION

Different solid waste management system scenarios were developed and compared for the Municipal Solid Waste Management System of Marianao using the life cycle assessment (LCA) methodology [4]. The solid waste management stages considered in the scenarios were collection and transportation of wastes, anaerobic digestion and landfilling.

The functional unit of the study was the amount of biodegradable solid waste generated in Marianao. The life cycle inventory analysis was carried out by scenario. The inputs and outputs of each management stage were defined and the inventory emissions calculated by the model IPCC.

The impacts were quantified with the weighing factors of each category to develop the environmental profiles of each scenario.

The aims of this paper is to apply the Life Cycle Assessment in the treatment process of the organic fraction of solid waste from the Agro-markets in the municipality of Marianao, Havana, Cuba, in a biogas plant, to evaluate negative impacts that are generated, and trace the plan of measures to mitigate the adverse effects are detected during the study.

METHODS

The biogas plant was built in 2008, according an international collaborative project with the UNESCO. It is located near the largest landfill in Cuba (1). The technological process consists of four main phases: preparation, hydrolysis, anaerobic digestion and the biogas uses. The processing capacity is 15 m3 per day of organic waste (4500 m3 per year), equivalent to about 1125 tons by year.. From biogas, is possible to produced 60 kWh (432,000 kW per year) and as a by-product is obtained 15 000 m3 of liquid nitrogen fertilizer annually.

Life Cycle Assessment in the Biogas Pilot Plant.

Life Cycle Analysis was performed to the biogas pilot plant located at the landfill on the "100 street" in Havana, in order to assess the impacts, both avoided as generated in the treatment process of organic matter in waste solid.

Three scenarios were selected:

Scenary 1.

In this alternative we evaluate the impact it has on the environment, the disposal of all MSW collected in the landfill. The inventory analysis for this scenario are shown in Table 1

Table 1: Inventory Analysis for Scene 1

Total population in the Municipality	137999 inhabitant
Waste in the landfill	22016 m^3
Years of operation of the landfill	34 años
MSW generation rate	0.50 kg/inh/day
Diesel Fuel Consumed (gallons/day)	740 liters
Methane Emissions (CH_4) m^3	780872.5 m^3/year
Carbon dioxide emissions (CO_2) m^3	567907.27 m^3/year

Source: Community Services Department Statistical Data.

Scenary 2.

In this alternative was evaluated the waste recycling, establishing that only 80% of waste generated can be recycled and the remaining 20% is deposited in the landfill. and anaerobic treatment it receives from the organic waste biogas plant located at the landfill on the "100 street" in Marianao, Havana.

Table II. Solid Waste Recycling in Marianao

Material	Ton (t)
Paper and Cardboard	5.56
Glass	4.67
Plastic	4.06
Wood	3.00
Other metals	0.92
Aluminium	0.78
Textiles	0.72
Total	19.71

Table III. Biogas plant Characterization.

Raw material (t)	15
Water (m^3)	275
Biogas production (m^3)	1000
Compost (m^3)	5
Liquid waste (m^3)	15
Electricity kWh	60

Objectives and Scope:

The objectives of this study are:

1. Evaluate the feasibility of anaerobic digestion for the treatment of organic solid waste.
2. To contribute to the development of efficient technologies to reduce resource use and emissions

Functional Unit: The functional unit is the amount of waste processed in the anaerobic digestion pilot plant: 15 tons/day.

Inventory Analysis: The analysis of life cycle inventory (LCI) quantifies the consumption of energy and resources consumed in the process of anaerobic digestion, air emissions and the different stages of the process in the limits of the system in relation to the selected functional unit. The detail level is achieved in the inventory depends on the availability of data which are recorded in the whole process and the level of complexity to be obtained and can be applied an approximation or simplification of these procedures where necessary.

System Limits: The system analyzed limited to anaerobic digestion process from sample preparation to obtaining biogas from waste collected in agricultural markets in the Pilot Plant located at 100 Street landfill in the province Havana, considers the consumption of energy and soil, air and water emission.

Results

The result of the study showed that when the wastes are disposed in landfill the most impacted categories were the climate change with a 54205.461 points score, followed by fossil fuel (52175.281 points), inorganic with 2026.0588 points and ecotoxicity (348.32099) points due to emissions to air and poor control of gas, for transportation of waste causes emissions to air of particulate matter (PM), Ox Ides of nitrogen (NOx) and sulfur.

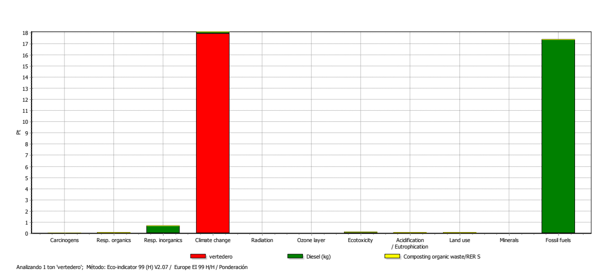


Figure 1: Solid Waste Analysis in the Landfill.

As shown the disposal of MSW at the landfill have significant values in the category of climate change, the category of fossil fuels and inorganic respiration, this is explained because the transportation and disposal processes are generating greenhouse gas-causing this impact.

The contribution of the process shows the weighted contribution of the process to the three categories of damage to the Eco-indicator 99, significantly influences the system of waste management in the municipality of Marianao in ecosystem quality.

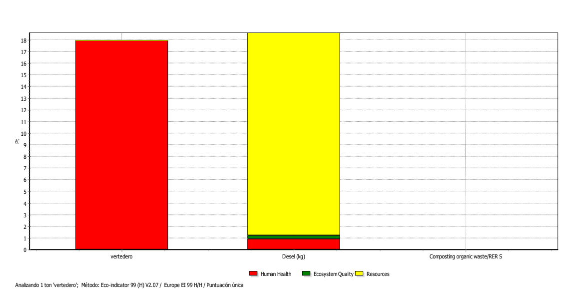


Figure 2: Environmental profile according damage categories

The impact categories listed above are responsible for.

• Impact on human health.
• Impact on plant and animal species.
• Destruction of the ozone layer.
• Over exploitation of resources.
• The damage caused by emissions of gases hydrological

The biogas plants alternative is a feasible solution from the environmental point of view, as shown in the figure 3.

The treatment of organic fraction reversed the damage in the categories of impact and ecosystem damage.

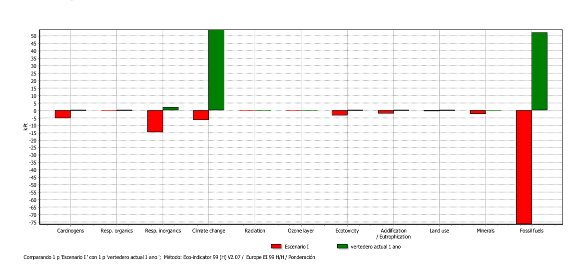


Figure 3: Management System Comparison in the landfill

The total contribution of scenario two on the treatment of organic fraction is also feasible since the usable materials are recycled at all stages of life.

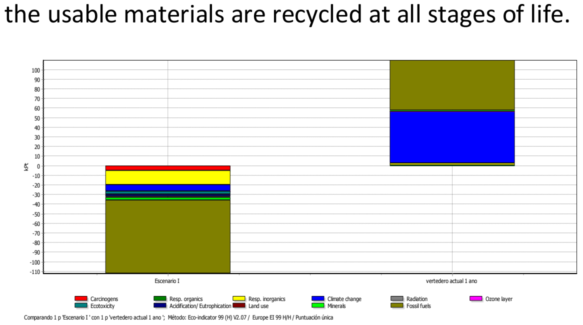


Figure 4 Total score for each alternative

The figure 4 shows the analysis of weighting of the categories of damage, shows the decrease of the impact, the use of organic matter for energy. The above results show that the alternative scenario two is feasible from an environmental perspective.

Conclusions:

1. The disposition of the mixed solid waste in the landfill is the worst alternative treatment due to the environmental damage.
2. The anaerobic treatment of organic waste in a biogas plant is an environmental and economical feasible alternative for reducing the damage to the ecosystem.

Bibliography:

1. U. Arena, M.L.M., F. Perugini, *The environmental performance of alternative solid waste management options: a life cycle*

assessment study. Chemical Engineering Journal 2003: p. 207–222.

2. Themelis, N.J. and P.A. Ulloa, *Methane generation in landfills.* Renewable Energy, 2007. **32**(7): p. 1243-1257.
3. Baldo, G.L., *A general introduction to LCA.* 2007.
4. Buttol, P., et al., *LCA of integrated MSW management systems: Case study of the Bologna District.* Waste Management, 2007. **27**(8): p. 1059-1070.

Plastic bags in Mexico: a review of results of a Comparative Life Cycle Assessment Study

Avila, A. Paulina; Campos, Alejandra; Encarnación, Guillermo.
Dirección General del Centro Nacional de Investigación y Capacitación Ambiental-Instituto Nacional de Ecología / National Environmental Research and Training Center -National Institute of Ecology. San Rafael Atlixco 186, Iztapalapa, 09340, México, D.F. 01 (55) 5613 3662
apavila@ine.gob.mx

Abstract

In 2008 plastic bags turned an important issue in the Mexican context. One of the principal Baking companies in Mexico, introduces plastic oxodegradable envelopes, in their products; legal initiatives were proposed related to the management of shopping plastic bags in the waste management context, some concerning their degradable or non degradable characteristics; some merchant facilities change their plastic bags for degradable; so society and private industry take to confusion. Positions arose assuring advantages of the degradable bags and others in against. These evidenced that non national studies or scientific information exists related with environmental impacts of plastic bags. A study conducted for the National Institute of Ecology evaluates environmental performance of five different plastic bags. The objective was to compare the most popular shopping plastic bags using Life Cycle Assessment Methodology; the evaluated plastic bags were: HDPE, LDPE, HDPE-OXO, LDPE-OXO, and PP. The impact categories evaluated were: Ozone depletion, Depletion of abiotic resources, Acidification, Climate Change, Aquatic Ecotoxicity and Eutrophication. For the scenarios evaluated, degradable plastic bags, HDPE-OXO and LDPE-OXO has no advantages over conventional shopping bags, HDPE and LDPE. The PP bag has less impact in the six evaluated categories. PEBD and PEBD-OXO are the alternatives with higher impacts in the six categories.

Topic: Gestion de residuos y reciclaje o Análisis de ciclo de vida sustentable

Keywords: plastic bags, LCA, degradable, landfill

Introduction

In the last years, plastic bags as shopping bags, have been a globally concern. Management of great volumes generated, visual pollution, drainage obstruction, air emission when burned in final disposal sites are problems related with plastic bags. In Mexico, plastic bags production (219 724 ton of bags and sacks of polyethylene in 2006; INEGI, 2007) and demand has grown so, that its presence at the end of its life could be significant (Ojeda-B, 2003). Actual patterns of consumption and disposition of plastic bags, as shopping bags, can be taken as a symbol of the throw-away society that exacerbates the seriousness of the human carbon footprint (Senthilkannan M, 2011). In Mexico City the principals uses of plastic bags are to content and transport the items bought in merchant facilities and as second use, to content household solid wastes (López, 2009).

In 2008, one of the principal Baking companies in Mexico introduces plastic oxodegradable envelopes, in their products. Parallel, legal initiatives in local legislations were proposed concern with the management of the shopping plastic bag and some merchant facilities change their plastic bags for degradable. Confused information and lack of scientific sustenance on new dispositions drove the society and the industry to the confusion. A necessity to establish environmental performance of plastic bags and degradable plastics bags launched to the market, were a duty for the authorities. A study conducted for the National Institute of Ecology (INE) of the Ministry of Environment and Natural Resources (SEMARNAT) of Mexico was the first official research related with the plastic bags. Its objective was to quantify the potential impacts associated with the production, transport, usage and final deposition, using the Life Cycle Assessment Methodology of the five most common plastic bags, conventional and degradable and the comparison between them. The bags considered were: bag of high density polyethylene (HDPE), bag of low density polyethylene (LDPE), bag of high density polyethylene with oxo-degradable additive (HDPE-OXO), bag of low density polyethylene with oxo-degradable additive (LDPE-OXO), and reusable bag of polypropylene non woven fabric (PP). The study was conducted to contribute with information to support decisions in public politics.

Methodology

The study compares the environmental impacts of HDPE bag, LDPE bag, HDPE-OXO bag, LDPE-OXO bag, and PP bag. It was based on the Mexican Norms: NMX-SAA-14040-IMNC-2008 "Environmental management – Life cycle assessment–Principles and framework" and NMX-SAA-14044-IMNC-2008 "Environmental management–Life cycle assessment–Requirements and guidelines".

Functional unit, system boundaries and allocation

The functional unit was to transport 9 568 liters of goods for one year for an average Mexican family, considering the use of 14 handbags and 16 rectangular bags**.** The evaluation methodology used was based on the CML's model and the SimaPro was the used software. Data collected is from 2006 to 2009. System boundaries are shown in Figure 1. For the allocation considerations (assumptions?) at the end of life, the disposal considerations for plastic bags dumped on landfill sites and the ones recycled are of 99% and 1%, respectively.

Limitations

For confidentiality reasons the Companies of oxodegradable additives provided just general data of transportation and quantities imported. So information for resource use and pollutant emissions for the Production of OXO bags was bibliographical.

Assumptions

No relevant changes in the Production Processes of oxodegradable bags with respect the conventional ones were reported by the consulted companies. Neither changes in the properties (resistance, transverse and longitudinal tension) of the bag were reported.

General Life-cycle Inventory (LCI)

The stages considered for all the bags were Production of raw materials (includes the extraction stage), Production of plastic bags, Use and Final Disposal. The stages include energy, water and raw materials. Include energy required for transportation and the associated transportations. Associated transports includes the delivery transportation of the raw materials to the productions plant (in the case of PP, production plants in China), from this point to the distribution centres. End of life includes the materials to recycling, to landfill site and the materials for treatment, as oils and water.

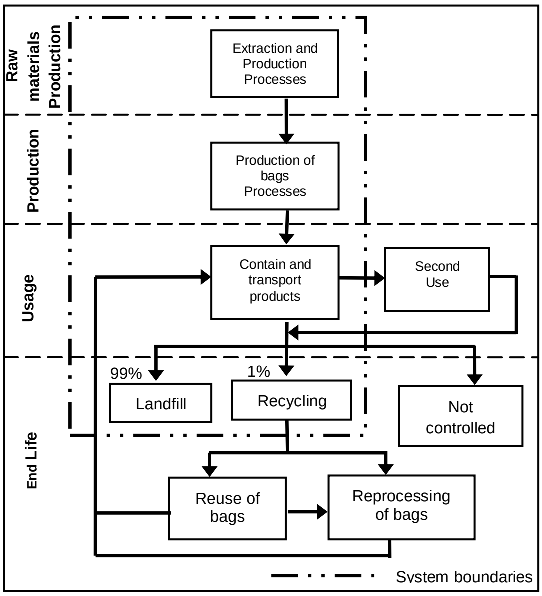


Figure 1. System boundaries.

Results and Discussion

Comparison by Impact Categories

Depletion of abiotic resources (DAR). The production of raw materials for all the bags contributes in this category. LDPE and LDPE-OXO bags use more resin, so the impact to the depletion of abiotic resources is 4 times higher than the HDPE and HDPE-OXO bags. Compared with the PP bag, the depletion of abiotic resources is 25 times higher for LDPE.
Acidification (AC). Transport is the stage that contributes more in Acidification. Next stage that contributes is the Production of the bag, the impact of LDPE bag is 3.3 times higher than HDPE, and 20 times higher than PP bag case.
Eutrophication (EP). Production of the resin of LDPE and LDPE-OXO bag is the stage that impact more, due to emissions to water during the process of production of the resin. LDPE bag impact is 34 times higher than for HDPE, and 65 times higher than de PP bag.
Climate change (CC). The production of raw material is the stage of highest impacts to the category. In this stage the HDPE-OXO bag has

an impact 24% more than the HDPE bag. The LDPE-OXO has an impact 3% more than the LDPE bag.

Ozone depletion (OD). For the LDPE and LDPE-OXO bags the stage with more contribution is the Production of the polymer in a 80%. For the HDPE and HDPE-OXO, the stage that contributes more is the Production of the bag with 70%, because of the energy required. LDPE bag have an impact 6 times higher than HDPE bags and 34 times more than the PP bags.

Aquatic Ecotoxicity (AE). The stage that impacts more is the production of resin: 56% by the HDPE bag and 76% by the LDPE bag. Next stage that impacts the category is Transport stage due to production and use of combustible: 30% by the HDPE AND 19% by the LDPE. The PP bag impacts more is the stage of Production of the bag, impacts 39% due the use of water, natural gas and electric energy; and 30% of the contribution is for the Production of the polypropylene resin. The LDPE and LDPE-OXO has an impact 3 times higher than the HDPE and HDPE-OXO bags and 3.8 higher than the PP bag.

Comparison between bags

PP bag is the bag that impacts less than all of the bags evaluated in the six impact categories. The LDPE and LDPE-OXO bags are the alternatives that have more impacts in the six categories (Figure 2).

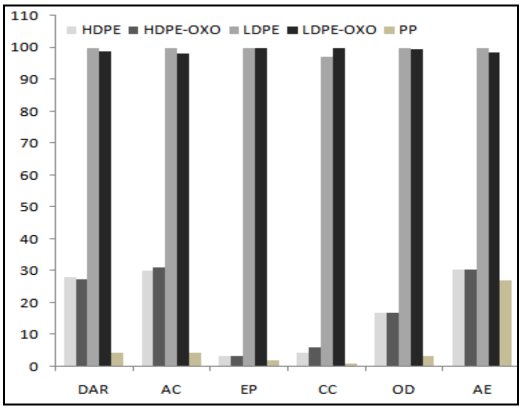


Figure 2. Contirbution of each bag to the impact categories.

Sensitivity analysis

Four analysis were made considering the critical parameters. (or process step). Increase of the percentage of HDPE and LDPE recycled; from 1% to 5%. No significant differences were obtained in the categories evaluated (Figure 3).

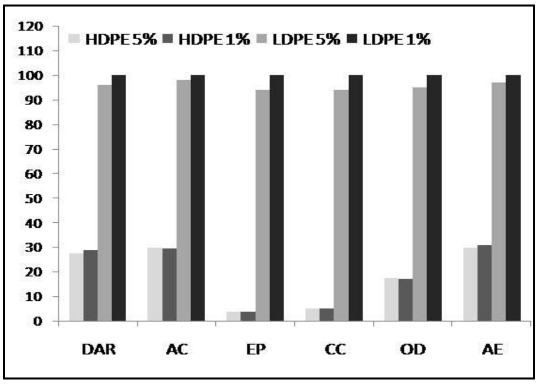


Figure 3. Increase of the percentage of HDPE and LDPE recycled.

Decrease of the PP bag useful life, from one year to 6 months. Useful life of PP bag is a parameter that influences in the categories evaluated. If the real useful life of the PP bag decreases, potential environmental impacts will increase.

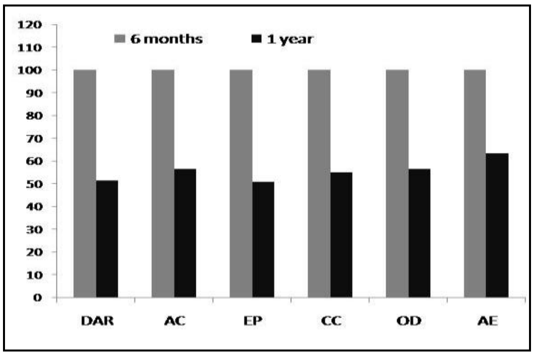


Figure 4. Decrease of the PP bag useful life.

Second use of HDPE and LDPE bags. The consideration was that 38% of the families reuse the handle bags and 22% the rectangular bags, based in a Market Study (referencia). Environmental impacts decrease in this analysis.

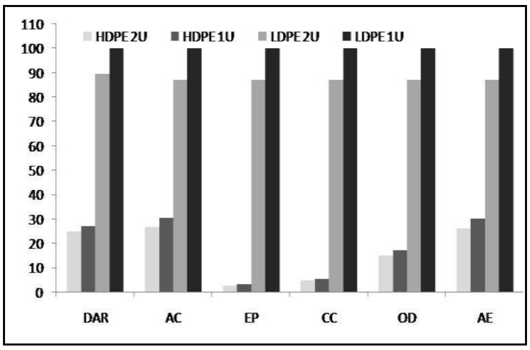


Figure 5. Second use of HDPE and LDPE bags.

Modification of landfill assumptions for degradable plastic bags; no landfill gas capturing. A desvantage of the OXO bags in the categories of Acidification, Climate Change and Aquatic Ecotoxicity; less impacts in Depletion of abiotic resources and Ozone depletion.

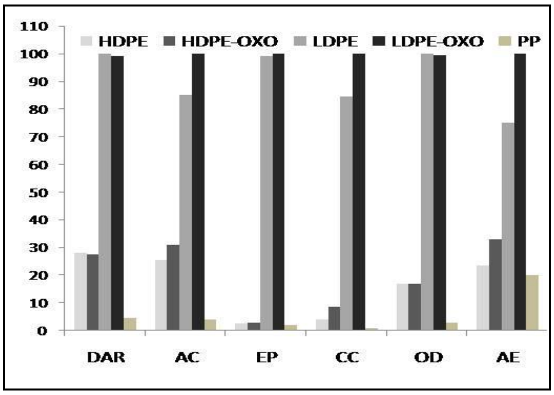


Figure 6. No landfill gas capturing.

Conclusion

In the context of the conditions of the assessment, the impact categories evaluated no significant differences exists on the environmental performance of the HDPE and HDPE-OXO in all their life cycle. The PP bag impacts less in the six categories evaluated. So is highly recommended its use. The HDPE and HDPE-OXO bags are the alternative that impact higher in the six categories. The relative impacts of the less impacting bag (PP) and the more impacting (LDPE and LDPE-OXO) differs in a range of approximaly 75% to 95% in all categories evaluated. The impacts between HDPE / HDPE-OXO and LDPE / LDPE do not vary in less than 10% in Climate change, Acidification and Eutrophication.

Therefore, to favour the employment of oxodegradable plastic bags and somehow, to prohibit the employment of conventional plastics bags does not have a complete technical support.
Evaluating more scenarios, like drainage, aquatic media and environment disposal in the End Life stage can bring more tools to consider a better management of the plastic bags, conventional or degradable.

References

López, Olga, 2009. Anexo II. Estudio sobre Usos y hábitos hacia las bolsas de plástico. Reporte final. México, D.F. Estadística Aplicada-Centro de Análisis de Ciclo de Vida y Diseño Sustentable.

INEGI, 2007. Encuesta Industrial Mensual. Sector Manufacturero. Sustancias químicas, derivados del petróleo, productos de caucho y plástico, 2007b. Estadísticas de Residuos Sólidos urbanos. http://www.inegi.org.mx/est/contenidos/espanol/rutinas/ept.asp?t=mamb60&s=est&c=8855. Accessed: 20 04 2009.

Ojeda-Benitez, Sara; Armijo de Vega, Carolina; Ramírez-Barreto, Ma. Elizabeth. Characterization and quantification of household soid wastes in a Mexican city. Resources Conservation and Recycling 39, 2003, 211-222.

Senthilkannan M., Subramanian; Li, Y.; Hu, J.Y.; Mok, P. Y., 2011 Carbon footprint of shopping (grocery) bags in China, Hong Kong and India. Atmospheric Environment, 45, 469-475.

Life Cycle Analysis of Solid Waste Generation in Santa Maria Beach.

Authors': Cárdenas Ferrer Teresa[1]; Santos Herrero Ronaldo[1], Contreras Moya Ana Margarita[1], Rosa Domínguez Elena[1], Nuñez Dominguez Jorge[1], Clemade Dania[1], Almarales Rios Mariurquis[1].

Affiliations: 1: Universidad Central "Marta Abreu" de Las Villas, Facultad de Química Farmacia, Carretera a Camajuani km 5½, C.P 54830 Santa Clara, Villa Clara, Cuba teresacf@uclv.edu.cu

Topic: Waste management and recycling.

Keyword: Landfill, Life Cycle Assessment (LCA), Municipal Solid Waste (MSW)

ABSTRAC

Tourist activity requires the use and enjoyment of a number of resources that have significantly influence in the generation of solid waste and the negative impact they have on the environment from the construction phase to operational phase of the facility.

In the present study was conducted on life cycle analysis to the current system of waste treatment generated in Santa Maria beach, which was used for the SIMAPRO Eco-indicator 99. The results showed that the main impact is on the ecosystem, emissions to air, soil and water due to the disposal of different types of waste in the landfill, it is recommended to study treatment alternatives to minimize the negative impact in this area with great tourist attraction and a high ecological fragility.

Introduction

it is necessary to consider appropriate strategies for managing solid waste in tourist areas due to the special activities of these places and considering that the main factors influencing the success of a tourist attraction is the cleaning and housekeeping of the site.

Sites that offer tourist attractions are very different activities that influence the amount and type of solid waste generated. In particular, the resorts main attraction with the sea and beaches, its main infrastructure up hotels, restaurants, shops, entertainment centers and beaches.

Background.

Santa Maria beach (tourist destination in the North of Caibarién, Santa Clara, Cuba) is a newly established institution in Cuba. There are a development process and growth, based in the use of its main attraction (sun and beaches) primarily. Commercial use is being developed by the business group Gaviota.

It covers a total length of 13.5 km. and a width of 1 to 2 km. Presents a land surface of 2 139.39 hectares.

The climate has an annual temperature regime warm and winds almost throughout the year.

This place is characterized by a relatively small area with the hotels located in the northern region of the keys and at the present time working in the construction of new hotels. It is expected that in 2016 the keys to reach a population of 16 200 tourists visiting for a solid waste generation rate of 4.67 Kg/tourists/day.[1]

Although the beaches areas have more than 3000 rooms, the collection of solid waste generated in their institutions are conducted by the Department of Community Services in Caibarién.

Physical Chemistry Characteristics of Solid Waste.

Solid wastes in tourist areas have a different composition compared to the percentage of those that are generated in the houses. [2]

Solid wastes are generated in commercial sources (shops, restaurants, offices, hotels). The

compositions are: food, nylon, paper, newspapers, books and magazines, office paper, cardboard, glass, bottles, plastics, wood, solid wastes from construction and demolition (ECOT), consisting mainly of aluminum, steel, copper and plastic.
The solid waste recollection in the tourist area is carried out three time by day. For appropriate characterization was taken into account the sampling during alternate days.
The final result of this sampling is corroborated by the results obtained by the National Design Department, in Havana.

Management System of the Solid Waste.

All waste generated (75 687 kg (75 t/d) with a density of 756, 5 kg / m^3) in hotels and construction areas are collected and disposed in the landfill. There are 9000 rooms, 1.8 inhabitants per room.
The final waste is disposed in the landfill. There leachate aren't recovered or evacuated.

Methodology.

To applied the life cycle analysis (LCA) in the studied system, we analyzed four stages [3]: The definition of the objectives and scope, inventory analysis, impact assessment and interpretation of results.
Objectives and Scope: The objective is to assess the potential environmental impacts associated with the current management of solid waste in the tourist area based of existing treatment option at present disposal in the landfill.
Limit: This study was limited to the existing system of MSW management in the tourist area in Santa Maria beach. The surface land is 2 139.39 hectares. The analyzed system considers the collection and transportation of solid waste and consumption of energy carriers and the emissions to soil, air and water.
Residue Limit type: The study considers the ordinary solid waste from shops, offices, hotels: paper, glass, cardboard.
Time frame considered: When the solid waste management is analyzed, the landfill lifetime is very important, due to the generators impact through the years. The landfill in Santa Maria have 5 years of operation.
Functional Unit: The functional unit is the amount of MSW generated in the Santa Maria beach tourist area and is equivalent to 75.68 t / day.
Inventory Analysis: The analysis of life cycle inventory (LCI) quantifies the consumption of raw materials and energy along with solid waste, air emissions and water discharges resulting from all processes that are within system boundaries, in relation to the selected functional unit. The level of detail is achieved in the inventory depends on the availability of data and level of complexity to be obtained and can be applied an approximation or simplification of these procedures where necessary.

Results.

Clearly the most impacted category ecotoxicity is more than 2100 points daily, due to the disposition of mixed wastes that cause greenhouse gas emissions to air from the rapid decay suffered by them due to high temperatures at the site and the emissions to soil because the conditions of the trenches where they are willing not have adequate waterproofing conditions and emissions to water because the runoff of leachate is close to coastal waters. (Figure 1)

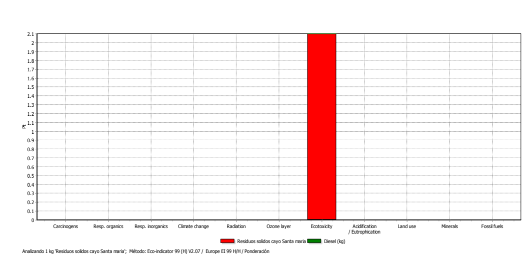


Figure 1. Total score daily

The study is not observed otherwise impacted, which is due shortly farm of the landfill, where there are no significant contributions. But it is estimated that in the coming years, tourism growth is 200% therefore also increase the level of generation in the area, both in the construction stage as the tourist hotels, adding the growth in fuel consumption fossils in the system of waste management
The contribution of the process shows the weighted contribution of the categories of damage, the Eco-indicator 99, has an impact of 1.59 x 10 5 Kpt (figure 2), which profoundly influenced by the current management system

in the Santa Maria cay Tourism to Ecosystem quality. These affectations are:

• Damages on human health.
• A plant and animal species.
• Deterioration of water quality.
• The damage caused by hydrological emissions.
• Damages landscape

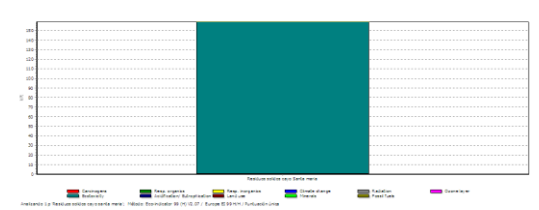


Figure 2 Environemntal profile according damage categories

It is important to note that the ecosystem of the keys is fragile due to climate factors in the region, for this reason is important the search of alternatives for solid waste management more feasible from economic and environment point of view in order to avoid damage to this tourist area.

Conclusions.

1. The current system of solid waste management in Santa Maria Beach is inefficient from the environmental standpoint due to the damage caused to the ecosystem.
2. The treatment of the solid waste landfill is not appropriate to mix the waste transportation and disposal.
3. It is important to take an special attention to the treatment of solid waste in the coming years given the fragile ecosystem that has the Santa Maria Cay

Recommendations.

1. Evaluate alternatives for the treatment of solid waste, such as setting up a biogas plant to treat organic waste.
2. Evaluate the selected treatment option economic and environmentally

Bibliography:

1. Rodríguez, R.M.P., *"Estudio de Factibilidad Tecnico Economica y Financiera de la Organizacion del Sistema de Recogida de Materias Primas en el Polo Turistico de la Cayería Norte de Caibarien.Instituto Nacional Diseño y Economía. .* 2008.
2. *"Composting Pig Manure in Hong Kong".* Biocycle Vol. 39, Num. 2, 1998.
3. Chaya, W. and S.H. Gheewala, *Life cycle assessment of MSW-to-energy schemes in Thailand.* Journal of Cleaner Production, 2007. **15**(15): p. 1463-1468.

Opportunities for the use of LCA in waste management in Portugal

Xará, Susana [1]
Fonseca Almeida, Manuel [2]
Costa, Carlos [3]

[1] **Portuguese Catholic University – College of Biotechnology**
Rua Dr. António Bernardino de Almeida, 4200-072 Porto, Portugal
Phone: + 351 22 5580192 Fax: + 351 22 5090351 Email: sxara@esb.ucp.pt
[2,3] **Laboratory of Processes, Environment and Energy Engineering, Engineering Faculty of Porto University,**
Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal

ABSTRACT
Despite the Life Cycle Assessment (LCA) has been used in the waste sector for nearly two decades, only with the entry into force of the new Waste Framework Directive in October 2008 (2008/98/CE), LCA has been recognized as a methodology with relevance in the definition of the waste management hierarchy options, not necessarily in the rank before established. This is particularly interesting in the definition of waste management plans for specific waste flows (as batteries, biodegradable waste, packaging, etc) but also for the MSW.
The present work is an analysis of the possibilities of using this technique in the planning and evaluation of both municipal solid waste management and some specific waste flows in Portugal, taking into account the current organization for the waste management and infra-structures existing or foreseen.

Topic: Waste management and recycling

Key words: LCA, waste management, Portugal, municipal solid waste

Introduction
The sector of municipal solid waste management in Portugal had a very significant evolution in recent decades. However, as a result of the challenges that exist in the country, particularly in light of requirements established by the European Community, there is a need for investment in new infrastructures, particularly for the recovery of waste (ERSAR, 2007).
The entire population of Portugal is already served by waste collection service and, the whole continent is covered by 29 pluri-municipal systems (14 inter-municipal and 15 multi-municipal systems) responsible for the treatment and recovery of waste (APA, 2007). Each of these systems have infrastructure to manage the waste produced in their area of influence until the final destination. The collection of mixed waste is mostly provided directly by municipal services, although the number of municipalities that contractually provide this service to private entities has increased in recent years (RASARP 2007). At the end of 2007 were in operation in continental Portugal 34 landfills, 8 recovery units for biodegradable waste, 2 incineration plants with energy recovery, 76 transfer stations, 26 sorting plants, 185 selective collection centres and 28 723 kerbside selective collection points (APA 2007). In 2006, were collected in continental Portugal 4,641,103 tons of MSW. Of this total, 89.5% corresponds to mixed collection and 10.5% to selective collection of dry recyclables and biodegradable waste. In 2007, production of MSW in continental Portugal reached 4,698,774 tons i.e. about 1.27 kg per capita per day, below the EU average (APA 2007). The analysis of typical physical characterisation of the MSW reveals that the biodegradable fraction is more than half the total (56%). This figure shows the need to give priority to organic recycling (composting and anaerobic digestion), the recycling of paper/cardboard and incineration with energy recovery, rather than landfilling. In addition, the remaining components of the MSW such as plastics, glass, metal and wood should preferably be sent for recycling (APA 2007).
According to European political guidelines for waste management, the focus should be on the environmental and public heath protection.
The present work is an analysis of the possibilities of using LCA in the planning and evaluation of both municipal solid waste management and some specific waste flows in Portugal, taking into account the current organization for the waste management and the infra-structures existing or foreseen.

Results

Given the current situation of waste management in Portugal and the constraints on their evolution, in particular those related to compliance with current legislation, we identified 10 situations where the use of LCA as a tool for assessing potential environmental impacts, may scientifically support the decision making. Note that, given their methodological characteristics, LCA allows on one hand to compare systems performing equivalent functions and on the other hand, for a given system, to identify the stage of the life cycle associated with this system which will have a greater potential environmental impact and as such, should be a focus of attention when you want to act in improving the environmental performance of this system.

These applications were designed at different scales of operations of waste management - locally, regionally and nationally. The local scale is related to operations within the municipality, the regional scale refers to the activities performed by associations of municipalities or affiliates and national concerns triggered activities at national level in particular promoted by central government entities. They are presented in this order (from local to national) because we consider that this is the best approach in policy development and analysis of improvement opportunities, and also in the development of the management operations. We propose three applications at local, 4 at regional and 3 at national levels:

1. The first application of LCA in waste management at local level concerns the operation of selective collection of dry recyclable materials - plastic and metal, paper and cardboard (packaging, newspapers and magazines) aiming at (i) compare the environmental performance of door-to-door with central collection schemes and (ii) compare the environmental performance of different types of containers.
2. Another possible application of LCA in waste management at local level also concerning to the operation of selective collection of dry recyclable materials is the identification of the environmental aspect most relevant to a particular collection system, existing or foreseen.
3. The next example of application of LCA in waste management at local level is to quantify the environmental aspects and potential impacts of the waste management system in each municipality, from collection to final destination. Can be addressed here existing systems and alternative systems foreseen.
4. Turning now to the application of LCA in waste management at the regional level, the first is related to waste treatment processes. At this level, the LCA studies may aim to compare alternative final destinations existing and/or planned for the waste management system. Also included here are comparisons of integrated waste management strategies.
5. The use of LCA in waste management at regional level is also of interest to compare the environmental performance of treatment technologies - such as the comparison of different technologies of incineration, composting and other biological treatment.
6. When considering an integrated waste management existing or foreseen for a given region, the LCA can be useful in the evaluation of steps or components of this system that have the greater potential environmental impact on the whole or in a particular impact category.
7. Current legislation both in Portugal in the European Union sets national targets for recycling packaging waste and diversion of biodegradable waste from landfills. LCA applied to regional scale can be used in the evaluation of potential environmental benefits associated with the diversion of waste from the current route.
8. At national level the challenges to the use of LCA are greater. One of the possibilities concerns the evaluation of environmental aspects of specific waste streams management taking into account: the final destination and including all the recycling loop, if any; the waste collection and transportation schemes.
9. Another possible use of LCA at national level is to assess the environmental benefits associated with the reorganization of municipalities in the management of waste considering: (i) facilities for treatment and final destination of waste; (ii) the location of these facilities and the municipalities; and also (iii) the characteristics of the waste.
10. To finish it we should emphasize the use of LCA in the hierarchy of waste management options, which is already present, in European legislation, which allows: (i) to focus the policy of waste management in environmental and public health protection; and so (ii) develop environmentally sound policies that respect both the environment and the citizens.

References

ERSAR (2007) Relatório Anual do Sector de Águas e Resíduos em Portugal. Entidade Reguladora dos Serviços de Águas e Resíduos.

APA (2007) Relatório do Estado do Ambiente. Agência Portuguesa do Ambiente.

Posters

CILCA 2011

MÉXICO

Assessment of the Water Footprint of Maize in Mexico

Carole Farell * (UAM -AZC), Sylvie Turpin (UAM-AZC) , Nydia Suppen (CADIS)

1. Introduction

Nowadays the water footprint concept is applied with two different approaches: a) as the accounting of the total volume of water required by a product or b) as a measure of the environmental impacts at all stages of product life cycle.

The water footprint defined in accounting terms [1] reports three types of water individually: the blue water (surface and groundwater), green water (soil water originating from rainfall), and grey water (volume of water that is required to dilute pollutants to such an extent that the quality of the ambient water remains above agreed water quality standards). Some advantages of this approach are that its meaning is intuitive and the required data is available in most cases. Nevertheless, with this methodology it is not possible to evaluate the depletion of the resource nor the environmental impacts caused by the use of water. Reference to the quality of the water is not made either, which can damage human health.

On the other hand, Life Cycle Assessment (LCA) is a widely accepted and applied environmental management tool to measure the various environmental interventions caused by products from cradle to grave.

The proposal of this investigation is to combine the methodology of water footprint [1] with Life Cycle Assessment LCA [2], with which it is possible to assess, within the grey water component, the environmental impacts generated by the use of water. In this zz way we obtain a complete and understandable methodology that assesses not only the use of the resource but also the impacts and shortage that such use causes. The proposed methodology was applied to the irrigated growth of maize in Mexico

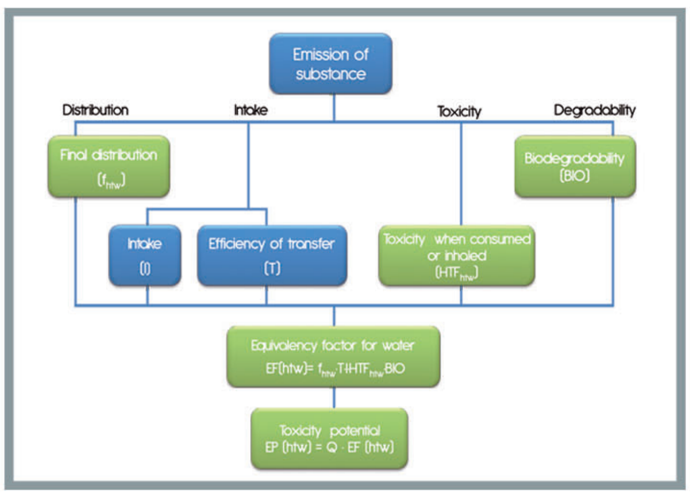


Figure 1 Calculation of ecotoxicity potentials [6]

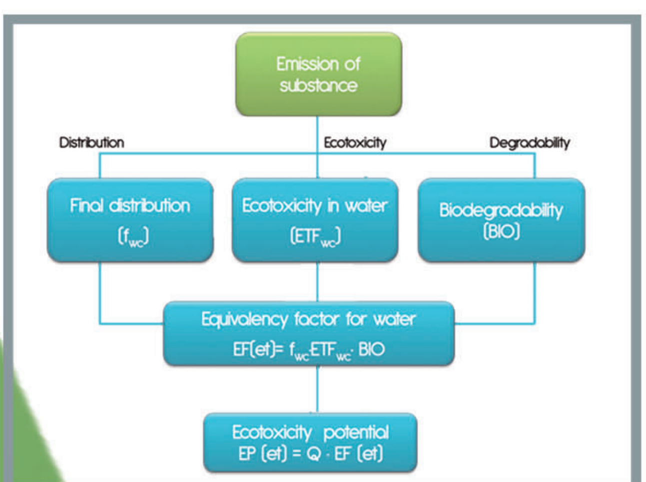


Figure 2 Calculation of ecotoxicity potentials [6]

2. Methodology

The assessment is made for a period of 5 agricultural years (2004-2009) and to maize from irrigated areas. The methodology proposed consists in the algebraic sum of the blue, green and grey components. The results are normalized with the water stress index in order to reflect the impact in terms of water depletion.

2 . 1 Calculation of Blue Water

The blue component of the production of maize in Mexico is obtained from the sum of the volume of fresh water used in irrigation of the field [3].

2 . 2 Calculation of Green Water

The green component is quantified with the FAO 56 Penman-Monteith method as the average monthly crop evapotranspiration under standard conditions (ETc)[4]. The weather parameters were obtained with a time step of 10 minutes from the Automatic Meteorological Stations located throughout the country [5].

2 . 3 Calculation of Grey Water

The evaluation of the grey component is proposed considering the three stages of an LCA [2]:

1. Life Cycle Inventory (LCI): consists in quantifying the volumes of water, phosphatized fertilizers, nitrogenated fertilizers, pesticides, land use and agricultural machinery needed to produce one ton of maize.
2. Life Cycle Impact Assessment (LCIA)is done using a weighted average of the sum of the pollutant emissions of the system, with the help of characterization factors. Two midpoint impact categories are assessed: ecotoxicity water chronic (Figure 1), and human toxicity (Figure 2), with the EDIP 2003 method [6] and with the Simapro 7.2 software.
3. Interpretation of results: the results obtained are analyzed according to the efficiency in the use of the resource, the yield of the production and the water stress of the area.

2 . 4 Normalization

The water stress index of the region from which the resource is extracted is used in order to normalize the impact categories. Water stress is commonly defined by the ratio of total annual freshwater withdrawals to hydrological availability. Severe water stress occurs above a threshold of 40% [7].

Country	Blue water (m^3 / Ton)	Green water (m^3 / Ton)	Grey water (m^3 / Ton)	Total water footprint (m^3 / Ton)
USA	63	522	176	761
China	74	791	295	1160
Brazil	1	1621	125	1747
México	62	1852	357	2271
World rain-fed	0	1082	187	1269
World irrigated	294	595	212	1101
World	81	947	194	1222

Table 1. Water footprint of maize productio for the major maize producing countries. Period: 1996-2005 [9]

3. Results

From the nutritional, economic and social, maize is the most important crop in Mexico. During the 1996-2006 period it took 51% of the area planted and harvested annually, generated 7.4% of the volume of total agricultural production reflecting 30% of the total value of production [8].

The blue component is under the limits of the theoretical efficiency (625-1250 m3/Ton). The national average yield of 2.564 Ton/Ha is considered low since the theoretical yield is 6-9 Ton/Ha. The green component is high due to the climate conditions under which maize is cultivated. The grey water footprint integrates the theoretical water volume that would be necessary to dilute all pollutants emitted from the extraction of raw materials, production and the use of fertilizers, pesticides, land use and agricultural machinery. In order to reflect the contribution of the process to the depletion of the resource, the results are normalized with the water stress index of the region (Table 1).

Table 2 Water footprint of maize in México. Period: 2004-2009

Country	Blue water (m^3 / Ton)	Green water (m^3 / Ton)	Grey water (m^3 / Ton)	Water stress (%)	Total water footprint (m^3 / Ton)	Coefficient of variation (%)
México	975	1,859	7,236	44	14,466	11.00

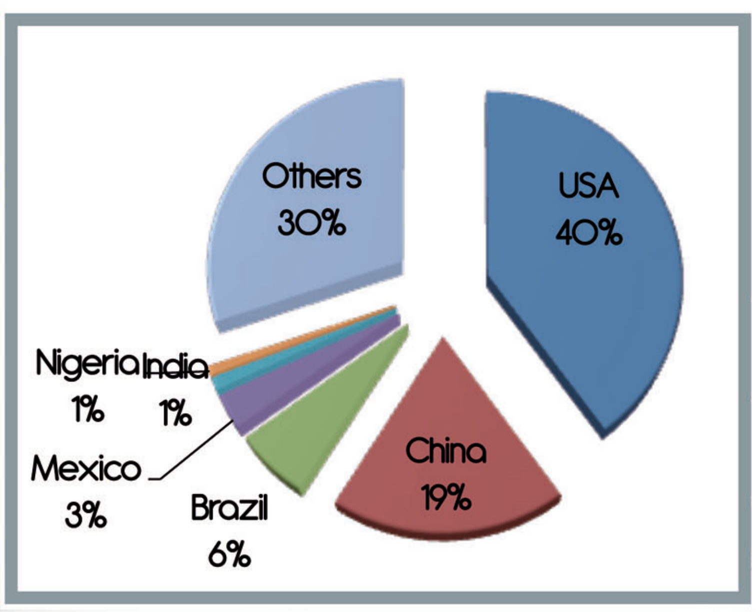
4. Discussion

In a study by Mekonen. M.M. et al. [9], the green, blue and grey water footprint of global crop production has been quantified using a grid-based dynamic water balance model. The model results are not consistent with this study (Table 2). The grey water footprint assessed with a life cycle approach shows a higher numerical value compared to the accounting volume approach, where the grey water footprint quantification is frequently related to nitrogen use only.

5. Conclusion

The assessment of the water footprint with a life cycle approach is a tool that facilitates the management of the hydric resource in a comprehensive way. It is important to assess not only the volume of water used, but also the impacts on the environment and the depletion that different activities cause when using this resource. The water footprint of irrigated maize in Mexico has been calculated in this way emphasizing that the assessment of a water footprint must be made locally. The intention of comparing water footprints is to make any necessary changes in order to diminish its effects. Hence, it is important to establish a standardized methodology that makes possible a comprehensive evaluation, comparison and the resulting decrease of a water footprint.

Figure 3. major maize producing countries [8]



References
1. Hoekstra, A.Y. et al. Water footprint manual: State of the art 2009. Water Footprint Network, Enschede, the Netherlands.
2. Environmental Management – Life Cycle Assessment- Principles and framework (ISO 14044:2006); European Committee for Standardization: Brussels, Belgium, 2006.
3. CNA. Estadísticas Agrícolas de los Distritos de Riego. Comisión Nacional del Agua, Edición 2004 al 2009.
4. Allen R.G., et al. Evapotranspiración del cultivo Guías para la determinación de los requerimientos de agua de los cultivos. Organización de las Naciones Unidas para la Agricultura y la Alimentación. Estudio FAO Riego Y Drenaje #56, 2006. ISBN 92-5-304219-2
5. Comisión Nacional del Agua. Estaciones Meteorológicas Automáticas . http://smn.cna.gob.mx/emas/
6. Hauschild, M.; Wenzel, H. Environmental Assessment of Products Volume 1. ISBN 0-7923-7859-8
7. Comisión Nacional del Agua. Estadísticas del Agua en México 2010.
8. SIAP. Situación Actual y perspectivas del maíz en México 1996- 2012. SAGARPA. México 2011.
9. Mekonnen, M.M. and Hoekstra, A.Y. The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, 2010.UNESCO-IHE, Delft, the Netherlands

* Corresponding author: carolefarell@mail.com

catedraunesco.cvcc@esci.es

CILCA 2011 MÉXICO

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura · Cátedra UNESCO de Ciclo de Vida y Cambio Climático · Escola Superior de Comerç Internacional (ESCI) Universitat Pompeu Fabra (UPF)

Life Cycle Initiative

UNESCO CHAIR IN LIFE CYCLE AND CLIMATE CHANGE

Fullana-i-Palmer, Pere[1]; Isasa, Marina[1]; Anglada, Marta[1]; Valdivia, Sonia[2].

INTRODUCTION

Last December 2010 a four year long Agreement between UNESCO and the *Escola Superior de Comerç Internacional* (ESCI) of the *Universitat Pompeu Fabra* (UPF) concerning the establishment of a UNESCO Chair in Life Cycle and Climate Change at ESCI- UPF duly signed by UNESCO´s Director-General was issued.

The Chair aims at contributing to research, education and dissemination of Life Cycle Management following the programme that UNEP-SETAC Life Cycle Initiative created for that purpose, with a special focus on climate change issues. The Environmental Management Research Group (GiGa) hosted in ESCI will act as the executing institution of the Chair and is the **only Spanish partner of the UNEP-SETAC Life Cycle Initiative**.

Amongst the over 40 different international institutions, technological institutes and research and university centers supporting the Chair, the following Latin American centers are included: "*el Centro de Análisis de Ciclo de Vida y Diseño Sustentable Mexicano*" and the "*Universidade de Brasilia*".

OBJECTIVES

The purpose of the Chair shall be to promote an integrated system of research, training, information and documentation in the fields of environment and sustainable development. It will serve as a means of facilitating collaboration between high-level, internationally recognized researchers and teaching staff of the University and other institutions in Spain, Latin America and the Caribbean, Africa and in other regions of the world.

The specific objectives of the Chair are to:

1. contribute to fostering environmental sustainability by building a knowledge pool on Life Cycle Management through research, education and the dissemination of the activities, with a special focus on climate change;

2. promote capacity building through the integration of research and education in **Latin America and the Caribbean**, as well as in Africa, establishing a network of institutions; and

3. disseminate interdisciplinary research projects integrating economic and social aspects, as well as governance, in environmental management so as to allow a substantial improvement in methodologies supporting life cycle applications on climate change and its prevention.

ACTIVITIES

Some of the activities proposed within the framework of the Chair to achieve these objectives include:

1. the establishment of LCM Networks;
2. training activities on LCM: e.g. hosting and training young researchers from different countries, collaborating with other research groups from Spain and abroad, producing training materials;
3. dissemination activities on LCM: e.g. seminars, conferences or a reference web site in Latin languages;
4. research projects on LCM focusing on the application of LCA (e.g. carbon footprint, water footprint, ecodesign, green procurement, ecolabelling, integrating social and economic aspects into environmental assessments, governance in environmental management, etc.) to the construction, packaging, energy and waste management sectors.

Examples of currently ongoing projects similar to the ones that could be developed within the Chair´s framework include:

CICLOPE: This project aims to develop a methodology based on LCA and a useful tool for the evaluation of environmental and economic impacts of buildings through their life cycle.

RENIA: This project aims at producing a new software tool which can be used to eco-design and produce Environmental Product Declarations for building-integrated solar thermal and solar photovoltaic installations.

Financiación del Ministerio de Ciencia e Innovación dentro del Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica 2008-2011: GOBIERNO DE ESPAÑA · MINISTERIO DE CIENCIA E INNOVACIÓN · Unión Europea · Fondo Europeo de Desarrollo Regional · "Una manera de hacer Europa"

FENIX (Giving Packaging a New Life): This project aims to assist municipalities and other territorial organisations in Spain and Portugal to look for more eco-efficient and sustainable solutions for packaging waste management.

LIFE PROJECT HApro WINE: This project seeks to contribute to sustainable development in the winery sector of the Castilla León region of Spain.

LCA for Energy Efficiency in Buildings (EnerBuiLCA): This project aims to develop a quantitative LCA methodology for the direct and indirect energy related impacts of buildings along their whole life cycle. The methodology and tool produced will be applicable to the French, Spanish and Portuguese context.

EnerBuiLCA · SUDOE Interreg IV B · EU/EU – FEDER/ERDF

Technical background study in support of environmental product policy for buildings: This project, funded by the European Joint Research Centre (JRC), aims at providing assistance to IPTS with the development of Ecolabel and Green Public Procurement criteria for the product group "Buildings".

NEXT STEPS

A website will be launched and a yearly activity programme will be produced. Some of the planned activities for this year 2011 include:

- stays of Latin American and other foreign students; and
- development of e-learning materials on LCM and greening events in collaboration with the UNEP-SETAC Life Cycle Initiative.

The UNEP-SETAC Life Cycle Initiative collaboration will focus on supporting:

(a) the enhancement of capabilities of the national life cycle networks in the Latin American region; and

(b) joint research and publications with Latin American scientists on priority life cycle based topics and climate change, such as:

EXPECTED RESULTS

Coherent with its aim of developing capabilities worldwide, The UNEP/SETAC Life Cycle Initiative considers that the platform to be developed by the Chair will contribute to deploy more activities in the Latin American region.

It is expected that the establishment of the Chair will help to build the required research, development and innovation structures to allow a substantial improvement of all those methodologies which support life cycle applications on climate change and its prevention adding value to the current state of the art. Forces will be joined with UNESCO to contribute to the achievement of the Millennium Development Goals focusing in Africa and Latin America.

CONTACT

[1] UNESCO Chair in Life Cycle and Climate Change, Escola Superior de Comerç Internacional (ESCi-UPF), Passeig Pujades 1; E-08003 Barcelona, Spain.
unescochair.lccc@esci.es
[2] UNEP, Division of Technology, Industry and Economics

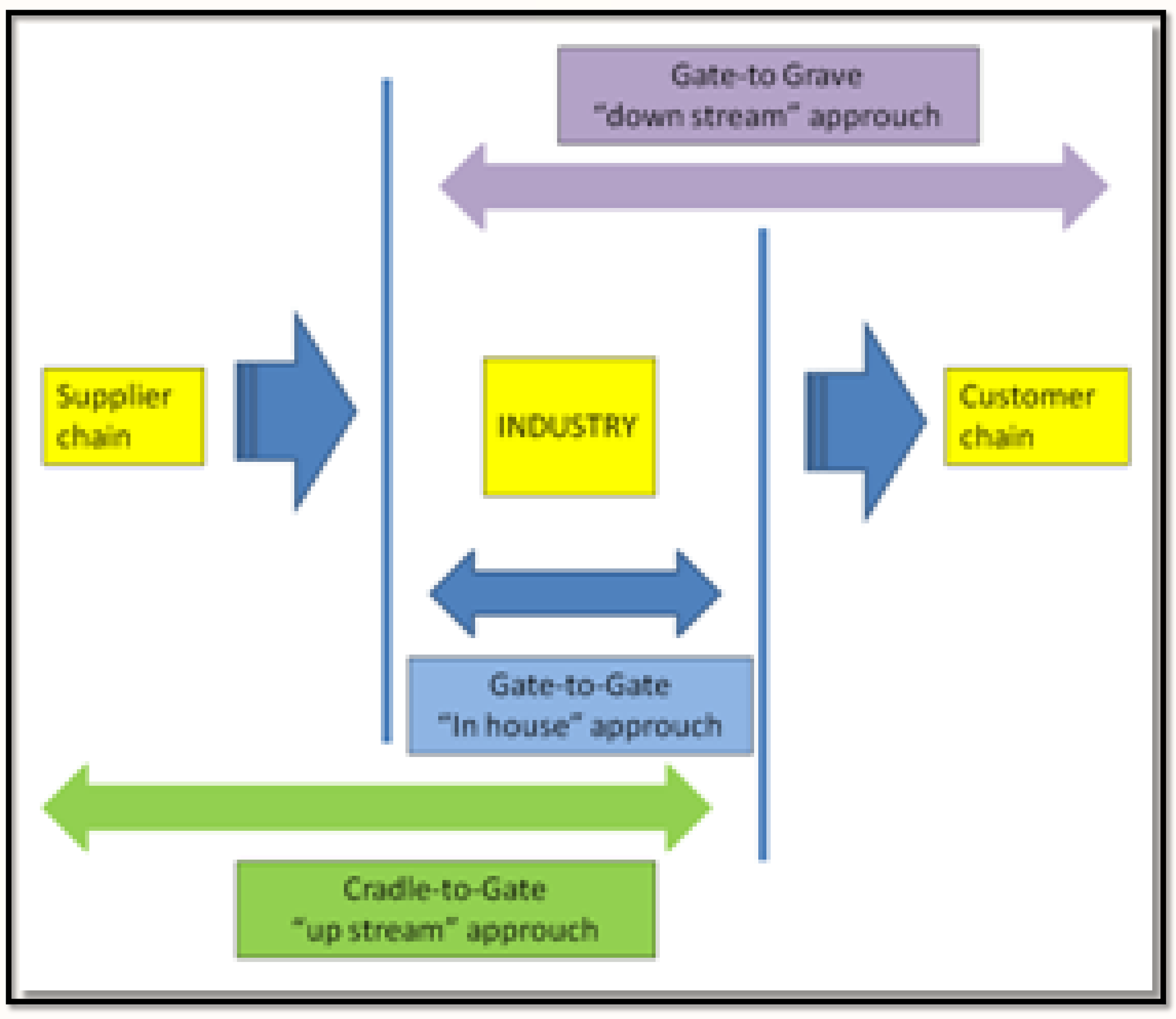
PEMEX PETROQUIMICA · CADIS · Life Cycle Initiative · INSTITUTO DE INGENIERÍA UNAM

LCA in industry: a process of sustainable evolution

Rita de Cássia Monteiro Marzullo[1]
Patrícia Helena Lara dos Santos Matai[2]

INTRODUCTION

Life Cycle Assessment methodology is a powerful tool for assessing the sustainability of products and services since it can be applied within dimensions of environmental impact assessment, social and economic issues as well. However, the major obstacle to use this tool is to obtain data at an acceptable level of quality, respecting properly the boundaries: regional, temporal and technological. The same product can be considered sustainable or not, depending of a given region of production. The reliability of the results presented in a product sustainability assessment is directly proportional to the quality of data used in the inventories. This work addresses the importance of behavioral change in the industry, within a process of sustainable evolution, in order to ensure greater reliability of data for implementing an environmental, social and economic performance assessment throughout all life cycle of a product and thus help to measure the sustainability as a Industry Inovation.



METHODOLOGY

• Consultation of some relevant literature sources in accordance with ISO 14040 and ISO 14044:

- Firstly, it is necessary to do the quantification (measure) of all environmental aspects related to the production of a particular product in a system of inventory analysis for further evaluation of environmental impact.
- This measure can also be applied in economic terms via LCC (life cycle costs) and social terms via SLC (societal life cycle.
- A LCA study can be divided according to the boundaries that indicate where the life cycle begins and ends in relation to the natural environment.

"Innovation can be systematically managed if one knows where and how to look… and it is impossible to manage what you can not measure"
P. Druker

DISCUSSION

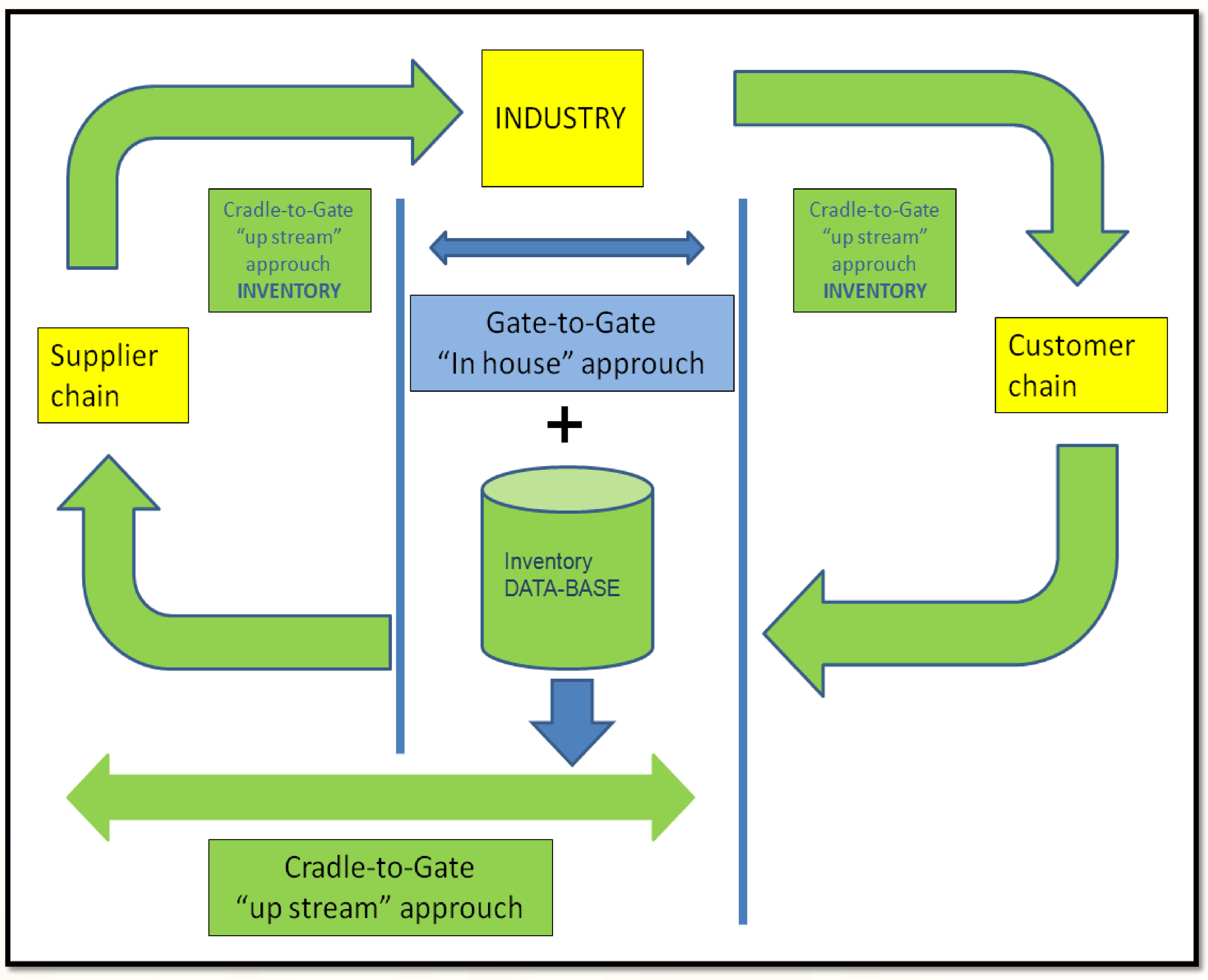
• Despite the method of life cycle evaluation is gradually spreading in the industry, basic information about the process (material /energy inputs and atmospheric emissions, liquid effluents and solid wastes outputs) are not yet available in the form of inventory to us because the management methodology do not include sustainability yet.

• Every life cycle assessment study is done to a certain "product system" and the whole "product system" is formed by a set of "process units" and each "process unit" is nothing more than an "gate-to-gate" inventory.

•From the moment that the whole industry to monitor its own gate-to-gate inventory, the probability of reliably and consistently for Sustainability Assessment of Products, according to the appropriate geographical boundaries, technological and temporal context, will increase significantly.

• Every industry needs to do a "gate-to-gate" inventory management and after this complete their "cradle-to-gate" inventory with data from data bank (or data from their supplier) in order to give this information to the customer. in a PSDS (Product Sustainability Data Sheet).

• Each inventory "gate-to-gate" approach of each product is just one piece that makes up the huge product life cycle puzzle.



CONCLUSION

The sustainability of a product depends on its performance over the life cycle, so we can conclude that it is essential that all industries do periodic monitoring of their environmental, social and economic inventories within a frontier "gate-to-gate". With this periodic monitoring, Industry can manage all sustainability aspects. These are confidential data that should not leave the company but shall be subject to constant monitoring. After this, the next step is consolidate "cradle-to-gate" inventory with data from a database, for example.

In the near future, every company can ask your supplier, along with product that is acquired, its inventory "cradle to gate" that could be called PSDS (Product Sustainable Data Sheet) in the same way that an MSDS – (Material Safety Data Sheet), in which the consolidated data (with the inclusion of aspects of the fuel energy used in transportation, production and use of electricity, as well as aspects related to the production of inputs used in process) is no longer confidential and become be part of the inventory "cradle to gate" of the product produced by your client, making a cycle. In this case, it will be possible to assess the level of completeness of the inventory "cradle to gate" from the data source (primary data sent by the supplier or secondary data from the database) and will be possible to have more consistency of results in the environmental, social and economical impact assessment phase. Foot printing evaluation of carbon, water, energy or land use can become be more easy and the consequent evaluation of sustainability as well. Thus, the entire industry will enter in a process of sustainable evolution.

USP IEE INSTITUTO DE ELETROTÉCNICA E ENERGIA

Affiliation info$_{1,2}$ - São Paulo University. LCA Laboratory from Energy Institute (IEE). Avenida Professor Luciano Gualberto, 1289, Cidade Universitária, Butantã, São Paulo-SP, CEP 05508-010, Brasil. **Contact:** rita.monteiro@usp.br (+ 55 11) 9721-7451 pmatai@usp.br

PEMEX PETROQUIMICA CADIS Life Cycle Initiative INSTITUTO DE INGENIERÍA UNAM

Social indicators in Life Cycle Assessment: a focus on wastewater technologies.

Padilla Alejandro, Güereca Patricia, Morgan-Sagastume J.M, Noyola Adalberto , Margarita Cisneros, Liliana Romero, Musharrafie Adba.
Universidad Nacional Autónoma de México, Instituto de Ingeniería, CU México D.F LGuerecaH@iingen.unam.mx

Introduction

This paper presents a set of indicators for evaluating Social Life Cycle Assessment (S-LCA) of wastewater treatment technologies in Latin America and the Caribbean countries. These indicators evaluate the social impacts thought the life cycle. Social life cycle assessment (S-LCA) allows identification of key issues, assessing, and telling social conditions in the production, use, and disposal of wastewater technologies. Social indicators capture cultural acceptance of the technology through public participation and also measure whether there is improvement in the selection of a set of indicators is depending on the geographic and demographic context of a particular community, the overall results of this proposal will be included in a Ph. D thesis.

SETAC UNEP , **Guidelines for social life cycle assessment of Products**

Indicators

Acceptance (Participation in selecting treatment technology)
Community size served
(Staffing required to operate plant)
Odor
Visual landscape
Noise
Level of education
Wage
Benefits
Gender equity
Open space availability

Results & Discussion

A sample of six countries were selected to represent the entire LAC, the methodology followed was based on "Regional Report on the Evaluation 2000 in the Region of the Americas", water supply and sanitation status and perspectives, however, select six countries of Latin America as a representative sample could represent an uncertainty in the application of social indicators, since each country in the region shows different socioeconomic conditions.

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Activated sludge

=

"Best social conditions"

http://spanish.korea.net/news.do?mode=news_sub&subcode=spa030001

Conclusions

The results of this study are an attempt to look for the most useful indicators to evaluate the social life cycle assessment associated with a particular treatment technology in management of wastewater treatment in Latin America and the Caribbean countries

.

It is acknowledged the many sources and range of data that proposed this evaluation, and the difficulty in identifying a "best overall option", what is interesting is that this study integrates the different stakeholder's categories and subcategories into a set of indicators which can evaluate the S-LCA.

The authors would like to express appreciation for the support of the International Development Research Center, IDRC.

Análisis del Ciclo de Vida (ACV) de Biocombustibles en Colombia

3 enfoques de ACV: convencional, espacial y simplificado

Rainer Zah, Simon Gmünder Empa, Technology and Society Lab, Life Cycle Assessment and Modelling (LCAM) Group, CH-8600 Duebendorf.

Antecedentes

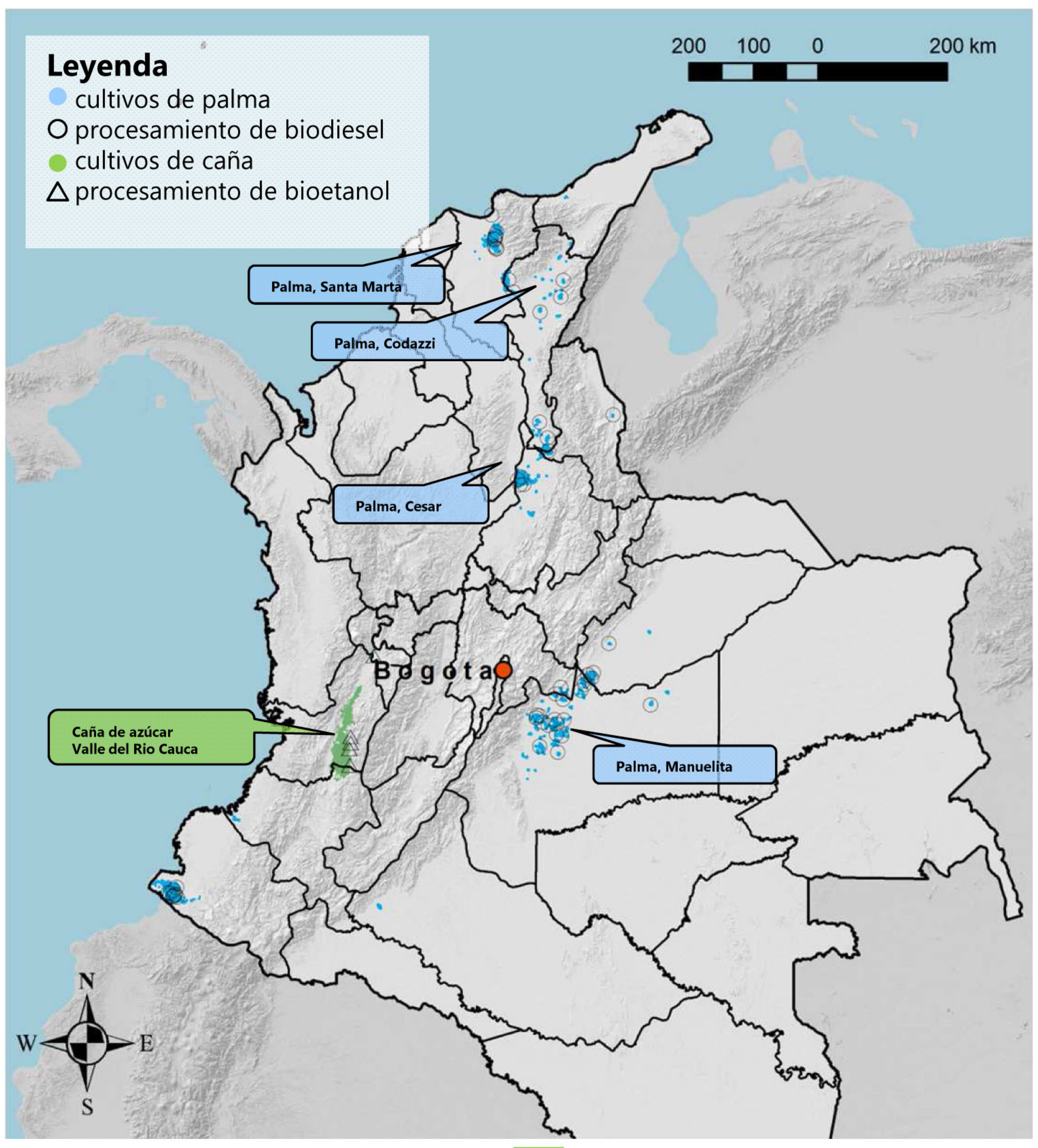
Colombia es el segundo productor de biocombustibles en Latinoamérica después de Brasil. Una expansión significativa de producción está prevista con 7 milliones de hectáreas adicionales de tierras aptas para cultivos energéticos.

A pesar de que los biocombustibles a primera vista ofrecen un posible reemplazo de combustibles fósiles y una nueva fuente de ingreso agrícola, los riesgos ambientales y socio-económicos están todavía prácticamente indeterminados.

Objetivo del estudio

El proyecto **"Evaluación del ciclo de vida de la cadena de producción de biocombustibles en Colombia"** financiado por el BID y el Gobierno de Colombia es un análisis de sostenibilidad evaluando la cadena de valor de los biocombustibles a partir de caña de azúcar y aceite de palma, comparándolos con sus equivalentes fósiles en Colombia.
Se presentan 3 componentes principales:

1. **ACV convencional:** ACV de biocombustibles actuales
2. **Mapas espaciales de GEI:** Impacto potencial de gases de efecto invernadero de nuevos cultivos
3. **ACV simplificado:** Herramienta web (SQCB) de ACV individual



1ª Parte – ACV convencional

Objetivo: Analizar el impacto ambiental promedio de la cadena de producción de biocombustibles actuales en Colombia.

Combustibles comparados:

- Bioetanol a partir de caña de azúcar
- Biodiesel a partir de aceite de palma
- Combustibles fósiles: gasolina 87 y diesel 50ppm

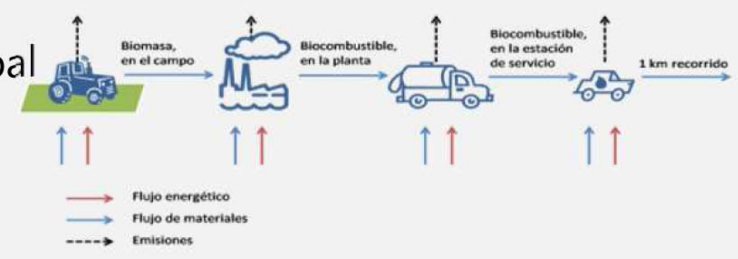
Unidad funcional: 1 vehículo-kilómetro (Renault Logan)

Límites del sistema:
El sistema incluye todos los procesos relacionados con el cultivo, el procesamiento , el transporte y el uso de biocombustibels y combustibles fósiles en Colombia.

Inventario:
Recopilacion de información primaria sobre el cultivo y procesamiento de biocombustibles en campo (zonas de producción marcadas en el mapa)
La información secundaria (background data) se extrae de la base de datos **ecoinvent v2.2**.

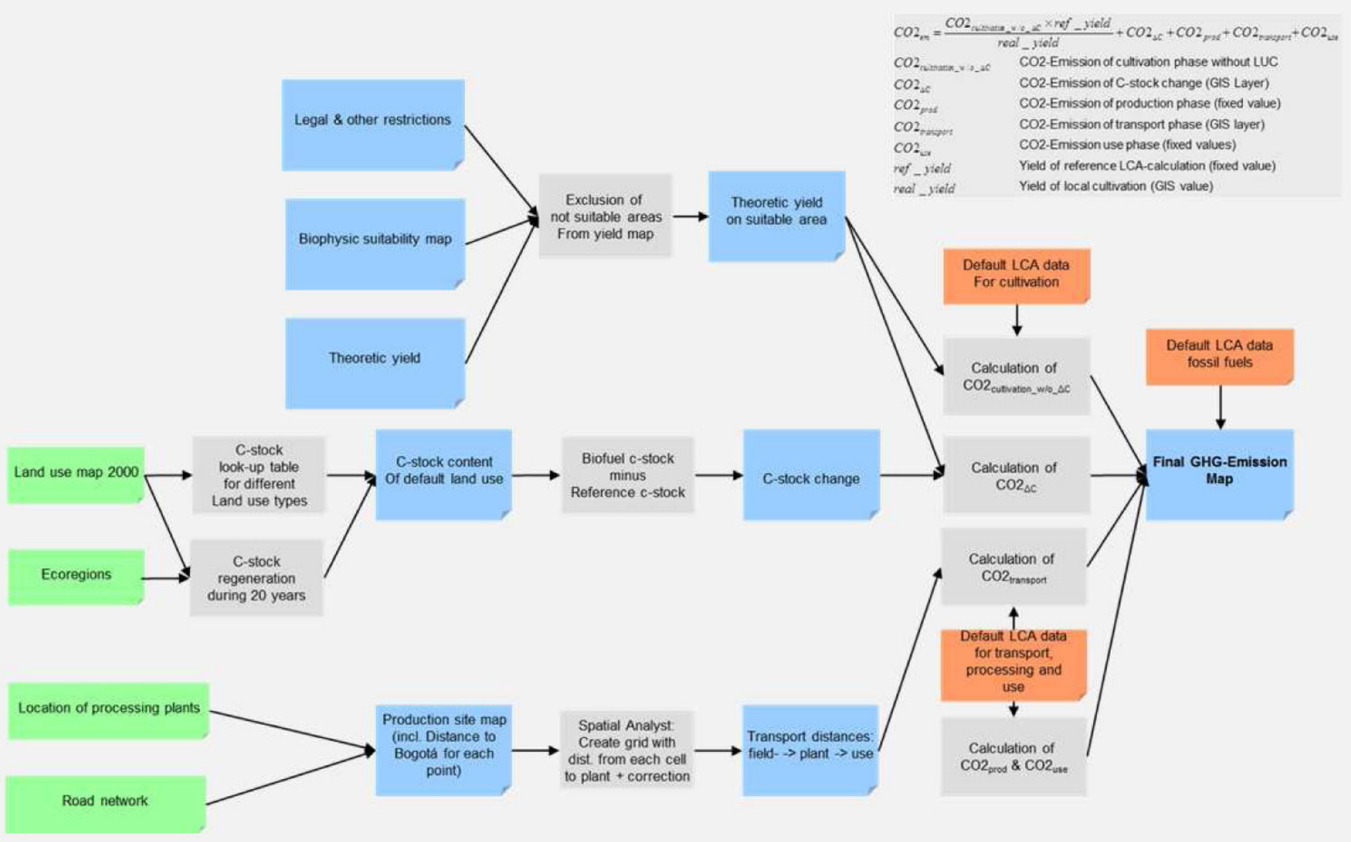
Evaluación del impacto:

- GEI calentamiento global
- Eco-Indicador 99
- Acidificación
- Eutrofización
- y otros



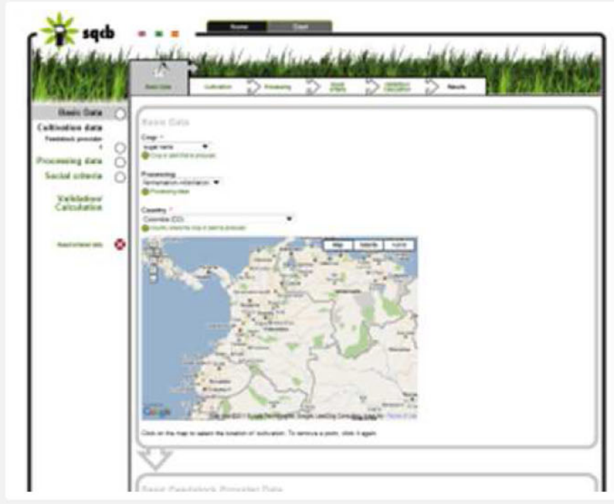
2ª Parte – Mapa espacial de GEI

La expansión de cultivos energéticos puede inducir diferentes efectos sobre el balance total de los GEI, dependiendo de la productividad agrícola, el cambio del uso del suelo y las distancias de transporte. Basado en información espacial e inventarios del ciclo de vida, se realiza un ACV para todas las potenciales zonas de producción con una resolución de 5x5 km.



3ª Parte – ACV simplificado (SQCB)

La herramienta web SQCB (Sustainability Quick Check for Biofuels) está diseñada para realizar cálculos simplificados de ACV para biocombustibles. Se combinan factores clave de la producción individual de biocombustibles con datos de referencia de ecoinvent.



http://www.sqcb.org

Conclusión

No se puede dar una respuesta sobre la sostenibilidad de la producción de los biocombustibles con un sólo estudio. Mientras el enfoque convencional de ACV (1ª Parte) demuestra la sostenibilidad de cadenas actuales, un estudio espacial (2ª Parte) analiza potenciales zonas de producción y el SQCB (3ª Parte) permite el análisis de proyectos específicos de biocombustibles. En consecuencia, se propone una combinación de estos enfoques de ACV para permitir una toma de decisión fundada respecto de la producción de biocombustibles en Colombia. Los resultados completos del estudio se publicarán en agosto 2011.

BID Banco Interamericano de Desarrollo
MME Ministerio de Minas y Energía
MADR Ministerio de Agricultura y Desarrollo Rural
MAVDT Ministerio de Ambiente, Vivienda y Desarrollo Territorial
DNP Departamento Nacional de Planeación

Contacto:
Dr. Rainer Zah
Rainer.Zah@empa.ch

Environmental and economic analysis of woody residual biomass transport for energetic use
Edmundo Muñoz, Sebastián Vargas and Rodrigo Navia

Environmental and economic analysis of woody residual biomass transport for energetic use

Edmundo Muñoz[1,2], Sebastián Vargas[3] and Rodrigo Navia[4]

[1]Doctorado en Ingeniería, [2]Instituto del Medio Ambiente, [3]Dirección de Innovación y Transferencia, [4]Departamento de Ingeniería Química, Universidad de La Frontera, Casilla 54-D, Temuco, Chile.
rnavia@ufro.cl, phone: 56-45-325477, fax: 56-45-325053

Resumen

Using LCA woody residual biomass transport for energetic use was evaluated according to three different pretreatment strategies. For the environmental analysis, CML 2000 impact assessment methodologies were used. The impact assessment was performed using software SimaPro 7.2. It was established that lower environmental impacts exist in all evaluated categories when chips from woody residual biomass are transported. A distance lower than 27 km was determined to be that who generated the lowest impacts in climate change, when the residual biomass was transported without any pretreatment. However, costs analysis is favourable for this scenario only in the case of transport distances of less than 12 km. It is clear that for defining the best residual biomass transport option, the distance, the charge capacity and pretreatment efficient should be taken into account. as

Life cycle assessment methodology

Goal and scope

The objective of this study was to compare transport performance of woody residual biomass using different pretreatment options for densification/compaction. The studied scenarios were the following:

- Scenario 1: Woody residual biomass transport without pretreatment
- Scenario 2: Chipped woody residual biomass transport
- Scenario 3: Compacted woody residual biomass transport

The functional unit was defined as 1 ton of transported woody residual biomass.

Inventory

Table 1. Summary data life cycle inventory

Item	Characteristic
Fuel	Database from ETH-ESU 96
Transport	standard truck of 28 ton from the Ecoinvent database
Woody residual biomass	Density: 100 kg/m^3
Chipped woody residual	Density: 300 kg/m^3
Compacted woody residual	Density: 700 kg/m^3
Chipping machine	Production: 45 ton/h Fuel consumption: 58 L/h
packaging machine	Production: 14 ton/h Fuel consumption: 39 L/h
Chipping machine	Production: 45 ton/h Fuel consumption: 58 L/h

Ecomomical backgroung

Table 2. Costs to piling and loading, pretreatment and transport of woody residual biomass

Costs	Biomass (US$/ton)	Chips (US$/ton)	Compacted (US$/ton)
Piling and loading	2.60	2.60	2.60
Pretreatment	0	1.75	4.48
Transport	0.25*	0.10*	0.096*

Results and discussion

Environmental analysis

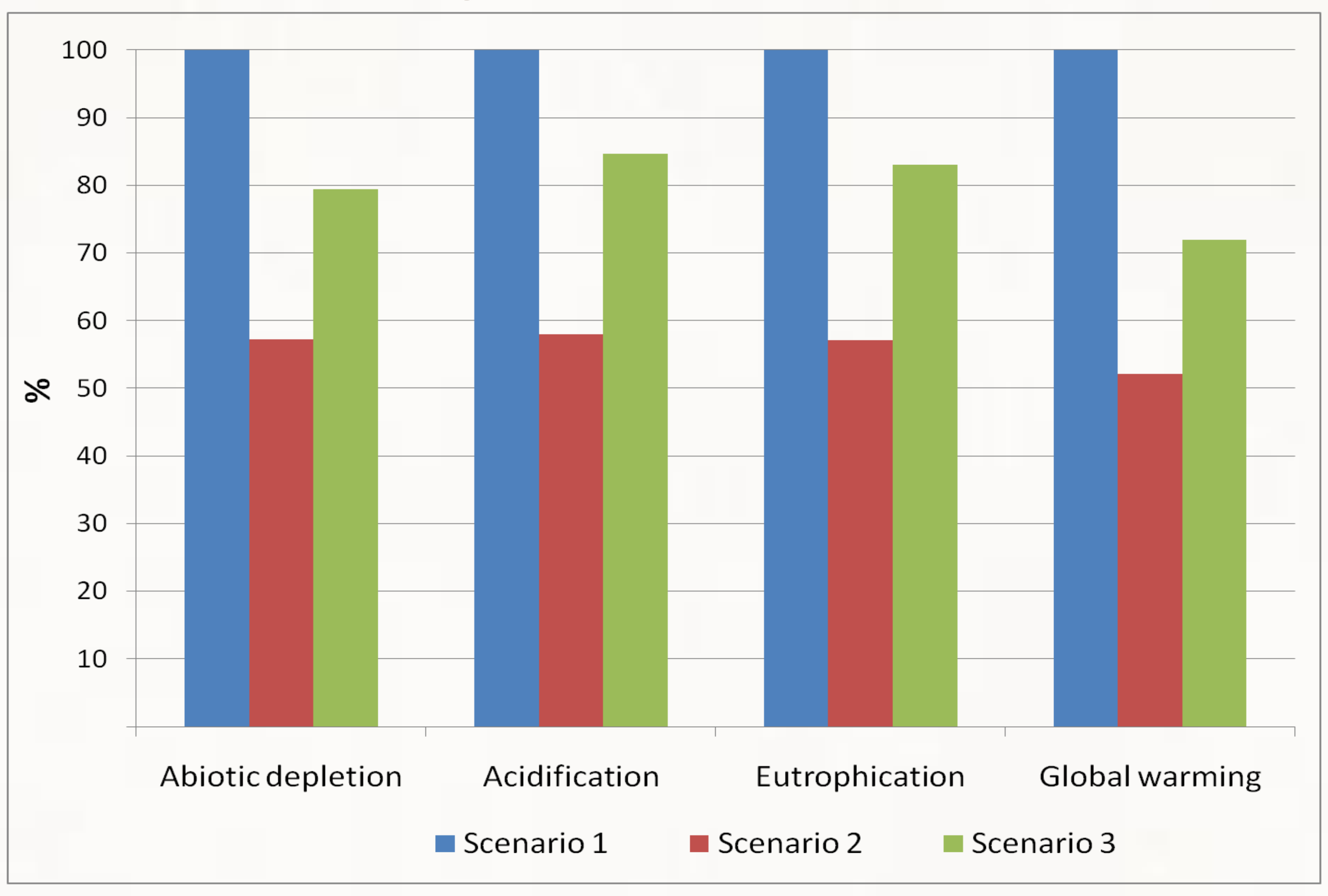


Figure 1. Results of scenario 1, 2 and 3 when using CML 2000 methodology

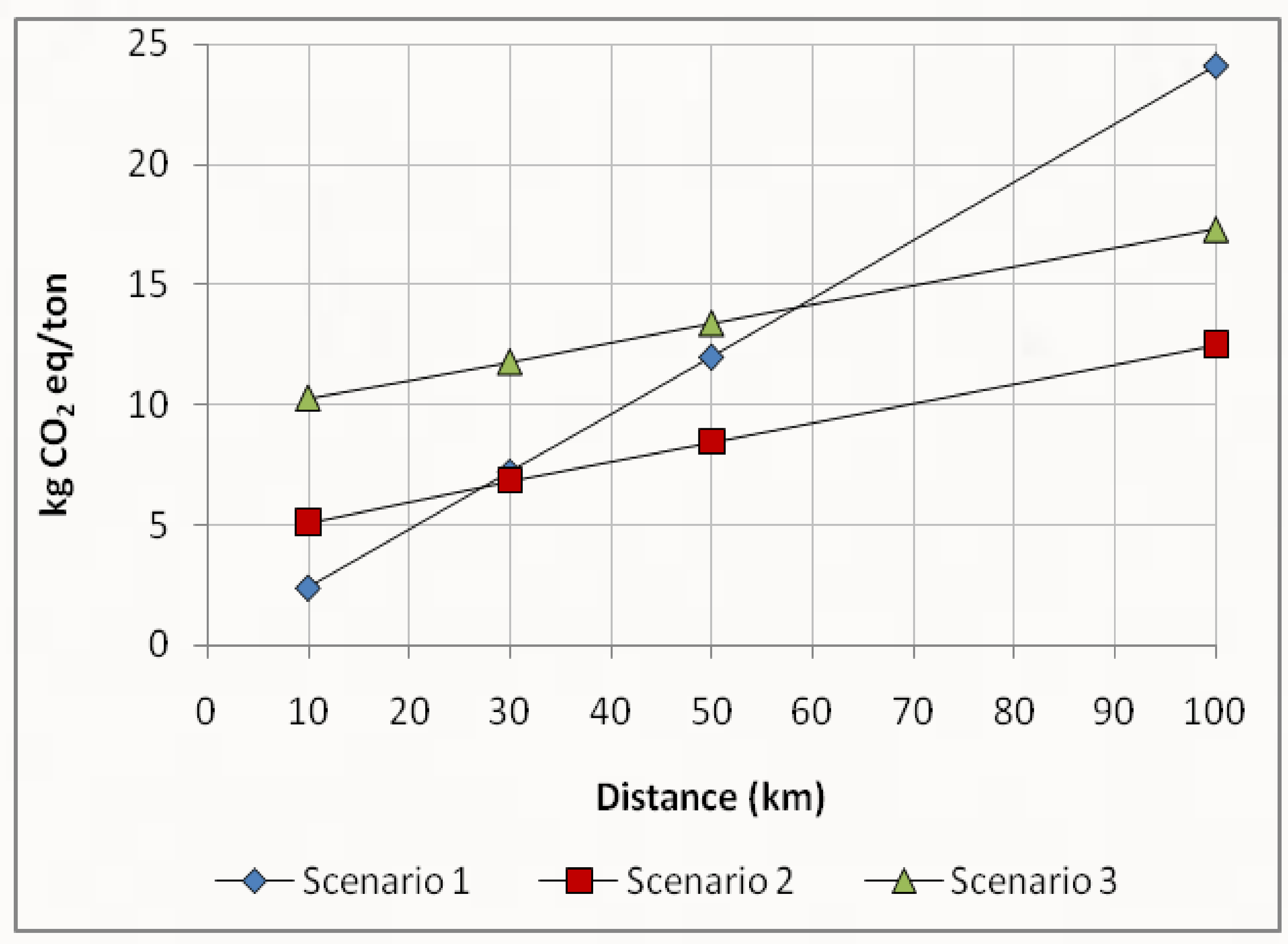


Figure 2. Influence of the transport distance on the climate change category for scenario 1, 2 and 3

Environmental impacts vs. costs

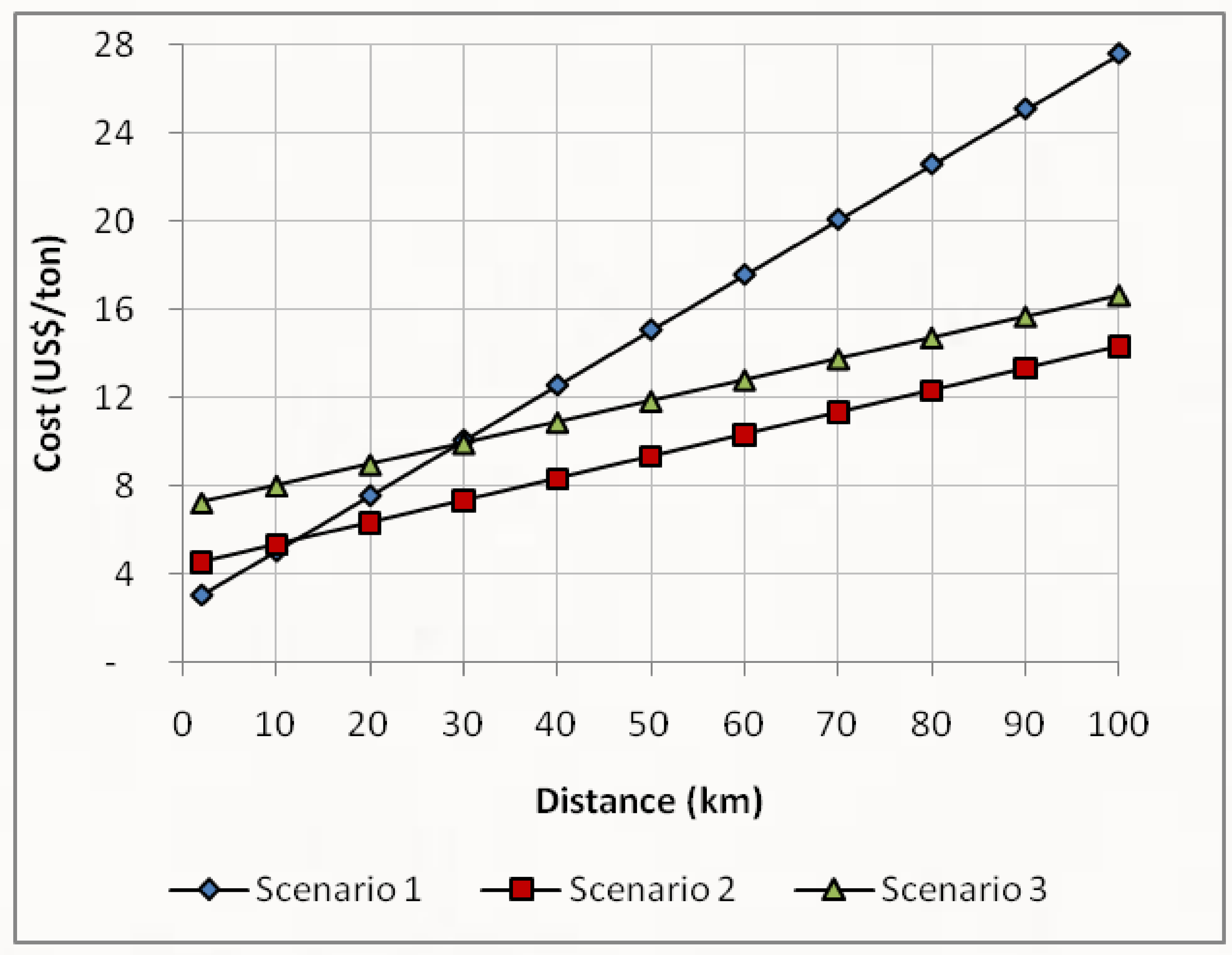


Figure 3. Influence of residual biomass transport distance on the costs for scenario 1, 2 and 3

Conclusions

For determining the best transport option of woody residual biomass, transport distance, loading capacity (biomass density) and pretreatment processes efficiency should be taken into account. For forestry residual biomass, transport distances of less than 12 km generate lower costs and less environmental impacts when the biomass is being transported without any pretreatment. The same situation was determined to be the most favorable when chipped biomass is transported in distances of more than 27 km.

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Vargas Zavala, Aída Viridiana*
Manzini Poli, Fabio**

LIFE CYCLE ASSESSMENT APPLIED TO WIND POWER GENERATION IN MEXICO

Centro de Investigación en Energía, Universidad Nacional Autónoma de México.
Privada Xochicalco S/N; Temixco, Morelos. C. P.: 62580, México.
**+52 (777) 362-0090 ext. 29704; **+52 (55) 562-29704.
E-mail: **fmp@cie.unam.mx, *avvaz@cie.unam.mx

BACKGROUND

Two-thirds of emissions of greenhouse gases (GHG) that cause global climate change, are produced by burning fossil fuels in current energy systems, it is mandatory to make Life Cycle Assessments of all energy technologies to determine the cleanest technology from an environmental point of view in order to determine which ones should be included in a transition toward clean and sustainable energy systems.

Mexico is ranked number 13 as an emitter of GHG and 5th highest annual GHG emissions rate. Mexican Power sector contributed with 29.4% of all GHG emissions reported in the 2006 National Inventory. Wind generation is the fastest growing technology in the National Electric System (SEN). Wind energy resourses in Mexico are over 70,000 MW [1, 2, 3] .

OBJECTIVES

The following objectives for doctoral research in the next three years are proposed:

- To describe the process associated with electricity generation from wind power and set it among the new and best technologies used worldwide. Pointing also to the barriers that this process has to face for its commercial use.
- To assess the environmental, social and economic life cycle of electricity generation from wind energy, identifying the possible technological self-reliance and energy sustainability that could be achieved in Mexico.
- To review the existing regulations concerning the use and exploitation of renewable energies and to propose modifications to Mexican regulations concerning wind energy use for power generation based on the results from its sustainability analysis.

METHODS

Using the methodology of Life Cycle Assessment (LCA) of electricity generation from wind energy, the LCA of wind turbines manufactured in Mexico will be compared with international studies, which evaluate the main environmental impacts of wind generation in all phases [4, 5, 6, 7] .

It will also examine social aspects (S-LCA, Social Lifecycle Analysis), environmental and economic aspects (LCC, Lifecycle Costing), in order to permit a more complete assessment of sustainability of a future wind energy industry in Mexico [8, 9, 10, 11, 12].

EXPECTED RESULTS AND CONCLUSIONS

Using a specialized software to perform a LCA and also using it to quantify the environmental impacts of the various production processes involved in wind generation.

The electricity generated from wind energy has one of the lowest environmental impacts. Like other low-carbon technologies, its major emissions occur during the manufacturing stage and construction around 98% of its total carbon life cycle. A global average life cycle emissions of GHG generated with wind generated electricity is 9 g/kWh [10, 13, 14].

REFERENCES

1. Secretaría de Energía, SENER, 2009. Prospectiva del Sector eléctrico 2009-2024.
2. beyond petroleum. BP Statistical Review of World Energy. June 2010.
3. Instituto Nacional de Ecología, Secretaría de Medio Ambiente y Recursos Naturales (INE-SEMARNAT), 2009. México. CuartaComunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático.
4. Environmental Protection Agency, (EPA) 2010. Life-Cycle Assessment (LCA). Life Cycle Assessment Research.
5. Environmental Protection Agency, May 2006. Life Cicle Assessment: principles and practice. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.
6. Environmental Protection Agency, 2010. Life-Cycle Assessment (LCA). Life Cycle Assessment Research.
7. Environmental Protection Agency, May 2006. Life Cycle Assessment: principles and practice. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.
8. International Energy Agency (IEA), 2008. Key Word Energy Statistics 2008.
9. INTERNATIONAL STANDARD, ISO 140000, 1997. Environmental management - Life cycle assessment - Principles and Framework.
10. German Wind Energy Association (BWE). More wind power capacity installed last year in the EU than any other power technology, 03.02.2010. [Consulta: 28 noviembre, 2010].
11. Huacuz V., Jorge M., 2003. Energías renovables: ¿Opción real para la generación eléctrica en México? Boletín IIE, octubre-diciembre del 2003. Instituto de Investigaciones en Energía.
12. Instituto de Investigaciones Legislativas del Senado de la República (IILSEN), Centro de Investigación en Energía (CIE-UNAM), 2004. Nuevas Energías Renovables: una alternativa energética sustentable para México.
13. Instituto Nacional de Ecología, Secretaría de Medio Ambiente y Recursos Naturales (INE-SEMARNAT), 2006. México. Tercera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático.
14. Brown, Marilyn A. and Sovacool, Benjamin K., 2007. Developing an 'Energy Sustainability Iindex' to evaluate Energy Policy. Interdisciplinary Science Reviews, Vol. 32, No. 4.

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ID: 85

Hernández Padilla Flor[1]
Güereca Hernández Leonor Patricia[2]
Adalberto Noyola Robles[3]
Juan Manuel Morgan Sagastume[4]
Margarita Cisneros Ortiz[5]
Liliana Romero Casallas[6]

Defining objectives and scope for a thesis Life Cycle Analysis of wastewater treatment in Latin America and the Caribbean

All the investments for improved designs of wastewater treatment in theory, help increase the quality of life of the population within the framework of sustainability, but how to identify whether treatment systems do not generate wastewater collateral environmental impacts that limit their benefits?

METODOLOGY

They were designed two formats, general information and specific information, which inquire about the operation and design of treatment plants in each country, from the standpoint of technical, environmental and economic.

The selection of the types of treatment was based on the technologies covered 65% of the total of the existing WWTP (see Figure 1).

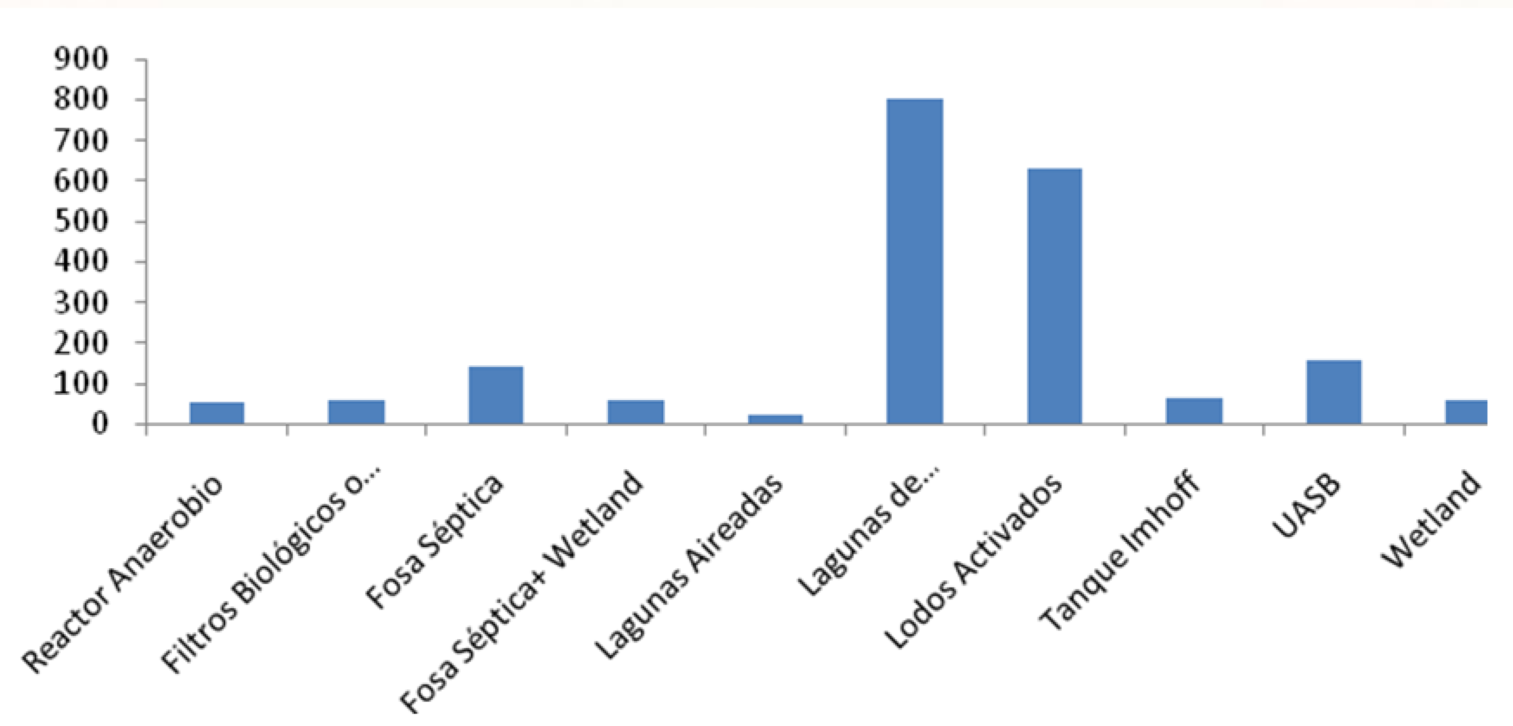

Figure 1. Quantity of WWTP by technologies more used

RESULTS

DEFINITION OF OBJECTIVES

Analyze the four sets of wastewater treatment commonly used in Latin America and the Caribbean under a life cycle approach to propose improvements that result in more environmentally efficient processes

SCOPE DEFINITION

1. System function: removal of the organic load of wastewater.

2. Functional Unit: In this research the volume of treated water for each technology in 15 years (lifespan of a machining system).

3. Limits: Region of Latin America and the Caribbean, on the selected countries to Mexico, Guatemala, Brazil, Colombia, Chile and Dominican Republic.

4. System description

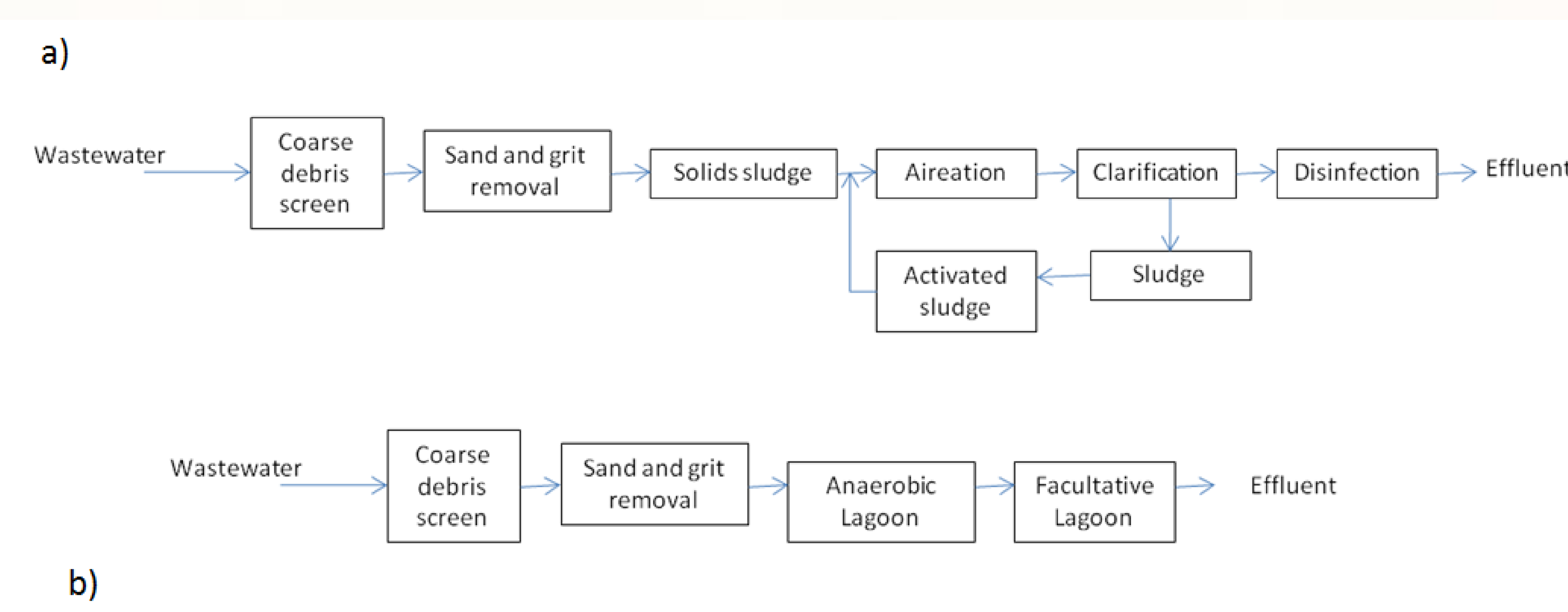

Figure 2. System Flowchart, a) Activated sludge, b) Facultative Lagoon

The evaluation system includes the production of electricity and raw materials used as shown in Figure 2.

PRELIMINARY FINDINGS

It is necessary within the Latin America and the Caribbean produce inventories of electricity, diesel, emissions.

It requires information on the disposal of solid waste treatment plants generate wastewater in the Latin American region.

[1] PhD Student Environmental Engineering
[2,3,4] PhD Environmental Engineering
[5,6] Master Environmental Engineering
Universidad Nacional Autónoma de México
E mail contact: fhernandezp@iingen.unam.mx
Telephone number: +52 555623 3500 ext 1658

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Biomethane as vehicle fuel

J. P. Lindner, A. Lozanovski and U. Bos

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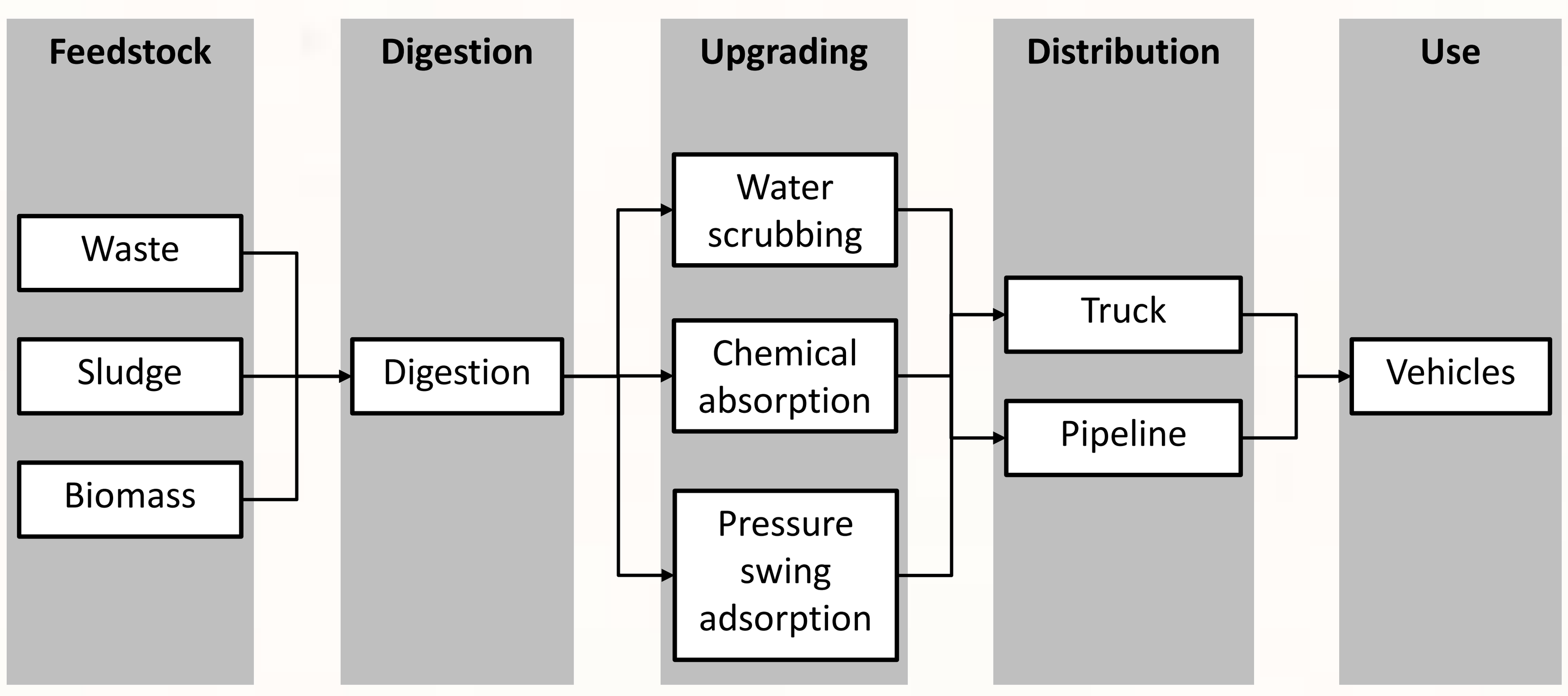
Biogas, as a renewable energy carrier, is generally considered sustainable. But exactly how sustainable is it? In the context of the Biogasmax project (Biogas as vehicle fuel – Market Expansion to 2020 Air Quality), the Department Life Cycle Engineering at the University of Stuttgart conducted a Life Cycle Assessment study of biomethane for use in public transport. The environmental impacts of several biomethane producing facilities in France, Sweden and Switzerland are assessed. The methodology and results are exemplified with global warming potential in this poster.

Product system



Feedstock
Sewage sludge and organic waste, little dedicated biomass

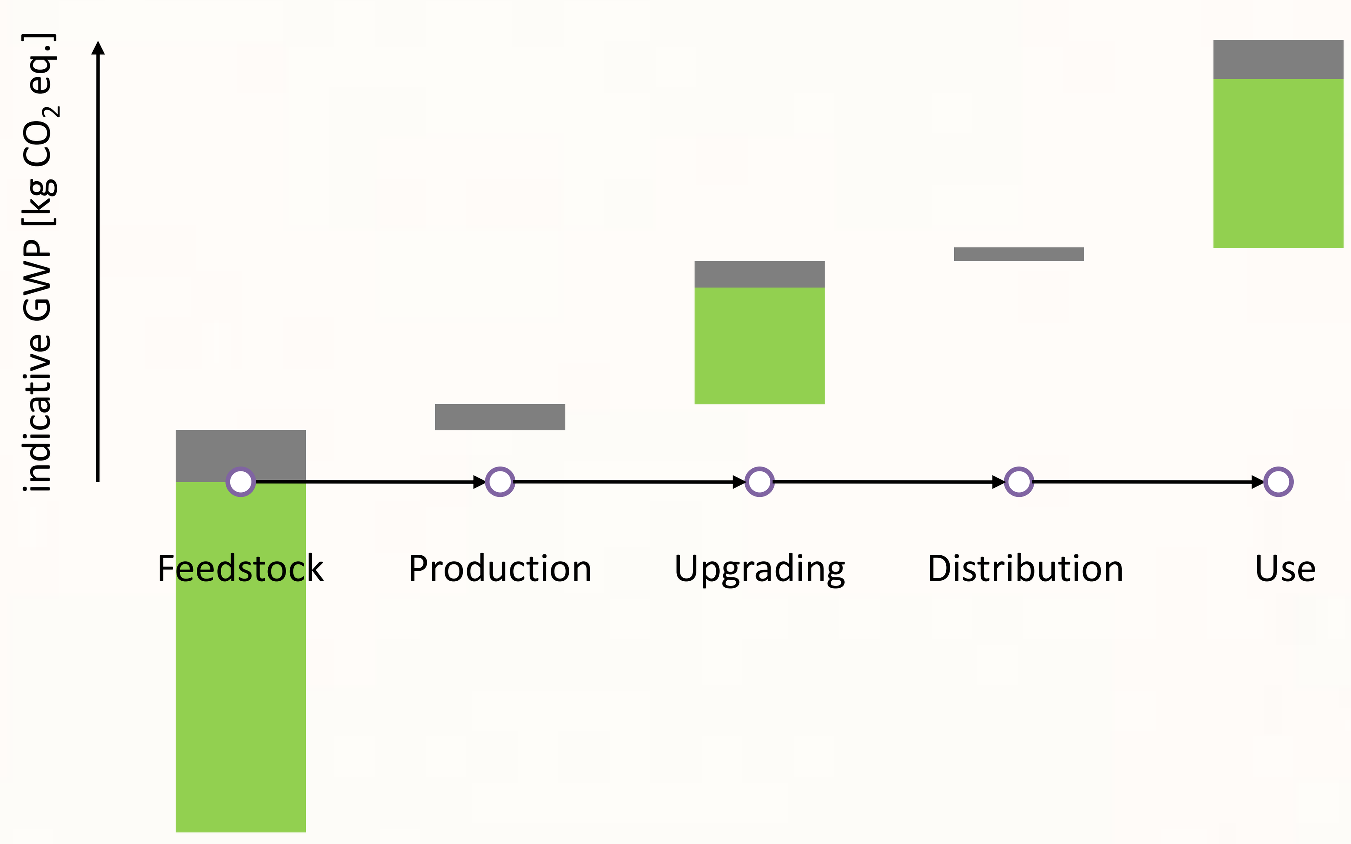
Biogas production
Bacterial digestion of organic matter to methane and CO_2

Upgrading to biomethane
Removal of CO_2, water vapor and impurities

Distribution
Handling like natural gas, in pipelines and pressure vessels

Use
Combustion in natural gas vehicle engines

Analysis

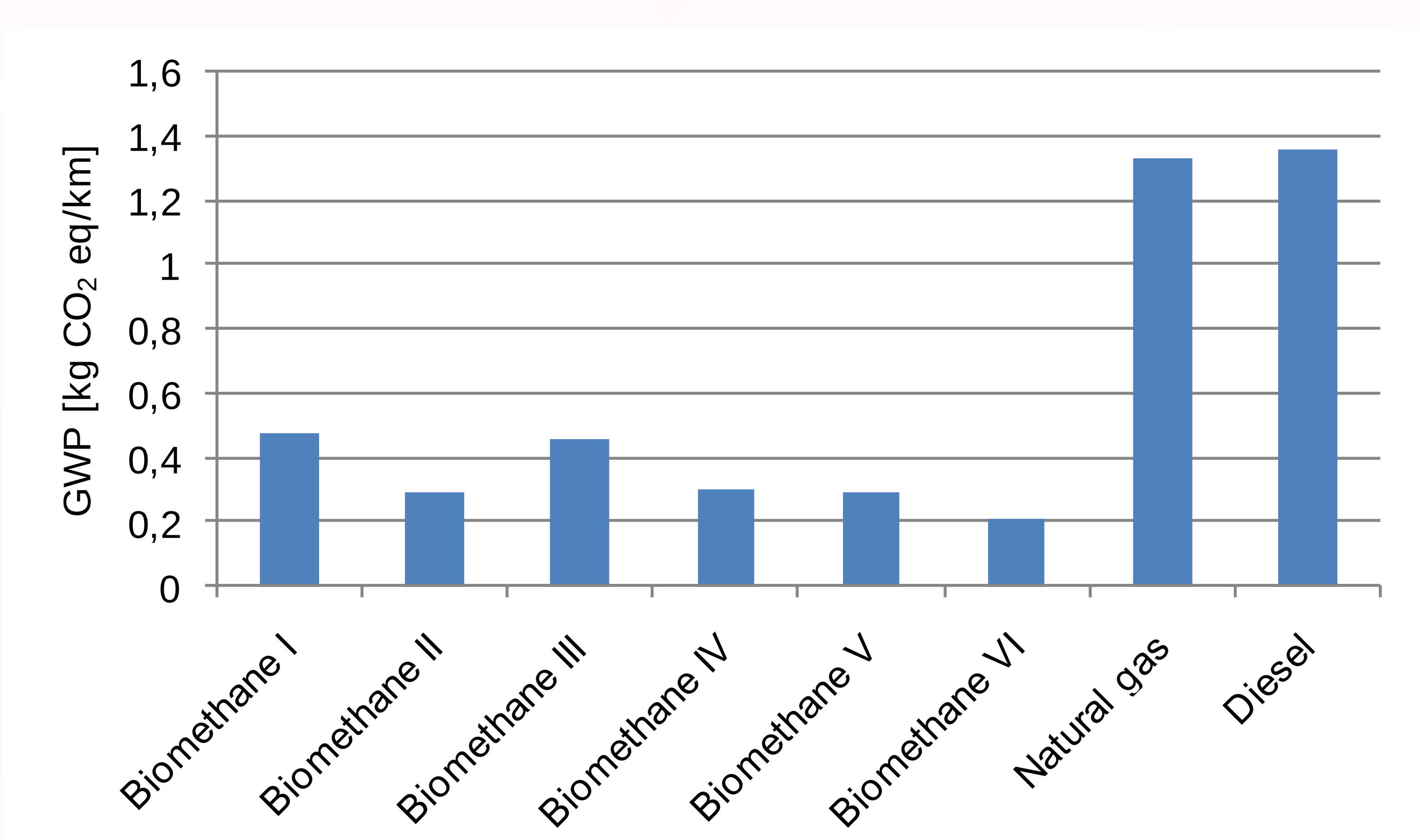


Biogenic carbon
Carbon bound in biomass feedstock → CO_2 credit (shown in green)
CO_2 released in upgrading and use phases → zero net emission
Heat/power provision, transport, etc. releases fossil CO_2

Impact hotspots
Heat for digestion → strongly linked to dry substance content in digester and means of heat provision
Methane slip from upgrading → technical reduction measures exist
Additives for conditioning of biomethane

By-products
Digestion residue → depending on legal and technical boundary conditions: use as fertilizer, solid waste fuel in cement kilns, or filler material → potential credit

Results



Climate/carbon neutrality of biomethane
Not 100% climate neutral
Lower climate impact than natural gas and diesel transport
Considerable improvement potential (just stretching into market)

Critical points for climate impact
Efficiency of biomass digestion
Reduction of methane slip at every stage
Valorisation of by-products

Other impact categories
Fossil resources demand much lower than for natural gas and diesel
Acidification, eutrophication, ozone creation roughly equal or higher than from natural gas and diesel

Contact and acknowledgement

Jan Paul Lindner
Aleksandar Lozanovski
Ulrike Bos
Dept. Life Cycle Engineering
University of Stuttgart, Chair of Building Physics
Hauptstrasse 113, 70771 Echterdingen, Germany
e-Mail: jan-paul.lindner@uni-stuttgart.de

biogasmax
A DRIVING FORCE

Biogasmax
Biogas as vehicle fuel –
Market Expansion to 2020 Air Quality
project funded by the European Commission
under the 6th Framework Programme
URL: www.biogasmax.eu

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CL11-041 Life Cycle Assessment of bioethanol production from sugarcane in Mexico.

Aurora Rodríguez (ara_vio@hotmail.com) IPN
Karina Nava (karina_nava87@hotmail.com) IPN
Moisés Magdaleno (mmagdale@imp.mx) IMP

INTRODUCTION

Ethanol, is not currently used as main fuel source, nevertheless it is planned to use in Mexico mixed with gasoline by 6%, replacing oxygenating additives such as MTBE, with the purpose to promote the introduction of biofuels in Mexican market.

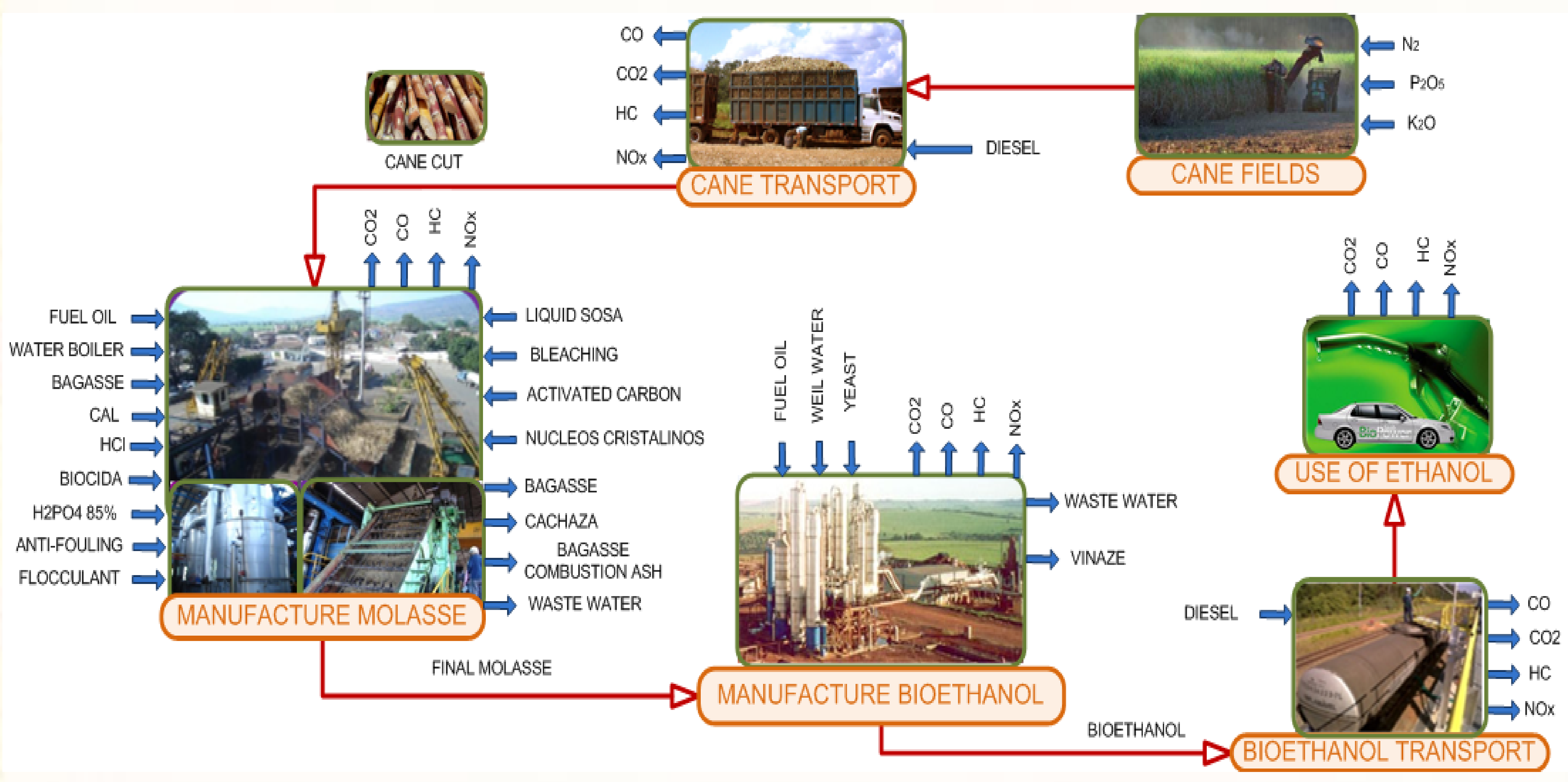
OBJETIVE

Assess the impact of the ethanol use as an oxygenating additive in the gasoline from cradle-to-grave using LCA methodology and SimaPro as a tool.

METHODOLOGY

LCI: It was selected as the base year 2010 due to it is the one with more information. Statistics were consulted for Sugar Cane Agro-Industry in Mexico in order to obtain all the necessary data for the manufacture of bioethanol. Air pollutant emissions were taken from studies conducted by Instituto Mexicano del Petroleo.

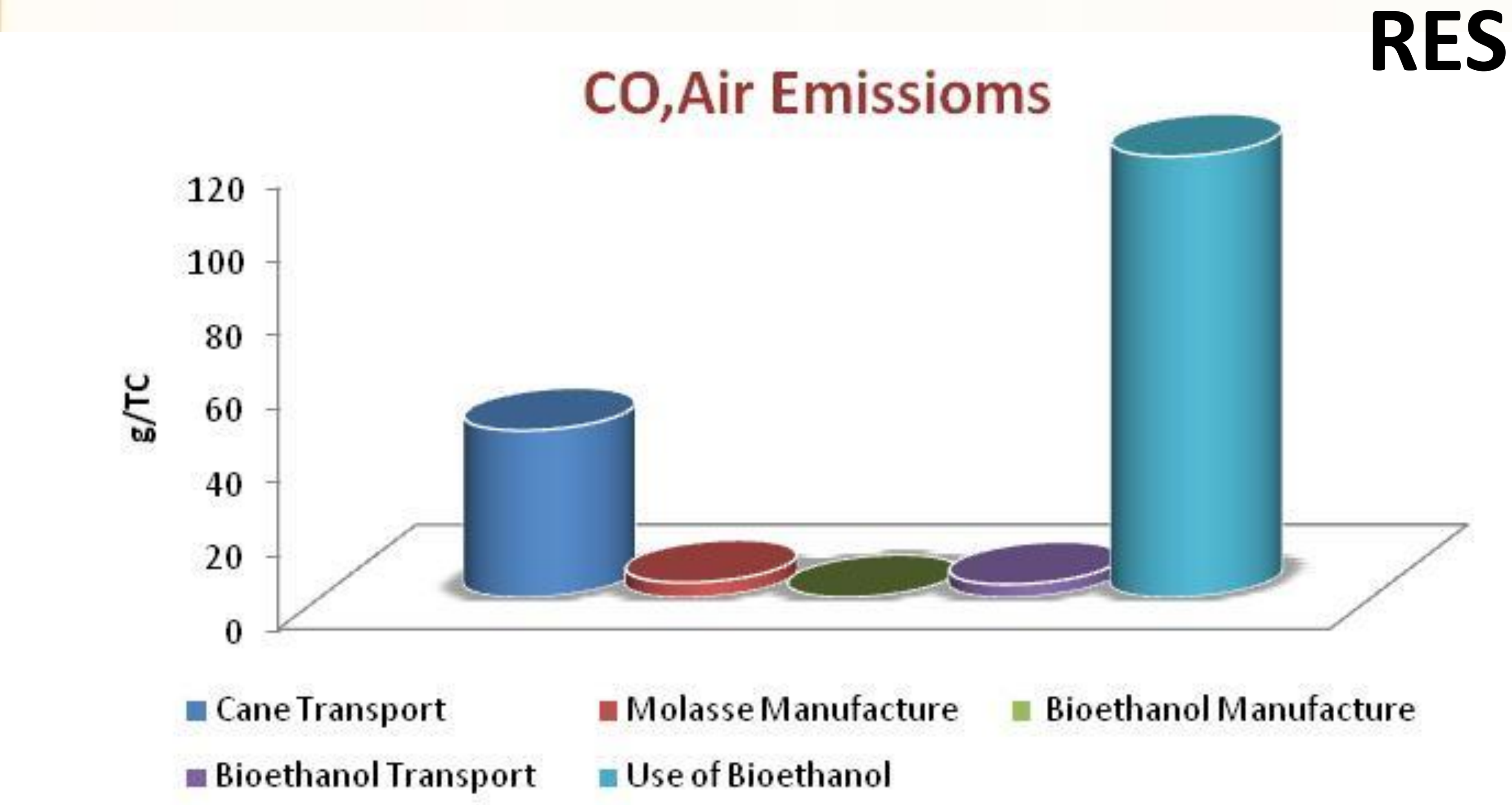
FLOW DIAGRAM OF BIOETHANOL MANUFACTURE

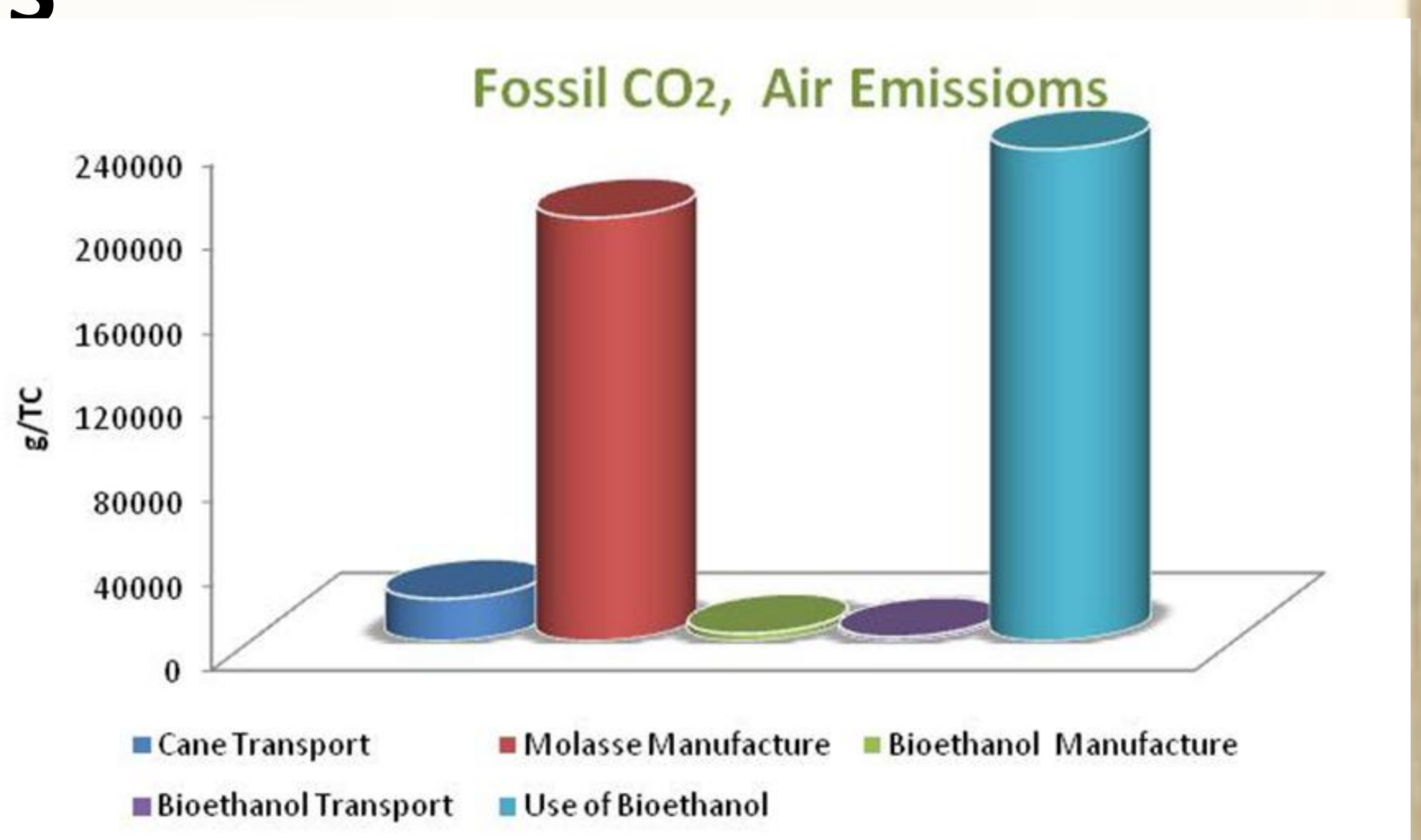


Life Cycle Impact Assessment: All the data were introduced to SimaPro platform and the Model used was ECOINDICATOR 99. The functional unit selected was 1 ton of sugarcane.

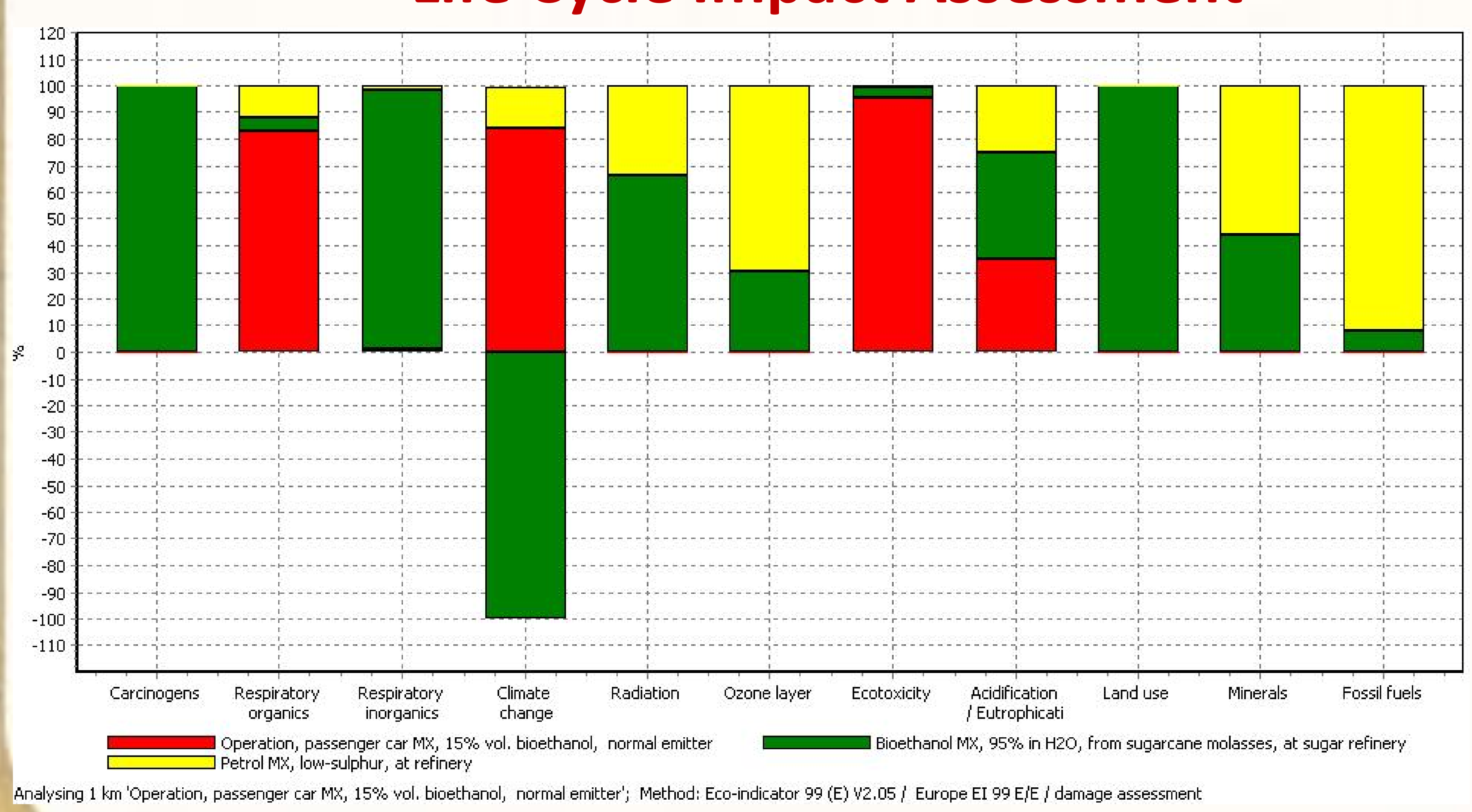
Subsequently were analyzed all the results in order to assess impacts that may occur in the production and use of this biofuel in Mexico.

RESULTS





Life Cycle Impact Assessment



CONCLUSIONS

From the LCI point of view, main emissions of CO and GHG are produced in the final use in cars.

Most of the LCA impacts due bioethanol production are produced on land use, carcinogens and respiratory inorganics. Nevertheless, there is a positive impact on climate change as shown in the graph.

On the other hand LCA impacts due to operation of passenger car are on climate change, ecotoxicity and respiratory organics.

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Biofungicides Life Cycle Assessment

Coatl Popoca Monserrat [1,3], Reyes Mazocco René [3]
Sojo Benítez Amalia [2], Garibay Pérez Miguel [1].

1. AgraQuest de México S.A de C.V. Autopista San Martín Texmelucan -Tlaxcala Km 6.5, San Felipe Ixtacuixtla, Tlaxcala. **2.** Centro de Análisis de Ciclo de Vida y Diseño Sustentable, Ruiseñor No. 35 Col. Arboledas, Tlalnepantla, Edo. México, C.P. 54020; **3.** Universidad de las Américas-Puebla- Departamento de Ing. Química y en Alimentos, Sta. Catarina Mártir C.P. 72820, San Andrés Cholula, Puebla, México;
e-mail: mcoatl@agraquest.com.mx, rene.reyes@udlap.mx, asojo@centroacv.com.mx, mgaribay@agraquest.com.mx

Introduction

Agriculture is a vital activity for human welfare. However, along with the many benefits derived from it there are also significant associated environmental impacts.

- According United Nations (UN), **over 800 million people** around the world do not have **enough food** for a healthy and **active life** .
- A greatest **global challenge** is to **increase food production** in a **sustainable method**.
- In Mexico the **increase** of **food demand** and the requirements of the **global market**, makes necessary the adoption of **new techniques** for **pest control.**

Aim of the study

Determine the environmental potential impacts of Serenade Max® Biofungicide (*Bacillus Subtillis*) produced and used in the Mexican agriculture.

Serenade Max ®
Biofungicide

Tomato crop

Grape crop

Methodology

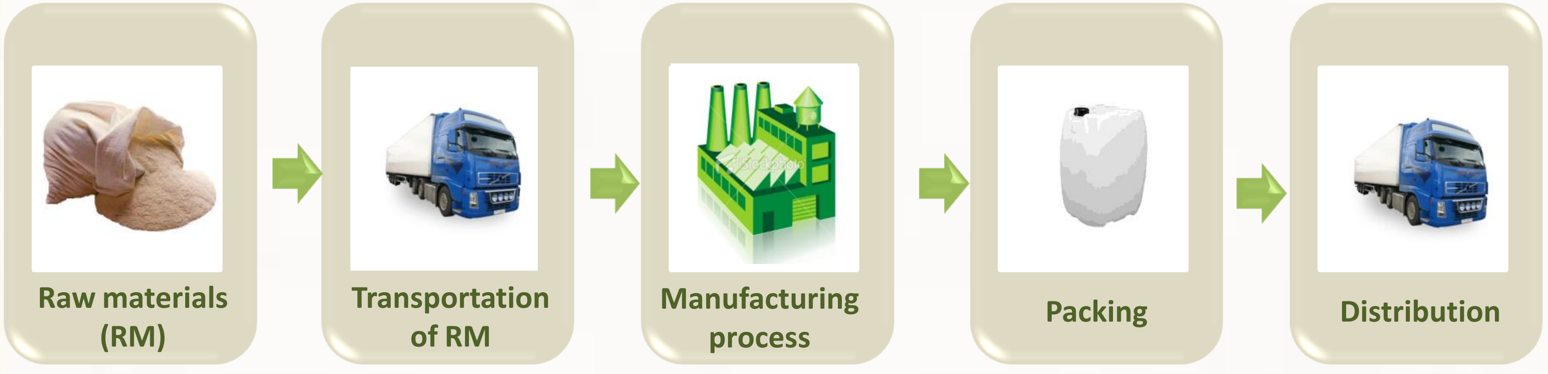
The study was conducted according to the requirements of the international standard ISO 14044.

Goal and Scope

- *Functional Unit*

Controlling the disease "powdery mildew" during the growing of one hectare of grape or tomato crop.

- *System boundary*



Life Cycle Inventory

Input → Unit process → Output

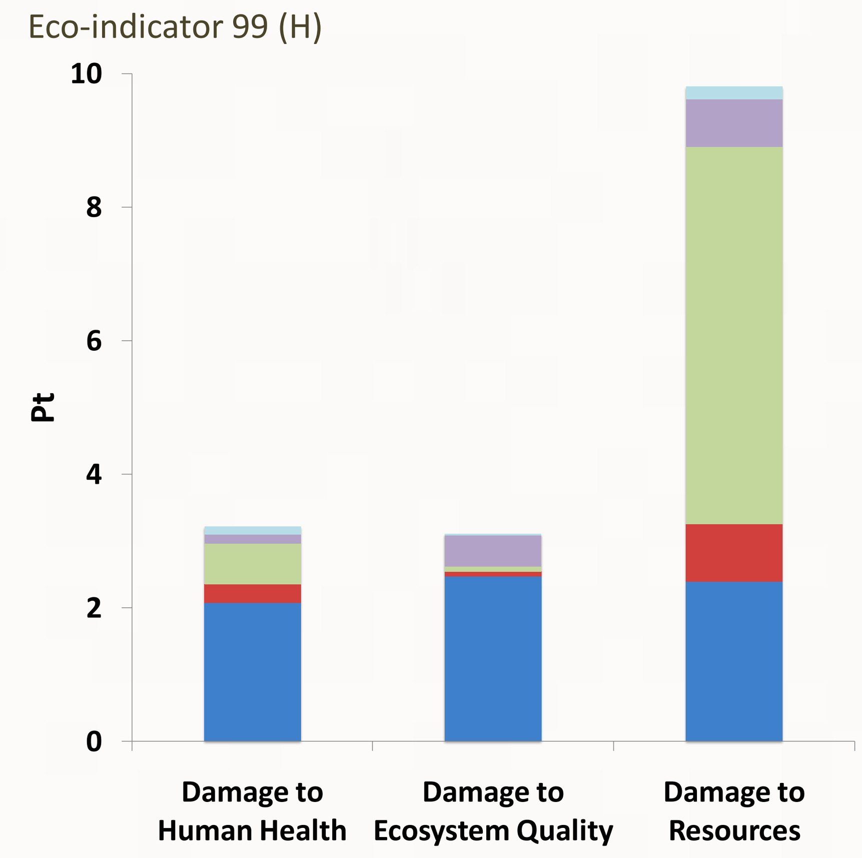
Input	Output
Materials	Air emissions
Natural gas	Water emissions
Electricity	Solid wastes
Water use	
Transportation	

Life Cycle Impact Assessment

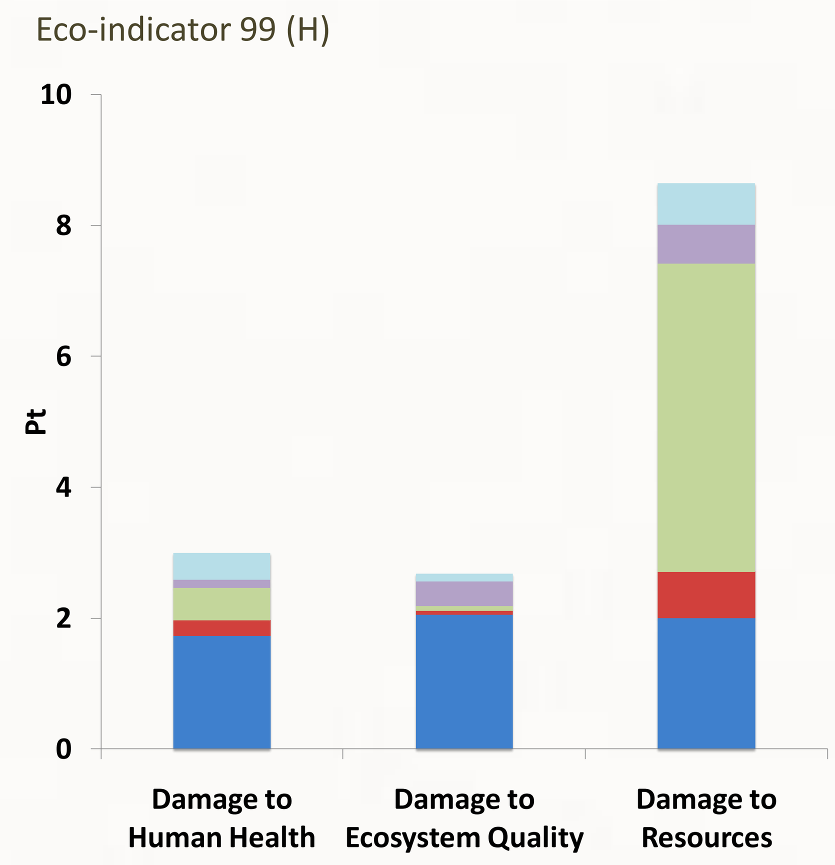
- *Software :* SimaPro 7.2.4
- *Impact Assessment Methods:*
  - •Eco-indicator 99 (H)
  - •IPCC 2007 GWP 100a

Results

Serenade Max → Tomato



Serenade Max → Grape



Major contributions

↓

Life cycle stages:

Raw materials
Manufacturing process

↓

Impact categories:

Fossil fuels
Land use
Resp. inorganic

→ Carbon footprint

IPCC 2007 GWP 100a

	Crop	GWP	
Serenade Max®	Tomato	132.4	kg CO_2 eq/hectare
		8.8	kg CO_2 eq/kg product
	Grape	118.2	kg CO_2 eq/hectare
		9.5	kg CO_2 eq/kg product

Conclusions

- LCA provides a better understanding of environmental potential impacts produced by Serenade Max® Biofungicide life cycle.

Possible improvements:
- Manufacturing process
- Packing
- Distribution

- Serenade Max® Biofungicide, used in tomato an grape crops, has low damage to human health and damage to ecosystem quality in comparison than its damage to resources.

FAO. (2010). The State of Food Insecurity in the World2010. Retrieved 22 Octuber 2010. www.fao.org/docrep/013/i1683e/i1683e00.htm.
Geisler, G.; Hellweg, S.; Hostette, T.; Hungerbuehler, K. (2005) Life-Cycle Assessment in Pesticide Product Development: Methods and Case Study on Two Plant-Growth Regulators from Different Product Generations. Environmental Science & Technology, 7: 2406-13.
García, S.; Mieller, T. (2003). Panorama actual de la producción comercial y aplicación de bioplaguicidas en México. Sociedades Rurales, Producción y Medio Ambiente.7: 65-81
Thakore, Y. (2006) Biocontrol: Biopesticide Market. *Industrial Biotechnology*, 3 (2), 194.